EQUINE VETERINARY EDUCATION/AMERICAN EDITION

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FEBRUARY 2022

EQUINE VETERINARY EDUCATION

American Edition | February 2022

BEVA

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

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References:
[1] Brendemuehl JP, Kopp K, Altman J. Uterine Inflammatory Response to Frozen Semen is attenuated by Oral Supplementation of a Blend of Omega-3 Fatty Acids (Algal DHA and Flax Seed) in Susceptible and Resistant Mares. Submitted to Theriogenology. [2] Brendemuehl JP, Altman J, Kopp K. Influence of dietary algal N-3 fatty acids on breeding induced inflammation and endometrial cytokine expression in mares bred with frozen semen. J Equine Vet Sci. 2014; 34(1): 123-124. [3] A.M. Adkin, A.V. Muniz, C.J. Mortensen, L.K. Warren. Maternal fatty acid supplementation influences memory and learning ability in yearling and 2-year-old horses. J Equine Vet Sci. 2015; 35: 418-436. [4] A.M. Adkin, L.K. Warren, C.J. Mortensen, J. Kivipelto. Maternal supplementation of docosahexaenoic acid and its effect on fatty acid transfer to the foal (longitudinal study). Equine Vet Sci. 2013; 33: 321-329. t[5] A.M. Adkin, L.K. Warren, and C.A. McCall. Effect of maternal docosahexaenoic acid supplementation on behavior and cognitive development in nursing foals. J Equine Vet Sci. 2013; 33: 321-399.

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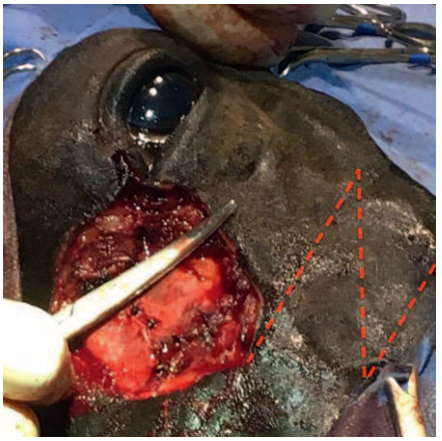
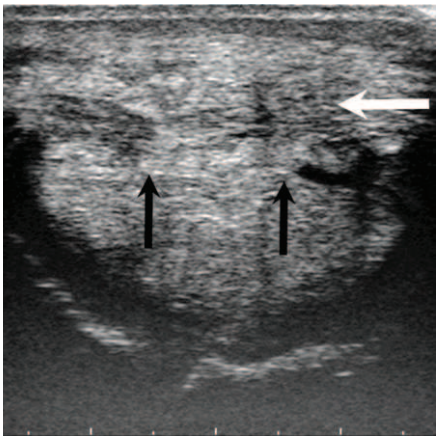
FEBRUARY 2022 • VOLUME 34 • NUMBER 2

CONTENTS





AAEP NEWS In this issue

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EQUINE VETERINARY EDUCATION
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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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The ethics of hard work

By Jackie Christakos, DVM

Dr. Jackie Christakos

Lazy.
Entitled.
Not committed.

How many times do these terms come up in generational discussions pertaining to more junior members of equine practice? As a member of the millennial generation (generally defined as those born from 1981–1996), I've heard this old yarn time and time again; however, I respectfully beg to differ as a practice shareholder, full-time equine veterinarian and parent of a toddler. A strong work ethic is part of my DNA. Oddly, as much as I disagree with this assessment of my generation, I find myself having the same suspicions of Generation Z (born from 1997–2012).

Why should a first-year associate have a better schedule than I expected at their career stage? And isn't it unfair that they are offered better compensation with more time off than I was as a newbie in practice? When I was an intern, I functioned on minimal sleep and made pennies. Why should it be any different now? If I walked three miles barefoot backward in the snow, shouldn't they?

After I dust off my inner grumpiness, I look at the overall condition of our profession. Burnout and compassion fatigue abound. Equine veterinarians are leaving at an alarming rate, citing better pay and more family-friendly environments elsewhere. Less competitive cultures and improved life balance expectations in other segments of veterinary medicine or in another career in general are also motivating factors. Recent industry surveys indicate only 1 to 1.5 percent of graduating students are entering equine practice. AAEP data suggests a startling rate of attrition from equine practice in the first five years post-graduation. From a health perspective, sleep deprivation and extreme stress are known risk factors for long-term wellbeing consequences and increased incidence of medical mistakes.

Are the young associates and new graduates really bringing up outlandish ideas? Or are they simply questioning the unhealthy and unsustainable path many of us have accepted as the "way it is done"? Perhaps we would be wise to listen with an open mind and consider if equine practice can evolve regardless of our generation. The real question may be if our long-established asks and expectations remain ethical.

All this being said, expertise is earned through experience, and this should not be lost in the conversation. The 10,000-hour rule popularized by author Malcom Gladwell says that 10,000 hours of deliberate practice is typical to develop expertise. The value of opportunity in practice to improve our technical skills and problem-solving abilities over time cannot be underestimated, especially with appropriate mentorship applied for greater efficiency of learning. Luckily, we still find ambitious veterinary students who have chosen to ignore years of warnings on the negatives of equine practice and have forged on, pursuing their passion despite the hard work that lies ahead. Lazy and non-committed individuals would be unlikely to have made it past these initial roadblocks in the first place.

Identification of problems is easy, but what about practical solutions? Some opportunities may exist as low-hanging fruit. Dr. Amy Grice, an AAEP member with strong business acumen, advocates for equitable pay for hours worked considering experience gained—internship and residency programs included. The goal is to make the education attained financially viable for new graduates with a crushing debt load. Fee increases are likely to be required to support improved compensation and will be bolstered by decreased supply of equine veterinarians in the face of projected stable demand.

Perhaps we would be wise to listen with an open mind and consider if equine practice can evolve regardless of our generation. The real question may be if our long-established asks and expectations remain ethical.

Consider development of a minimum sleep strategy or flexible team leverage to allow appropriate rest for all staff. Positions that frequently require several days with limited sleep may warrant creative scheduling. Solo or small practice approaches may include cooperative models for emergency coverage. While challenging to manage, appropriate rest is critical to the long-term health of veterinarians and limiting mistakes due to sleep deprivation.

Time off may hold more or equal value than traditional monetary compensation among a younger group of veterinarians. Watching parents struggle during an economic downturn and living through a pandemic has changed the perspective for many. More recent generations may choose

continued on next page

AAEP ETHICAL PRACTICE Every Day-Every Time

Dr. Christakos is a partner at Littleton Equine Medical Center in Littleton, Colo., and serves on the AAEP's board of directors and Professional Conduct & Ethics Committee.

5 things to know about AAEP this month

1. Secure one of only 60 spots for Focus on Sport Horse Pre-Purchase Exam, May 2–3 in Lexington, Ky., by registering for the hands-on CE event at aaep.org/meetings.
2. AAEP Virtual Convention participants are reminded that CE from on-demand recordings of educational sessions must be claimed by March 31.
3. Solicit advice on a difficult case or share your expertise by joining the more than 1,400 members of AAEP Member Vet Talk on Facebook. Search for the private group on Facebook to join.
4. Submit a paper by March 15 for consideration for presentation at the 2022 AAEP Annual Convention at https://s3.goeshow.com/aaep/annual/2022/AAEP_paper_submision.cfm.
5. New practitioners: Acquire advice on navigating the early stages of your career by signing up for AAEP's Outrider mentorship program at aaep.org/mentoring-program.

New Practice Life podcast offers insight into equine veterinary business trends

Despite an increase in demand for services among existing clients, equine veterinary practices are navigating some difficult trends in dually providing the highest quality of care to clients and a fulfilling and satisfying work environment for employees.

During the January episode of the AAEP Practice Life podcast, which recaps the Business News Hour session from the 2021 AAEP Annual Convention, Dr. Mike Pownall explores the state of the equine and veterinary economy as well as the challenge of attracting and retaining equine veterinarians with session panelists Dr. Caitlin Daly, owner of Mid Coast Equine in Waldoboro, Maine; Dr. Amy Grice, veterinary consulting practice owner in Virginia City, Mont.; and Dr. Kelly Zeytoonian, owner of Starwood Equine Veterinary Services and Starwood Veterinary Consulting Inc. in Redwood City, Calif.

During a discussion of retention, it was noted that many practices are becoming more progressive to attract and retain veterinarians due to the surplus of available jobs. Dr. Zeytoonian highlighted safety (due to lack of support staff), debt-to-income ratio, practice culture and emergency coverage as the top reasons employees leave a practice.

"What an amazing opportunity if we take advantage of this moment to say, 'people need us, there is a demand for our services, it's time for us to reconfigure our expectations for the clients we deal with, the expectations we have from them, and, in turn, build up and improve the practices we are bringing employees on to,'" said Dr. Zeytoonian.

Among the topics explored during the 38-minute episode are the causes and effects of "The Great Resignation," the wide discrepancy in average starting salary by gender in equine practice, lack of diversity within the profession and suggestions for improving, importance of purpose and autonomy, and tips for establishing boundaries with clients and colleagues.

Download or listen to the episode at podcast.aaep.org or on iTunes.

The ethics of hard work, continued

to have a career that does not define their identity to the same degree as established practitioners. If desire for excellence as a professional remains unchanged, quality of care is not sacrificed and a shift in mindset may result in greater sustainability over the course of a career.

Our population of horse doctors is shrinking. More veterinarians are retiring than entering our sector of practice. We need all of us working together to care for our equid population. Collaborative, supportive environments must replace competitive, cut-throat and toxic cultures. Improved wellbeing and retention can result in a career that ultimately feels like one of the coolest jobs in the world when done well.

The current rate of attrition from veterinary medicine, continuous escalation of educational costs and documented increased risk for self-harm make evolution essential to steady our path forward. Change comes hard to all of us, but I am reminded of the immense clinical knowledge gained personally from working with new graduates and interns. Hearing our young comrades and implementing new information for the staffing and wellness side of practice only makes sense. Consider the Platinum Rule: Treat others the way they would like to be treated. An unintended consequence may be learning that how we want to be treated is no longer equivalent to what we have traditionally accepted for ourselves.

Reward excellence with an AAEP award nomination

Deadline to nominate is June 1

Honor a colleague who is serving the profession, association or welfare of the horse in outstanding ways with a 2022 AAEP annual award nomination. The AAEP is accepting nominations in the following categories until June 1:

The **Distinguished Educator – Academic Award** honors an individual educator who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners.

The **Distinguished Educator – Mentor Award** honors an individual who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners through mentoring.

The **Distinguished Life Member Award** recognizes a member who has demonstrated outstanding or extraordinary service to the AAEP throughout their career.

The **Distinguished Service Award** recognizes an individual who has provided exemplary service to the AAEP or a similar organization to the benefit of the horse, horse industry or the profession of equine veterinary medicine.

The **George Stubbs Award** recognizes the contributions made to equine veterinary medicine by individuals other than veterinarians.

The **Sage Kester Beyond the Call Award** is named in honor of its first recipient, the late General Wayne O. "Sage" Kester, DVM, and represents the highest honor bestowed by the AAEP upon a current or former member. The award is presented to an individual who has made significant and long-lasting contributions to equine veterinary medicine and the community.

The **Lavin Cup (The Equine Welfare Award)** recognizes a non-veterinary organization or individual that has demonstrated exceptional compassion or developed and enforced rules and guidelines for the welfare of horses.

Dr. Bill Moyer, left, accepts the Distinguished Life Member Award from 2021 AAEP President Dr. Scott Hay during the 67th Annual Convention in Nashville, Tenn.

The **AAEP Research Award** recognizes an individual who has recently completed research that has or will make a significant impact on the diagnosis, treatment or prevention of equine disease. Nominations are open to all individuals whose research is acknowledged by presentation or publication and by peer review as a significant advancement in equine medicine or innovation in equine science. Nominees must have had their research presented or published during the two years prior to when nominations are submitted to the AAEP.

Visit aaep.org/about-aaep/annual-awards for nomination forms as well as additional information about the awards and selection process. Nomination forms are also available from Sue Stivers at (859) 233-0147 or sstivers@aaep.org.

Award recipients will be honored at the AAEP's 68th Annual Convention in San Antonio, Texas, Nov. 18–22, 2022.

New *EVE* podcast focuses on antimicrobial use in horses

In the latest episode of the *Equine Veterinary Education* podcast, Dr. Cajsa Isgren discusses her review article, "Improving clinical outcomes via responsible antimicrobial use in horses." Download or listen to the 35-minute episode at equineveterinaryeducation.podbean.com.

Zap the generational gap!

Tips for embracing the unique strengths of younger veterinarians

By Meagan Johnson

Meagan Johnson

Equine practices risk losing young vets to small animal practices when the toll of long hours, no days off and less pay leads to burnout. In this article, we will examine some small steps you and your practice can take to keep young equine veterinarians committed and devoted to the care of horses.

Feedback is my favorite word

Younger generations have a higher desire for feedback and collaboration than previous generations.

- Greater than 65% of Generation Z (born between 1997–2012) want weekly feedback at a minimum (and preferably more often).[1]
- 74% of millennials (born between 1981–1996) name collaboration as one of the top two priorities they want in a workplace.[2]

What can practice managers do to create the culture of feedback and collaboration millennials and Generation Z crave?

> Over 70% of Generation Z are motivated to go above and beyond when they feel their employer cares about their welfare.[4] Greater than 80% want to work for someone whom they can relate to both professionally and personally.

An HR manager I recently interviewed told me he abolished the yearly review. He said, "Young people do not care about feedback that is a year old. They care about the day-to-day relationship they have with their employer."

One tool he uses to solidify the employer/employee relationship is the Stay Interview, which helps managers understand why people stay and why they leave. Additionally, it is an effective tool that allows people to feel heard and their opinion has value.

Some sample Stay Interview questions:[3]

- What do you like most about working here?
- What kind of feedback would you like about your performance that you are not currently receiving?
- What have you felt good about accomplishing during your time here?
- When was the last time you considered leaving your job and what was the reason you thought about leaving?

To learn more about what questions to ask and how to conduct a Stay Interview, search "stay interview questions" in Google.

Give younger veterinarians a mentor

According to a Deloitte study, millennials who are at their current job or organization for longer than five years are two times more likely to have a mentor. And according to Price Waterhouse Cooper, 98% of millennials feel that working with strong mentors is very important.

We often think of a mentor as someone from our personal life—a coach, a teacher or a community leader. Today, younger people are looking for mentorship in the workplace. According to a study by Springtide Research Institute, over 70% of Generation Z are motivated to go above and beyond when they feel their employer cares about their welfare.[4] Greater than 80% want to work for someone whom they can relate to both professionally and personally.

WLB (work-life balance)

Young practitioners want and expect a healthy balance between work and personal time. This does not mean they do not love their jobs. Young equine veterinarians have chosen this career because they are passionate about horses and their welfare. Here are four steps to take to ensure everyone in your practice is experiencing WLB equilibrium:

- **50% of Millennials have children.** They want family-related benefits such as childcare providers and paid parental leave.
- **Holistic wellness initiatives.** Help your young practitioners with stress management. Provide wearable devices (i.e., fitness watches), mental health support and accessible healthy food options. (This also ties into the Generation Z desire to work for someone who cares about them.)
- **Tuition reimbursement.** The younger generations have more student debt than previous generations. Additionally, they are experiencing higher levels of financial stress than older generations. Even partial assistance is a great stress reliever to someone who is just beginning their career.

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Meagan Johnson is a professional speaker and generational enthusiast who writes and speaks about the ever-changing multiple generations and the best practices of the organizations who employ and sell to them. She delivered the keynote presentation at the AAEP's 2021 Annual Convention.

Deadline nears to submit papers for 2022 convention in San Antonio

Papers due March 15 at 3:00 p.m. ET

Time is running out to submit a paper to be considered for presentation during the 68th Annual Convention in San Antonio, Texas, Dec. 4–8. The presenting author of selected papers will receive complimentary registration and an honorarium.

Eligible for consideration are scientific papers, "how-to" papers, review papers, abstracts and The Business of Practice papers. All paper presentations are limited to 15 minutes with an additional 5 minutes for Q&A.

Papers must be submitted by March 15, 3:00 p.m. ET, at https://s3.goeshow.com/aaep/annual/2022/AAEP_paper_submission.cfm. Authors should visit the site in advance to set up a profile and provide paper and author information

before uploading the paper when it is finished. Complete considerations and ethical guidelines are available in the General Instructions area of the site.

Contact Carey Ross, scientific publications coordinator, at cross@aaep.org with questions concerning educational paper submission.

Resort Symposium attendees enjoy sun, sand and science

Warm sunny skies greeted the 116 veterinarians from the United States, Canada and Switzerland who ventured to the Big Island of Hawai'i Jan. 19–21 for tropical mid-winter CE at the AAEP's 23rd Annual Resort Symposium.

While making memories and recharging for the year ahead, attendees acquired practical management and treatment strategies in the areas of reproduction, early-life care and sport horse medicine. Half-day sessions left ample time to enjoy the island's natural beauty or relax on the beach.

If you're interested in a small, casual educational experience featuring plenty of practical information and natural splendor, you'll have another opportunity to feel the sand between your toes in early 2023 at a destination to be announced in an upcoming issue.

Resort attendees enjoy local fare and camaraderie on the beach during the Welcome Reception.

Zap the generational gap!, continued

- **Guaranteed day off.** I heard this comment from every young equine veterinarian I interviewed. The knowledge that there is one day that is a guaranteed day off makes the 10- to 12-hour days doable.

It can be challenging to change our methods or challenge the "way we have always done it." I encourage everyone to embrace the younger generations and appreciate the opportunities they bring to your practice. At the end of the day, young and seasoned generations all want the same thing: to take care of the client and their horses to the best of their ability.

Footnotes:

1. Shenton Chris, *Gen Z in the workplace: Culture needs to be 'frequent feedback' focused,* https://www.weekly10.com/gen-z-and-workplace-feedback, 5/15/20
2 *4 Workplace Elements Sure To Engage The Millennial Worker*, https://www.hrcloud.com/blog/4-workspace-elements-sure-to-engage-the-millennial-worker, 4/28/15
3 *Stay Interview Questions*, https://www.shrm.org/resourcesandtools/tools-and-samples/hr-forms/pages/stayinterviewquestions.aspx
4 Deichler Andrew, *Generation Z Seeks Guidance in the Workplace*, https://www.shrm.org/resourcesandtools/hr-topics/organizational-and-employee-development/pages/generation-z-seeks-guidance-in-the-workplace.aspx, 6/28/21

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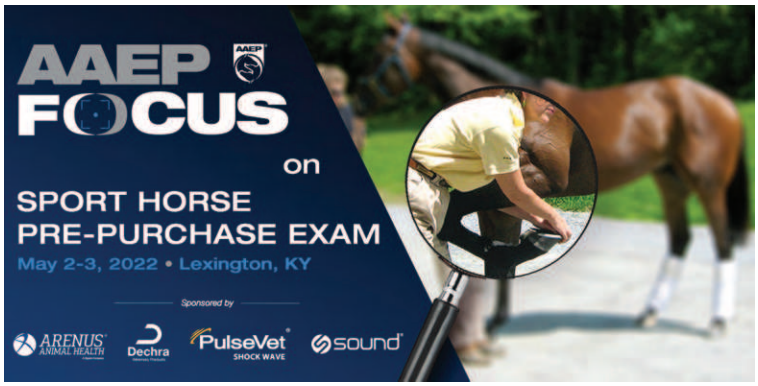
Performance practitioners: Refine your pre-purchase exam technique at hands-on Focus meeting



A proper and thorough pre-purchase exam is fundamental to providing practical advice to your client considering acquisition of an equine athlete. But what constitutes a comprehensive exam? Which abnormalities are acceptable, and which demand further scrutiny based on the intended use of the horse?

At the AAEP Focus on Sport Horse Pre-Purchase Exam, May 2–3 at Spy Coast Farm in Lexington, Ky., you'll acquire pre-purchase exam protocols applicable to all sporting disciplines from an all-star cast of performance practitioners; techniques from board-certified specialists to further investigate identified issues; and judicious guidance from veteran equine attorneys to avoid negligence claims.

Among the clinical topics covered will be upper airway endoscopy, radiography and alternative imaging, cardio-pulmonary testing, ophthalmic exam, dynamic gait analysis, and distinguishing between neurologic or lame. The meeting will utilize a flipped classroom model in which registrants will view relevant talks online prior to the event so that in-person time is focused on experiential learning.

On-site, you'll observe a pre-purchase exam demonstration and rotate through six wet labs that will refine your pre-purchase examination skills on live horses at stations devoted to:

- Radiography of the neck and back
- Radiography of the foot, hock and stifle
- Radiography of the fetlock, metacarpus and carpus
- Application and evaluation of dynamic gait analysis
- Neurologic vs. lameness
- Practical application of ultrasound in the purchase exam

Practical takeaways include:

- Understanding the components of a comprehensive exam
- Employing imaging modalities to clarify issues discovered
- Knowing when to consult a specialist
- Communicating expectations and results with clients effectively
- Avoiding legal/malpractice pitfalls

Attendance is limited 60 participants, so early registration is encouraged. The AAEP-member registration rate is $945. Register for the meeting, book your hotel and view the educational program at **aaep.org/meetings.**

Presenters:

Dr. Kent Allen
Dr. Mark Baus
Dr. Stephanie Bell
Dr. Jeff Berk
Dr. Lisa Casinella
Dr. Vern Dryden
Dr. Mary Durando
Dr. Scott Hopper
Dr. Kit Miller
Dr. Rick Mitchell
Dr. Steve Reed
Dr. Kurt Selberg
Dr. Laurie Tyrell
Dr. Brett Woodie
Mike Casey (attorney)
Anna Ford (New Vocations Racehorse Adoption Program)
Mike Meuser (attorney)

CE Hours: 27.5 (Online presentations – 17; On-site demo and labs – 10.5)

The AAEP Focus on Sport Horse Pre-Purchase Exam is sponsored by:

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Welcome to new AAEP members!

The following practitioners joined the AAEP between Oct. 1–Dec. 31, 2021:

Kristin Abderhalden, DVM, Murrysville, PA
Elizabeth Acutt, DVM, Fort Collins, CO
Morton Norris Adams, DVM, DACVS, DACVSMR, Oxford, PA
Pablo Adrados, DVM, Madrid, Spain
Morgan Apke, DVM, Danville, CA
Brodie James Argue, DVM, Gatton, QLD, Australia
Lindsey Arthur, DVM, Lexington, KY
Amanda Avison, DVM, Kennett Square, PA
Lelia Barden, DVM, Petaluma, CA
Brent D. Barrett, DVM, CJF, Ocala, FL
Catarina Barros, DVM, Lexington, KY
Ramon Batalla, DVM, Lexington, KY
Heather Beach, DVM, Ashford, CT
Robert J. Bloomer, DVM, MS, Manhattan Beach, CA
Rafael J. Borges, DVM, Aguadilla, PR
Ann M. Bower, DVM, Stillwater, MN
Ryan E. Brenner, DVM, Escalon, CA
Maria Isabel Calero, DVM, Los Olivos, CA
James Carleton Campbell, DVM, Baddeck, NS, Canada
James Canant, DVM, Ralph, AL
Daniel Chavez, DVM, Riverside, CA
J. Erick Cobb, DVM, Lake Elsinore, CA
Cate Crowley, DVM, North Scituate, RI
Jorge F. Cruz Zavaleta, MV, Mississauga, ON, Canada
Julia E. Daggett, DVM, Newtown, CT
Cody Dalton, DVM, MS, Ash Grove, MO
DD Davis, DVM, Russellville, KY
Wayne R. Deason, DVM, Floresville, TX
Richard Dixon, DVM, Shelby, NC
Trent Dozier, DVM, Merkel, TX
Singen Elliott, DVM, Doylestown, PA
Cameron Etherington, DVM, Taylorsville, UT
Daniel Fordham, DVM, Monroe, NC
Bambi Lynn Fox, DVM, Paducah, KY
Tara Frisch, DVM, Manitou, MB, Canada
Sarah Holbrook Garcia, DVM, Gainesville, FL
Amy Ellen Gaw, DVM, New Liskeard, ON, Canada
Roberto Gottarelli, DVM, Castel Bolognese, Italy
Annie Graves, DVM, Zachary, LA
Ricardo Gutierrez, DVM, Somers, CT
Elizabeth Siobhan Hanly, DVM, Calgary, AB, Canada
Darrell Harvey, DVM, Fort Myers, FL
Jessica Harvey, DVM, Buckhannon, WV
Joseph Hatfield, DVM, La Grange, TX
Rylee Marie Hatfield, DVM, La Grange, TX
Anna Henderson, DVM, Rocky View County, AB, Canada
Sandra Viviana Hernandez, DVM, Uxbridge, ON, Canada
Stephanie Hernandez, VMD, Leesburg, VA
Sandra L. Hickey, DVM, Eaton, OH
Gene J. Hill, DVM, Ocala, FL
Kevin L. Hill, DVM, Kaysville, UT
Katlin J. Hornig, DVM, Gainesville, MO
Loy D. Hosselton, DVM, Flora, IL
Jessica Hutchings, DVM, Solvang, CA
Alexis Nicole Ivanecky, DVM, Tucson, AZ
Camilo Jaramillo Morales, DVM, MS, Davis, CA
Meghan Kartley, DVM, Middlefield, OH
Lyndsay Klemens, DVM, Union Mills, IN
Florian Lackner, DVM, Kungsbacka, Sweden
Kara Laird, DVM, Fenton, MI
Robert Leakos, DVM, Port Moody, BC, Canada
Kerry Levin, DVM, Ukiah, CA
Scott Lewis, DVM, Asheville, NC
Andrew Lott, DVM, Lake Worth, FL
Isabelle Louge, DVM, Groton, NY
Nareela Lupton, DVM, Duncan, BC, Canada
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Members in the News

Dr. Frank Nickels

Dr. Frank Nickels honored by ASPCA's Right Horse

Honor Roll member Dr. Frank Nickels, longtime professor of equine surgery at Michigan State University College of Veterinary Medicine, is among the 2021 recipients of Good People for Good Horses Awards from the ASPCA's Right Horse for his dedication of time and talent to help horses in transition.

A veterinary graduate of Washington State University and recipient of the AAEP's 2013 Distinguished Educator – Academic Award, Dr. Nickels has diagnosed and repaired injuries suffered by Thoroughbred racehorses who retire from racing into CANTER Michigan, a Thoroughbred aftercare organization begun in 1998.

Benefit: Mentorship program helps foster career satisfaction

To help young equine veterinarians successfully navigate equine practice and find lasting professional fulfillment, the AAEP offers a mentorship program called Outrider to facilitate the creation of relationships between early-career AAEP members and members with more experience.

The program provides mentorship in the non-clinical areas of equine practice that are critical to long-term success and wellbeing, such as general career advice and supportive interpersonal relationships. The intent is not to provide specific case management advice.

The exact nature of the relationship between mentors and mentees is up to the pair; however, most conversations consist of phone calls, emails and/or text messages at least on a monthly basis. Pairings have a one-year term; both parties need to opt back into the relationship for it to continue. If one or both parties elect not to renew the relationship, each can return to the pool and receive a new match.

If you would prefer not to sign up for a full mentorship relationship but instead just need to seek advice on something, you can submit a question in any of nine areas such as contract negotiation, handling difficult clients, financial management and more. Your question will be directed to a veteran practitioner experienced in that area for a reply. To submit a question, visit aaep.org/mentoring-program and click the "Ask a Mentor a Question" button.

If you are in your first five years of practice and would like to find a mentor, register as a mentee at aaep.org/mentoring-program. After uploading your CV or work samples, you will be able to review a list of volunteer mentors and their background before requesting an engagement. You'll negotiate and set expectations for time commitment up front so you both get the most value from your interactions.

If you are a veteran practitioner who would like to volunteer as a mentor to a new practitioner, register as a mentor at aaep.org/mentoring-program. You will then create your mentor profile by uploading your CV or work samples.

If you have questions about this benefit, contact Megan Gray, AAEP member concierge, at mgray@aaep.org or (859) 233-0147.

AAEP Educational Partner Profile: Zoetis

Zoetis has been committed to providing horse care you can count on for nearly 70 years. Our team includes numerous equine veterinarians and other experts who are inspired daily by the opportunity and profound responsibility to support horses, the owners who love them, and the equine veterinarians and other care team members who safeguard their wellbeing every day.

As the world's leading animal health company, Zoetis is driven by a purpose to nurture our world and humankind by advancing care for animals.

Zoetis' trailblazing approach to horse care drives our ongoing commitment to innovation. In 2018, Zoetis launched **CORE EQ INNOVATOR®**, the first and only vaccine to contain all core equine disease antigens to protect horses against West Nile virus, Eastern and Western equine encephalomyelitis, tetanus, and rabies—in one injection. In addition, Zoetis recently added Platinum Performance® nutrition products, the **Stablelab®** point-of-care diagnostic blood test, and the Owl Manor portfolio of regenerative medicine devices featuring **Pro-Stride® APS** to its portfolio, giving veterinarians even more ways to provide comprehensive care to equine patients.

Advancing the Equine Veterinary Profession

As a longtime Educational Partner of the AAEP, Zoetis sponsors The Foundation for the Horse Scholarship for students and matches donations to the AAEP Equine Memorial Giving program. Additionally, Zoetis is proud to sponsor the AAEVT. The company's support of the AAEP and AAEVT is part of the Zoetis Commitment to Veterinarians program that supports professionals in the industry through continuing education, veterinary wellness, research and development, and philanthropy.

In addition to supporting healthy horses and healthy veterinary practices, Zoetis is deeply committed to the health of the equine industry. Zoetis hosts local meetings and events at veterinary practices, as well as supports veterinarian/veterinary technical organizations including the NEAEP, FAEP, TEVA, NOMV and more. Zoetis also supports local and national horse competitions/events and our broader equine community, such as the American Horse Council, The Foundation for the Horse, American Quarter Horse Association's Equine Research Foundation, The Right Horse Initiative and more.

For more information, visit www.ZoetisEquine.com


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Highlights of recent clinically relevant papers

Laryngeal function grade

There is persistent concern among some trainers, owners and veterinarians regarding the effect of preoperative laryngeal function grade on the outcome of laryngoplasty and ventriculocordectomy (LPVC). The aim of this retrospective case series by Ali Broyles *and co-workers based in the USA was to determine the effect of laryngeal function grade prior to LPVC on postoperative performance.*

Medical and race records of Thoroughbred racehorses diagnosed with recurrent laryngeal neuropathy (RLN) and treated with LPVC at Rood and Riddle Equine Hospital between 1998 and 2013 were reviewed. Horses were placed into three groups based on preoperative laryngeal function grade (grade III.1, grades III.2/III.3, and grade IV). The effect of preoperative laryngeal function grade on postoperative performance was determined by multivariable logistic regression, Cox proportional hazard model and multivariable linear regression analysis.

In a multivariable logistic regression, grade III.2/III.3 horses had 1.88 times higher odds (95% CI: 1.03–3.43) of racing after LPVC than grade IV. A multivariable Cox's proportional hazard analysis controlling for race prior to surgery showed that likelihood of racing postoperatively was not different between grade III.1 and grade IV. Kaplan–Meier survival analysis showed that grade IV horses took a longer time to race compared with grade III.1 and grade III.2/III.3. Laryngeal function grade did not influence the mean earnings per start. The main limitation was the small number of horses in the grade III.1 group (n = 68) compared with the III.2/III.3 (n = 313) and IV (n = 242) groups.

Laryngeal function grade may affect likelihood of racing after LPVC, but not earnings per start. Grade III.2/III.3 horses were more likely to race postoperatively than grade IV horses, and grade IV horses took a longer time to first race after LPVC.

ACTH as a biomarker for PPID

Accuracy of baseline adrenocorticotropic hormone (ACTH) for the diagnosis of pituitary pars intermedia dysfunction (PPID) in horses varies between studies. The aim of this systematic review and meta-analysis by James Meyer *and co-workers in the USA and UK was to estimate the diagnostic accuracy of ACTH as a biomarker for PPID in adult horses or ponies and appraise potential causes of heterogeneity.*

A literature review identified studies reporting diagnostic accuracy data for extraction. Risk of study bias was evaluated using QUADAS-2. To account for variations between studies, such as variable positivity thresholds, two random-effects models (the hierarchical summary receiver operating curve (HSROC) and the bivariate binomial normal model (BBN)) were used to pool accuracy measurements. Meta-regression was performed using study-level variables. The impact of diagnostic test accuracy on the frequency of false-positive and false-negative results at various pre-test probabilities was calculated using the BBN model's accuracy results.

Patient selection and index test evaluation demonstrated significant risk of bias. Mean and 95% confidence intervals for sensitivity and specificity for all studies (n = 11) were 0.72 (95% CI: 0.62–0.82) and 0.88 (95% CI: 0.79–0.93), respectively. When studies with a common positivity threshold of 35 pg/ml ACTH were evaluated (n = 6), sensitivity and specificity were 0.66 (95% CI: 0.54–0.77) and 0.87 (95% CI: 0.74–0.94). In a hypothetical group of 1000 horses with PPID prevalence of 2%, 20%, and 90%, the frequency of resulting false-positive and false-negatives would be 127 and 7, 104 and 68, and 13 and 306, respectively. Factors leading to increased accuracy were case-control design, clinical reference standard and data-driven choice of ACTH threshold.

In horses with clinical signs of PPID, ACTH may be a functional "rule-in" test. Baseline ACTH is not recommended for screening purposes or use in horses without clinical signs of PPID. To minimise false negatives in horses with clinical signs of PPID, a negative ACTH test should be followed up with a thyrotropin-releasing hormone (TRH) stimulation test.

Pregnant broodmares with colic

This study by Hope Douglas *and co-workers in the US evaluated, following colic admission during pregnancy, (1) broodmare survival; (2) the frequency of recurrent colic in broodmares and its associated variables, and (3) pregnancy outcome and the variables associated with a negative pregnancy outcome.*

Admissions of 104 pregnant mares over a 6-year period were included. Cox proportional hazards regression analysis was performed to evaluate variables associated with broodmare survival. Logistic regression analysis was used to examine the variables associated with recurrent colic and pregnancy outcome.

Broodmares from 73/104 (70.2%) admissions were discharged alive. Lesion category, admission hyperlactataemia (hazard ratio (HR): 3.24; 95% CI: 1.28–8.22), and admission high packed cell volume (HR: 2.89; 95% CI: 1.29–6.47) were associated with reduced survival. Recurrent colic was observed in broodmares from 33/70 admissions (47.1%). The final multivariable model for recurrent colic included Thoroughbred breed (OR: 5.09; 95% CI: 1.58–16.4) and age (OR: 0.876; 95% CI: 0.747–1.03). Overall, negative pregnancy outcome was 14/65 (21.5%). Lesion category, evidence of systemic inflammatory response syndrome (SIRS) in hospital (OR: 31.2; 95% CI: 2.09–466.5), and diarrhoea in hospital (OR: 379.3; 95% CI: 97.1–1482.0) were associated with increased negative pregnancy outcome. Altrenogest administration was inversely associated with negative pregnancy outcome (OR: 0.029; 95% CI: 0.004–0.222).

Pregnant broodmares admitted for colic had lower survival than anticipated and were at risk of recurrent colic. Markers of broodmare disease severity were associated with pregnancy outcome. Lesion category, haematologic variables (packed cell volume and l-lactate concentration), evidence of SIRS, and diarrhoea were useful for predicting broodmare and pregnancy outcomes.

Rope-assisted recovery

In this knowledge summary, Ffion Lloyd *and Pamela Murison from the University of Glasgow, UK considered the PICO question 'In horses undergoing general anaesthesia, does*

assistance with ropes result in better recoveries when compared to no assistance ('free' recovery)?'

Only three studies were found to address the PICO question directly by comparing rope-assisted and unassisted recoveries in horses. One was a randomised, non-blinded controlled trial and two were retrospective cohort studies.

These three studies arrive at different conclusions regarding the utility of rope assistance in recovery from general anaesthesia in horses but examine very different populations. The randomised controlled trial provides weak evidence that rope assistance can shorten recovery and improve recovery quality in healthy (American Society of Anesthesiologists (ASA) I–II) horses. One retrospective cohort study provides weak evidence that rope assistance confers a reduction in fatality in both healthy and sick horses. The other retrospective cohort study provides weak evidence that rope assistance confers no benefit to horses undergoing emergency colic surgery. Both assisted and unassisted groups in each study had fatalities and all studies reported complications related to the rope recovery system.

Insufficient evidence is available to permit a full recommendation regarding rope assistance during recovery from general anaesthesia in horses. Rope assistance may improve recovery time and quality in some horses. The decision to perform a rope-assisted recovery must be made considering individual patient, team and clinic factors. Rope assistance cannot prevent fatalities in recovery.

Faecal microbiota transplantation

The aim of this study by Marco Costa *and co-workers in Canada and Brazil was to characterise the faecal microbiota of horses with acute and chronic diarrhoea before and after faecal microbiota transplantation (FMT).*

Six client-owned horses with acute and chronic diarrhoea received FMT from two healthy donor horses. Microbiota analysis using next-generation sequencing was performed on faecal samples collected before and 2 and 7 days after FMT. Signs of diarrhoea improved in four horses, whereas the remaining two horses did not survive. There was a significant difference in the number of bacterial species between donors and recipients. The Order Lactobacillales and the genera *Lactobacillus, Intestinimonas*, and *Streptococcus* were increased in the microbiota of diarrhoeic horses, and *Saccharofermentans* genus increased in healthy donors. The results suggest that FMT from the healthy donors was not effective over a 7-day period as it did not change the faecal microbiota of the diarrhoeic horses. Further research to improve the efficacy of FMT in horses is needed.

Recovery quality

The objective of this retrospective case study by Isabel Santiago-Llorente *and co-workers in Spain was to determine demographic, preoperative and anaesthesia-related variables that may be associated with unsatisfactory recovery quality in horses undergoing emergency abdominal surgery (colic) in an equine teaching hospital.*

The anaesthetic records of 313 horses admitted for surgical treatment of colic over a 14-year period were examined. Overall quality of recovery was assessed as dangerous, poor, fair, good or excellent. The following categories were constructed as a dichotomic variable: unsatisfactory recovery (poor and dangerous recoveries) and satisfactory recovery (excellent, good and fair recoveries). Univariable and multivariable analyses were performed to evaluate the association between all studied variables and recovery.

All recoveries were unassisted. Unsatisfactory recovery quality totalled 17.2% (3.5% dangerous and 13.7% poor), whereas satisfactory recoveries totalled 82.8% (26.2% fair, 40.9% good and 15.7% excellent). Univariable analysis showed that unsatisfactory recoveries were associated with high preoperative packed cell volume, pain behaviour, poor premedication and induction quality, high intraoperative mean heart rate, low mean arterial blood pressure, dobutamine dose ≥1.5 μg/kg bwt/min, non-administration of romifidine, long anaesthesia time and prolonged time to stand. The multivariable model showed that factors strongly associated with unsatisfactory recovery quality were dobutamine dose ≥1.5 μg/kg bwt/min (adjusted odds ratio (AOR) = 6.60; 95% CI: 2.91–14.96), poor premedication quality (AOR = 4.60; 95% CI: 1.73–12.23) and a time to stand >70 min (AOR = 2.59; 95% CI: 1.13–5.91).

This study shows that high dobutamine requirements, poor premedication quality and a prolonged time to stand are risk factors for unsatisfactory recovery quality in horses undergoing anaesthesia for colic surgery. Addressing these factors may enable clinicians to improve the quality of the recovery phase.

S. WRIGHT
EVE Editorial Office

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Editorial

Peter D Rossdale, OBE, MA, PhD, Dr. (h.c.) Berne, Dr. (h.c.) Edinburgh, DVSc (h.c.) Sydney, DESM, FACVSc, FRCVS. 1927-2021

> Progress depends, therefore, on an aggregate, contributed by a high proportion of those involved, with an emphasis on collaborative efforts where possible
> (Rossdale, 2000)

> Authors without readers may be likened to a whale on a beach: devoid of the strength and purpose of their being. (Rossdale & Mayall, 2007)

Peter Rossdale was first and foremost a clinician. He attained an honours degree in natural sciences from the University of Cambridge in 1949, then graduated from the Royal Veterinary College, London, became a member of the Royal College of Veterinary Surgeons in 1952 and, after 2 years in Sussex, he took up a position as an equine practitioner in Newmarket where he remained for the remainder of his clinical career, retiring in 2004. He was awarded his Fellowship of the Royal College of Veterinary Surgeons in 1960 for work performed in practice describing the clinical features of the newborn foal, data which he published, unusually for a practitioner in those days, in a pair of papers in the British Veterinary Journal (Rossdale, 1967a, 1967b). This marked the start of a career as an author of clinical research which ultimately led to the publication of around 150 research papers based primarily on clinical data generated from his caseload and a further 100 or so editorial and educational articles relating to both clinical practice and academic publishing. Completing his portfolio of academic degrees, Peter gained the degree of Doctor of Philosophy from the University of Cambridge for his published work in the field of equine perinatology and reproductive biology in 1985. He also wrote and edited numerous veterinary textbooks, including Equine Stud Medicine, written with his partner, Sidney Ricketts; a textbook read by every undergraduate of the 1980s who aspired to a career with horses.

However, Peter Rossdale's massive and lasting impact on the equine veterinary profession of today lies in his vision, his commitment to the education of others and his drive towards improving standards in clinical practice. Yet, vision alone is not enough: implementation can be the bigger challenge and Peter had a unique ability to form collaborative groups and motivate them to work to improve equine clinical practice and turn his vision into reality. Peter was generous with his knowledge and he happily shared information and expertise with anyone and everyone willing to learn. This earned him the respect of both the veterinary profession and academia, recognised with additional honorary degrees from the Universities of Edinburgh, Berne and Sydney, honorary membership of British Equine Veterinary Association in 1978 and Honorary Fellowship of the Australian College of Veterinary Scientists in 1975 and with numerous prizes and honours including the John Henry Steel Memorial Prize, the William Hunting Prize and the George Fleming Prize, the Tierklinik Hochmoor International Prize, the Dalrymple Champneys Prize and Cup, the Duke of Devonshire Award for contributions to the British Breeding Industry and the BEVA Equine Welfare Award. He was inducted into the University of Kentucky's Equine Research Hall of Fame and received the Order of the British Empire for services to equine veterinary science.

Peter lectured extensively and this included many inaugural lectures in the UK and abroad, including the Peter Wilson Bequest Lectureship in Edinburgh and in 1978, the D.L.T. Smith inaugural lectures in Saskatoon and the Frederick Hobday Lecture in the UK in 1985 (Rossdale, 1985) and cumulating with a comprehensive review of equine perinatal illness in his 2004 American Association of Equine Practitioners' Milne Lecture, The Maladjusted Foal: Influences of Intrauterine Growth Retardation and Birth Trauma (Rossdale, 2004).

Peter was amongst a small group of equine practitioners who, in the late 1950s, developed what ultimately became BEVA in 1961. He held the positions of Treasurer (1961–1962), Chairman of Programmes Committee (1973–1975) and President (1976). Arguably his most pivotal role for BEVA was as Editor of Equine Veterinary Journal (EVJ), a position he held from 1979 to 2010 and thereafter as EVJ's Emeritus Editor.

Peter was fascinated by the philosophy of science and indeed read extensively on scientific method, psychology and the process of decision making (Rossdale, 2009a). He believed 'the duty of clinicians to publish is one which, in many respects, is as strong as that of the duty of care of the individual patient'(Rossdale, 2000). Core beliefs which Peter wrote on frequently was that research should seek to address clinically relevant questions and that cases seen in practice were a fruitful source of both pertinent questions and valuable data. He wrote a fascinating summary of these principles in an EVJ article published in 1975 in which he explained the fusion of clinician and researcher which characterised his entire career. In this article, he wrote 'In any appraisal of the subject of research we must ask ourselves the question why is it interesting to find out. The clinician in equine practice is faced with a scarcity of clinical data on which to make a diagnosis. Clinical research can elevate the art of the clinician and contribute to the aggregate of knowledge within the profession'. In the same article, he went on to summarise the benefits of engaging in research which practitioners could access under the headings (1) more accurate diagnosis, (2) more satisfaction from work, (3) the currency of interests, summarising his appreciation of the benefits of working with others and (4) opportunity of travelling where he addressed his pleasure in being able to attend international meetings, share ideas with clinicians and researchers of like mind and gain transferrable knowledge of clinical approaches adopted elsewhere (Rossdale, 1975). We

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did not get to know Peter Rossdale personally until the 1990s, but these points, made 20 years earlier, describe his career-long ethos of working with others, from a private practice setting to gain and share knowledge to improve our ability to provide for the horses under our care.

Peter's first publication appeared in the Lancet, reporting seizures in newborn foals and drawing parallels with human neonatal illness (Mahaffey & Rossdale, 1959). This became the underpinning theme of much of his subsequent research effort. In addition to describing clinical findings and behaviour of foals (Rossdale, 1967b), he performed early work on electrocardiography (Rossdale, 1967a), blood gas analysis (Rossdale, 1968a; Rossdale & Mullen, 1970), ventilation parameters (Rossdale, 1969a) and indirect blood pressure measurement (Franco et al., 1986). He reported neurological signs in compromised neonates (Mahaffey & Rossdale, 1959; Rossdale, 1968b, 1969b) and by the 1970s, Peter proposed a classification of differential diagnosis of the collapsed neonate differentiating (1) infection, (2) non-infective behavioural disturbance, (3) failure of development and (4) immunological conditions (Rossdale, 1972). To the modern reader, these classifications are somewhat descriptive. Nevertheless, they are accurate precursors to what we would currently think of as sepsis, neonatal maladjustment syndrome/perinatal asphyxia syndrome/hypoxic-ischaemic-encephalopathy and haemolytic disease of the newborn, terminology which continues to evolve as our understanding of pathogenic mechanisms develop.

True to his ethos that research should be applicable to practice, Peter's interest in the clinical challenge of managing foals with neurological and developmental problems, led him to join forces with researchers at the University of Cambridge working on physiology and pathophysiology, and Peter's work with Dr Marian Silver's group enhanced understanding of equine fetal physiology and, in particular, the importance of adrenal function and steroid hormones (Broughton Pipkin et al., 1984; Challis et al., 1995; Fowden et al., 1984; Han et al., 1995a; Ousey et al., 1987, 1998, 2004; Rossdale et al., 1984; Silver et al., 1984, 1987). The Cambridge group's work on progesterone profiles in the pregnant mare (Holtan et al., 1991; Rossdale et al., 1992), steroid hormone production in the placenta (Han et al., 1995b) and the effects of placental pathology on maternal plasma progestogens (Rossdale et al., 1991) ultimately paved the way to our understanding that progesterone may mediate neurological signs in neonatal maladjustment (Ousey et al., 2005; Rossdale et al., 1995). Peter led a team working on *in vivo* studies of normal and abnormal fetal development based on a pony research herd in Newmarket which advanced our understanding of prematurity and dysmaturity (Rossdale, 1993; Rossdale et al., 1985) and on induction of parturition (Leadon et al., 1986).

In parallel with this basic research on fetal and neonatal pathophysiology, Peter continued to have a strong focus on developing and validating techniques which had immediate relevance to clinical practice, exemplified by his work on use of mammary secretions to assess fetal readiness for birth (Leadon et al., 1984; Ousey et al., 1984, 1989). Throughout his career as a researcher, he continued to ensure that knowledge gained in the research laboratory informed clinical practice, for example, in his review of disturbances in equine fetal maturation which was included in a 1993 EVJ supplement on perinatology research, he sought to make sense of the link between placental pathology and dysmaturity and explain the phenomenon he called 'the second day syndrome' whereby foals compromised *in utero* may progressively develop clinical signs relating to dysmaturity, respiratory compromise and neurological dysfunction having appeared at birth to be fairly healthy (Rossdale, 1993).

Peter's interest in the Thoroughbred was not limited to the foal. His clinical practice led him to spend much of his time on the coalface of the Newmarket Thoroughbred breeding farms. He published extensively on aspects of problems and management of the broodmare (Allen et al., 1987; Chandley et al., 1975; McGladdery & Rossdale, 1992a, 1992b; Michel et al., 1986; Pemberton et al., 1994; Rossdale, 1984, 1994; Rossdale & D'Eath, 1987; Rossdale & Gerber, 1968; Rossdale et al., 1976; Samuel et al., 1979; Steven et al., 1979) and horse in training (Frauenfelder et al., 1986; Harris et al., 1990; Jeffcott et al., 1982), infectious diseases (Browning et al., 1991; Jeffcott & Rossdale, 1976, 1977; Mumford & Rossdale, 1980; Mumford et al., 1987; Pepys et al., 1989; Ricketts & Rossdale, 1979; Ricketts et al., 1977, 1978; Rose et al., 1974; Rossdale, 1978; Stoneham et al., 2001), heart disease (Cottrill & Rossdale, 1992; MacDonald et al., 1988), clinical nutrition (Ousey et al., 1997) and sales assessment, (McEvoy et al., 1998) and he thought and wrote extensively on how early life and veterinary management might impact performance of the finished product, the racehorse (Allen et al., 2002; Rossdale, 1998, 2005).

Returning to Peter's approach to the role of Editor, he saw EVJ as serving as a conduit between clinicians in practice and those who wish to contribute new knowledge for the benefit of the horse (Rossdale et al., 2008). To ensure that equine practitioners could remain entirely up to date with progress in their field, under Peter's leadership EVJ not only published primary research and clinical reports but also provided EVJ's readers with access to recent and ongoing work through supplementary issues linked to groups such as the International Conference for Equine Exercise Physiology, the International Symposium on Equine Embryo Transfer, the International Congress on Equine Clinical Behaviour, the International Colic Symposium and the International Workshop on Animal Locomotion. Peter also worked closely with those organising meetings with the Havermeyer Foundation to disseminate state-of-the-art knowledge on equine diseases.

Peter was consistently innovative throughout his long tenure with Equine Veterinary Journals. He was not EVJ's first editor, this honour falling to Col John Hickman and then Leo Jeffcott succeeded him before Peter took on this challenge in 1979. However, Peter was undoubtedly its most influential. Under Peter's watch, EVJ evolved into the leading international journal for equine veterinary science and it performed consistently well in the citation indices for veterinary sciences. His life-long belief in the importance of practice-generated research was more widely articulated by the evidence-based medicine (EBM) movement of the 2000s, although it clearly amused him greatly that this discipline was extolled, by some more passionate adherents, as a novel approach to practice. Peter had been talking, and writing, about exactly the same principles for almost 50 years by that time (Rossdale, 1975). Nevertheless, he saw the enthusiasm for EBM amongst younger clinicians of the day as an opportunity to promote his belief in the clinic as a laboratory, and in 2003, he established EVJ's evidence-based medicine

group and began prioritising rapid publication of articles that achieved specific EBM-related criteria including a clearly defined clinical question in studies addressing naturally occurring disease and providing strong clinical evidence to define outcomes relating to specific therapeutic or diagnostic interventions and/or refined prognostic indicators (Rossdale, 2009b; Rossdale et al., 2003). He embraced developments in scientific publishing with interest and enthusiasm; when aged almost 80 years, he pushed forwards the introduction of online publishing (Rossdale, 2010) for EVJ, although the inclusion of fast track and early view papers that were enabled by online publishing removed the main author benefit of the EBM series.

Peter Rossdale (right) and Gary Carpenter (executive director of the American Association of Equine Practitioners) (left) signing the agreement between BEVA and AAEP to publish EVE content jointly in Newmarket in 1999.

Peter was committed to veterinary education at all levels. He recognised that a scientific journal created a key archive of data to support change in practice, but there was an additional need to help support learning within the profession. To meet this need, he established Equine Veterinary Education (EVE) in 1989, pointing out, in EVE's first editorial that 'Practitioners cannot afford to leave education at the gateway of graduation for fear of becoming old-fashioned and redundant' (Gerring et al., 1989). By engaging the support of both BEVA and AAEP for EVE and by ensuring that motivated younger colleagues took on the challenge of editing and contributing to EVE, Peter was able to rapidly develop the journal into the most important education journal for equine practitioners in existence, combining both novel case reports with authoritative clinical commentaries and review articles which are essential reading for every practitioner who seeks to keep up to date with developments in the field.

Every equine clinician who has practised since the 1960s owes Peter Rossdale a debt of gratitude. His recognition that practice must be based on science and that science has a central place in daily clinical practice, his vision and drive to improve the world he found himself in, and his ability to motivate others to help him implement that vision has created a legacy in the form of the two journals he was instrumental in developing, Equine Veterinary Journal and Equine Veterinary Education that look set to continue to have a central role in equine practice long beyond Peter's retirement. It is all the more surprising to consider that he did this in his spare time, in parallel with a busy and successful career as a Thoroughbred practitioner and clinical researcher. As Peter's successors as editors of the two journals that he did so much to establish and develop, we looked to him for inspiration, guidance and advice. This brief summary of his achievements seems hopelessly inadequate in the light of his contributions to equine veterinary science, but the plethora of awards, prizes and honours he received during his lifetime confirm that the veterinary profession has and will continue to recognise his huge influence and importance.

C. M. MARR
Editor-in-chief, Equine Veterinary Journal
T. S. MAIR
Editor-in-chief, Equine Veterinary Education

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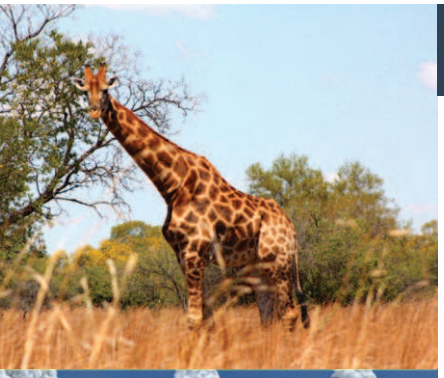

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All-inclusive* Safari Event 30 October - 5 November 2022

Mongena Game Lodge**, Dinokeng Game Reserve, South Africa**
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Dr. David Sutton MA, VetMB, PhD, CertEM(IntMed), Dipl.ECEIM, MRCVS – Professor in Equine Medicine, University of Glasgow, Scotland
Dr. Laurie Goodrich DVM, PhD, Dipl.ACVS – Professor of Orthopedics, Colorado State University, USA
Dr. David Stack MVB, MSC, Dipl.ECVS, MRCVS – Senior Lecturer in Equine Surgery, University of Liverpool, England
Dr. Sarah Smith MA, VetMB, MVetMed, Dipl.ACVIM, MRCVS – B&W Equine Vets, England
** airfare/travel not included*

Lake Louise Powder Adventure 28 January - 2 February 2023

Fairmont Château Lake Louise**, Banff National Park, Alberta, Canada**
(2h from Calgary International Airport)
5 days of skiing / snowboarding / alternative outdoor activities & 26h Lectures / Case-Discussions & 15h Wetlabs on live horses

Dr. Wes Sutter DVM, MS, Dipl.ACVS, Dipl.ACVSMR – Kentucky Equine Hospital, KY, USA
Dr. Cristobal Navas de Solis LV, MS, PhD, Dipl.ACVIM – New Bolton Center, PennVet, PA, USA
Dr. Frank Andrews BS, DVM, MS, Dipl.ACVIM – Louisiana State University, LA, USA

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Equine Alaskan Mushing Experience 21 - 25 January 2023

Big Lake, near Anchorage, Alaska (1.5h from Anchorage International Airport)
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2nd Speaker TBC

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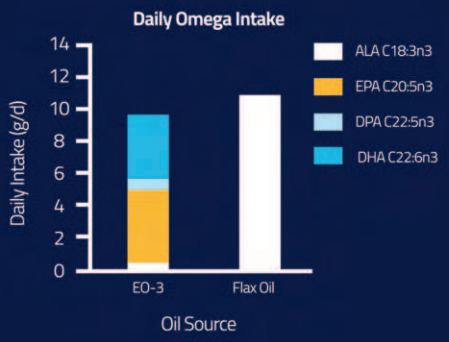

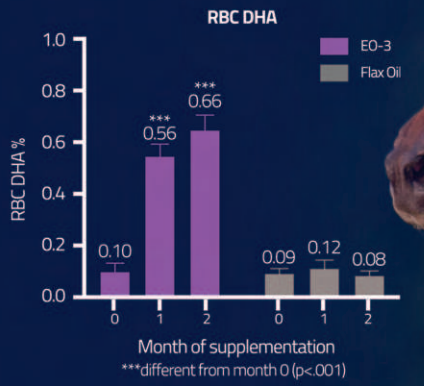

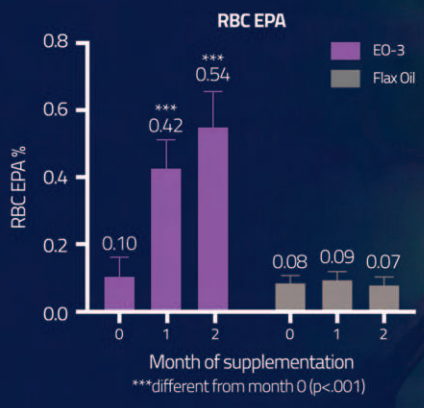

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Case Report

Successful treatment of a severely contaminated open metatarsophalangeal joint luxation by arthrodesis

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Keywords: horse; arthrodesis; fetlock; luxation; salvage

Summary

A 1-year-old Warmblood mare with a bodyweight of approximately 400 kg was presented with a severe open medial luxation of the left hind metatarsophalangeal joint (**Fig 1**). There was erosive damage to the cartilage of the sagittal ridge, and the exposed bone, cartilage and soft tissues were heavily contaminated. Both the medial and the lateral collateral ligaments of the fetlock had ruptured, as well as the medial and lateral collateral ligaments of the proximal sesamoid bones. The joint capsule was mostly unidentifiable because of tissue damage and contamination. Neurovascular bundles, extensor and flexor tendons, flexor tendon sheath, suspensory ligament and distal sesamoidean ligaments were all intact. On radiographs, no fractures could be identified. The owners requested that every effort be made to save the horse for breeding purposes. Because normal joint function would be permanently impaired, an arthrodesis would ultimately be necessary, but the use of implant material in a heavily contaminated environment would have resulted in infection and loss of stability. Therefore, a two-stage approach was used. In a first stage, all involved structures were debrided and rinsed, the luxation was reduced, and the skin defect was sutured. A plate shoe with silicone pad was applied to the contralateral hoof to prevent laminitis. The horse was recovered in a distal limb cast bandage, which was changed under general anaesthesia at 14 and 35 days after surgery, together with the contralateral plate shoe. Post-operative treatment consisted of sodium penicillin, gentamicin and phenylbutazone intravenously for 20 days. At 56 days after surgery, the cast and contralateral shoe were removed, and 7 days later, an arthrodesis of the metatarsophalangeal joint was carried out using a dorsally placed 13 hole broad 4.5 LCP plate along with 3 x 4.5 cortical screws placed transarticularly in lag fashion, and fixation of the proximal sesamoid bones to the metatarsal bone with 4.5 cortical screws in lag fashion. A distal limb cast bandage and a contralateral plate shoe with silicone pad were applied and changed under general anaesthesia at 14 and 35 days after the arthrodesis. The horse was treated with sodium penicillin, gentamicin and phenylbutazone intravenously during 14 days after surgery. The cast was taken off at 56 days after the arthrodesis, after which the horse was kept on box rest for one more month. The horse was then hand-walked for 3 weeks and then turned out in a small paddock. The horse remained comfortable during the entire treatment period, except for some days between cast removal and arthrodesis. No signs of contralateral laminitis developed, other than a palpable pulsation of the right plantar digital arteries. No complications developed, and at 213 days after the arthrodesis, the horse remains comfortably weight bearing.

Fig 1: A severe, contaminated, open luxation of left metatarsophalangeal joint was present.

Key points

- A severe, contaminated, open luxation of the fetlock was managed by a two-stage approach.
- In the first stage, all tissue was debrided and rinsed, the luxation was reduced and the skin is sutured. When the infection was eliminated, an arthrodesis was carried out in a second stage.
- When owners refuse immediate euthanasia, horses with a severe open contaminated luxation of the fetlock can be salvaged using the two-stage approach, with a satisfactory outcome.

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Case Report

Use of random pattern skin flaps for wound closure in two horses

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Keywords: horse; skin flap; z-plasty; rotation flap; skin expander

Summary

Case 1

A 9-year-old Thoroughbred broodmare presented with a mass rostral to the medial canthus of the left eye. Due to economic reasons, the mass was removed without prior biopsy.

The mass was removed under general anaesthesia using a diode laser. An extension of the mass protruded into the maxillary bone overlying the maxillary sinus. It was removed and two reverse periosteal flaps were created to cover the defect. The size of the skin defect prevented primary closure. A Z-plasty permitted closure of the ventral component of the surgical site (**Fig 1**). Dorsally, the incision was only partially closed due to the size of the skin defect. The bed of the mass was injected with an emulsion of carboplatin.

Histopathology identified a spindle cell tumour likely to be sarcoid, sarcoma or leiomyoma. Based on these findings, a follow-up local infusion of carboplatin was performed at 3 weeks post-surgery. The mass recurred and subsequently was resected twice. It has not recurred 68 weeks post-treatment.

Case 2

A yearling Thoroughbred colt presented with a chronic wound on the dorsomedial aspect of the right metatarsus. Histopathology revealed non-neoplastic, chronic inflammatory tissue. Removal of the chronic wound was required to achieve satisfactory cosmesis for sales purposes. The use of skin expanders was elected in this case to achieve primary closure of the defect. During the first surgery, the skin expanders were placed around the dorsal, proximal and distal aspects of the wound. The chronic wound was superficially debrided using hydrosurgical debridement.

Removal of the mass and closure of the wound under general anaesthesia was done 18 days after the first surgery. A single curvilinear incision was made over the dorsal aspect of the wound. All skin expanders were removed. The entire nonhealing wound was removed, and the periosteum was curetted. Attempts to close the wound directly failed due to excessive central tension. A random pattern rotational flap was created with a semi-circular incision distally along the expanded skin to allow primary closure of the main defect (**Fig 2**).

The incision healed primarily with good cosmetic appearance.

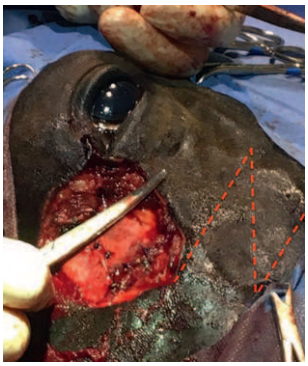

Fig 1: Case 1. Closure of the surgical site proved difficult due to the lack of tissue available. To overcome this, a z-plasty (red lines) was created to allow closure of the ventral component of the defect.

Fig 2: Case 2. Photograph taken after the final surgery. It is illustrating the fusiform incision (red dashed marking) used to remove the wound tissue and the incision line (yellow dashed marking) for the rotational flap which was moved plantarly to close the remaining defect. The pressure sore from the previous underlying skin expander is also highlighted (green circle).

Key points

- The use of skin flaps provides surgical options when dealing with similar wound types, especially when cosmesis and function are paramount.
- Self-expanding soft tissue skin expanders are useful in equine surgery.
- Multimodal chemotherapy and surgical debunking are often required for management of equine sarcoids.

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Clinical Commentary

Simple techniques to decrease tension on sutured wounds of horses

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Keywords: horse; technique; tension; suture; wound closure

The report by Jansson *et al*. (2022) in this issue describes the use of random skin flaps to heal wounds of two horses. In one case, a Z-plasty was used successfully to aid closing a wound created when a sarcoid was excised from the horse's face, and in the other case skin expanders and a rotational flap were used to close a fresh cutaneous defect, created by excising a chronic wound on the distal portion of the limb. Each technique was used to allow a cutaneous defect to be closed primarily, without tension.

There is limited information describing clinical use of Z-plasty and skin expanders in horses (Bowman and Swaim 1982; Whittaker *et al*. 2020), so the preceding article provides valuable information for equine practitioners. This accompanying clinical commentary describes basic techniques that can be used to allow cutaneous defects to be closed without tension.

Horses are wounded frequently due to their flighty nature, and these wounds are often accompanied by avulsion of skin, necessitating the use of tension-relieving techniques to enable primary repair. This is true especially of wounds of the extremities, where skin cannot be advanced easily to allow for tension-free primary repair.

Skin can be stretched to close large wounds primarily (Stashak and Schumacher 2016). Stretching relies on the viscoelasticity of the skin, which allows skin to elongate, when tensed, by mechanical creep and stress relaxation. Mechanical creep enables skin to be stretched, over time, beyond its normal limits of extensibility, when placed under a constant tension. It occurs because constant tension applied to skin straightens the randomly oriented collagen fibres in the dermis. When the skin is stretched, the tension required to hold it at a constant length decreases gradually, and this reduction in tension is referred to as stress relaxation. Simple techniques used to relieve tension on sutured wounds rely heavily on these biomechanical properties of the skin and include the following: presuturing the wound; applying a mesh overlay; applying tension sutures, such as horizontal or vertical mattress sutures, walking sutures or near-far-far-near (NFFN) tension sutures; and applying a skin stretching device. Another simple technique to relieve tension on a sutured incision, one that does not rely on stress relaxation, is to create relief incisions adjacent to the sutured wound.

Presuturing entails placing heavy sutures preoperatively to imbricate and stretch skin over a mass to be removed (Harrison 1991; Zide 1994). Sutures are placed using an inverting suture pattern, such as a Lembert suture pattern, 2–8 h before the mass is to be removed. Sutures are inserted with the horse sedated and the surgical site desensitised with local or regional anaesthesia. These sutures maximally stretch the skin surrounding the mass or wound, allowing the wound to be closed primarily after the mass has been excised. This is a simple, inexpensive method used to close a cutaneous wound, created by removing a lesion, that otherwise could not be closed (**Fig 1**).

A mesh can be used to relieve tension on a wound sutured under excessive tension, similar to the method that is used for repairing incisional body wall hernias (Kelmer and Schumacher 2008). Using this technique, a polypropylene or polyester mesh is centred over the sutured wound, and one edge of the mesh is anchored to the underlying skin using nonabsorbable sutures, inserted using a simple-interrupted pattern. The opposite edge of the mesh is anchored to the skin on the opposite side of the sutured wound using preplaced sutures inserted using a Mayo mattress suture pattern (also referred to as the vest-over-pants suture pattern). Tension on the sutured wound is transferred to the mesh when the preplaced sutures are tightened and tied. Two or more staggered rows of simple-interrupted sutures anchoring the mesh to skin are placed axial to each sutured

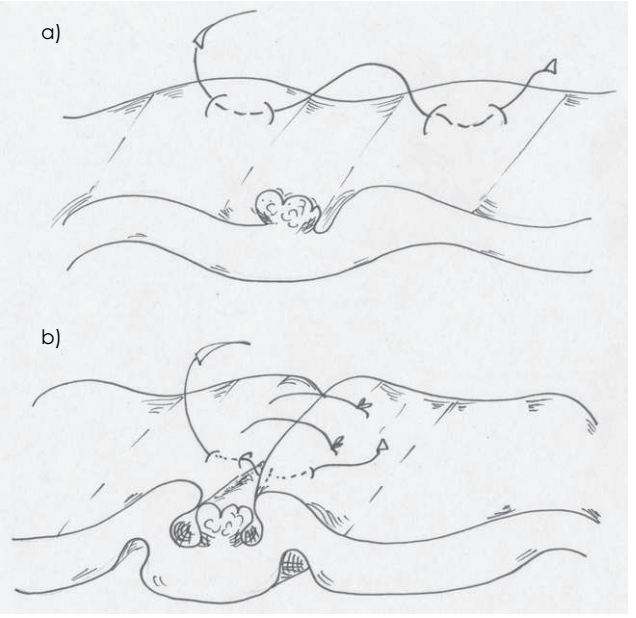

Fig 1: Illustration demonstrating presuturing to allow mass removal and skin apposition with less tension allowing primary closure.

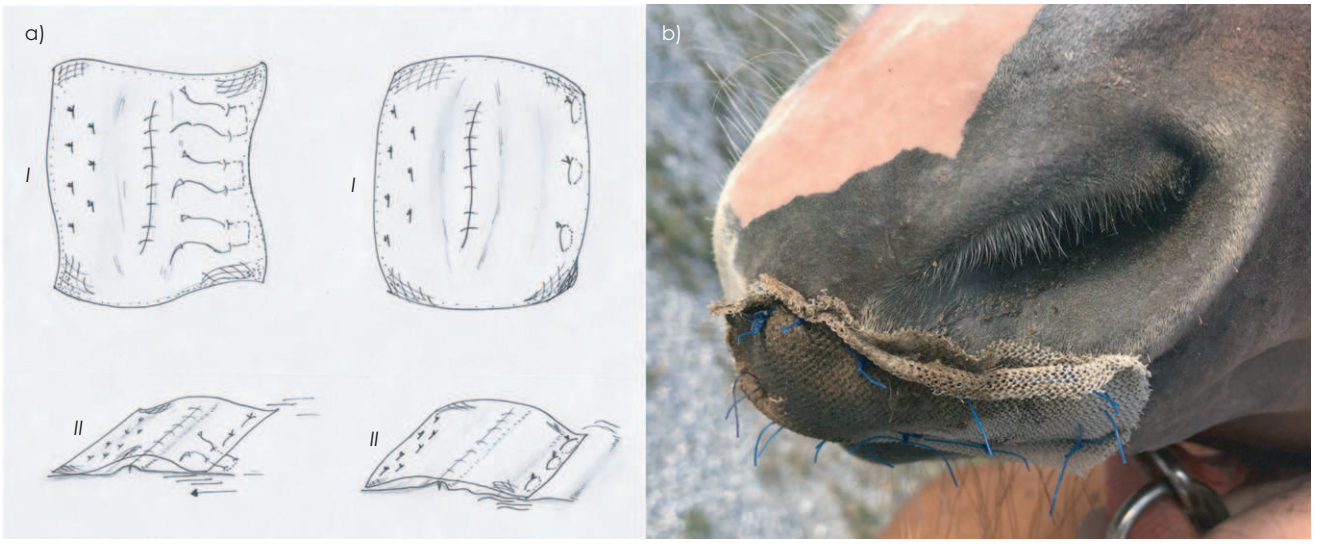

Fig 2: a) An illustration demonstrating the use of a mesh and a mayo mattress suture for tension releasing. b) A doubled mesh spanning a sutured laceration of the upper lip of a horse.

edge of the mesh to distribute tension over a wider area (**Fig 2**). The technique is especially useful for relieving tension on an area subjected to constant movement, such as a lip or nostril (**Fig 2**).

Horizontal or vertical mattress tension sutures placed well away from the margin of the wound (**Fig 3**) can be used to decrease tension at the margin of the wound (Stashak and Schumacher 2016). The wound can be closed before or after the tension sutures are inserted, usually with simple-interrupted sutures or with inverted cruciate sutures placed closer to the skin edge. Vertical mattress tension sutures are less likely to interfere with blood flow to the sutured margin of the wound than are horizontal mattress tension sutures. Sections of rubber or plastic tubing can be placed beneath the loops in the tension sutures to distribute pressure (**Fig 3**), but tubing should not be used if the wound is to be covered by a bandage, because a bandage places pressure on the tubing causing skin underlying the tubing to necrose. The horizontal or vertical mattress tension sutures are removed in 5–7 days, by which time tension on the approximating sutures has greatly dissipated. Leaving the tension sutures for a longer time may result in suture tracts and pressure necrosis beneath the tubing.

The near-far-far-near (NFFN) suture serves as both an approximating suture and a tension suture. The near component approximates the sides of the wound, and the far component relieves tension on the near component. The loop in the suture increases the strength of the suture and the holding power of the tissue into which it has been placed (**Fig 4**). In areas when there is less tension, inverted cruciate pattern can be a useful alternative to accelerate the repair (**Fig 4**).

Walking sutures (**Fig 5**) can be used to decrease tension on a sutured wound (Stashak and Schumacher 2016). To place walking sutures, the margin of the wound is undermined, and a suture is placed into the dermis of the skin at the junction of the undermined skin and the underlying subcutaneous tissue on one side of the wound. The suture is then placed through the underlying subcutaneous tissue on

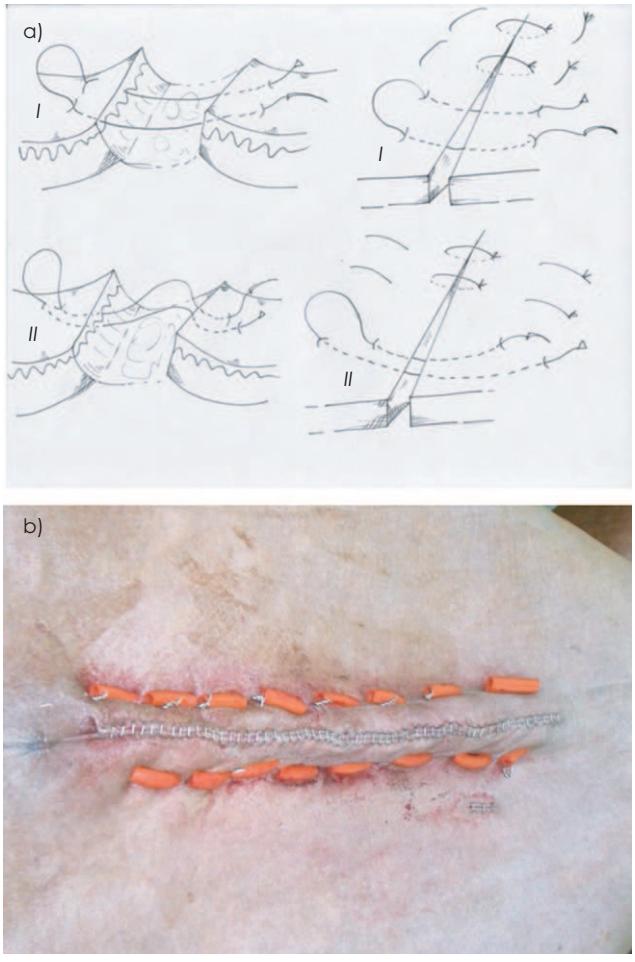

Fig 3: a) An illustration showing vertical and horizontal mattress sutures for tension releasing over a laceration sutured under tension. b) Horizontal mattress with cerclage wire for primary full-thickness body wall closure in a dehiscing incision to prevent eventration.

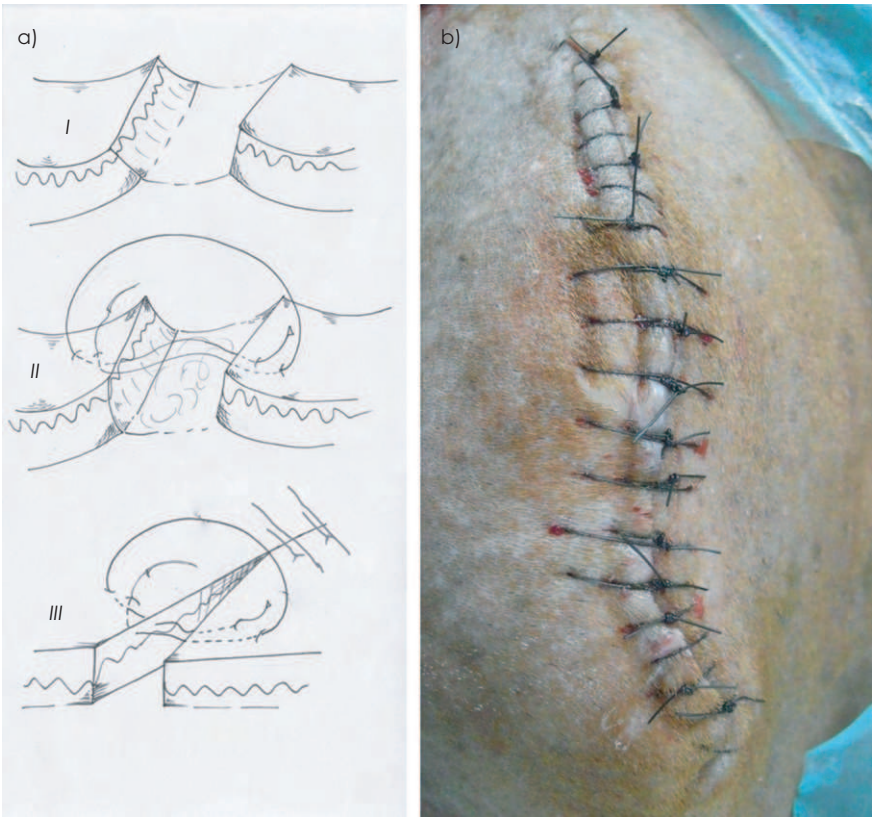

Fig 4: a) Illustration demonstrating near-far-far-near (NFFN) suture pattern. b) Photograph of a clinical case using NFFN and inverted cruciate patterns to repair a laceration under tension.

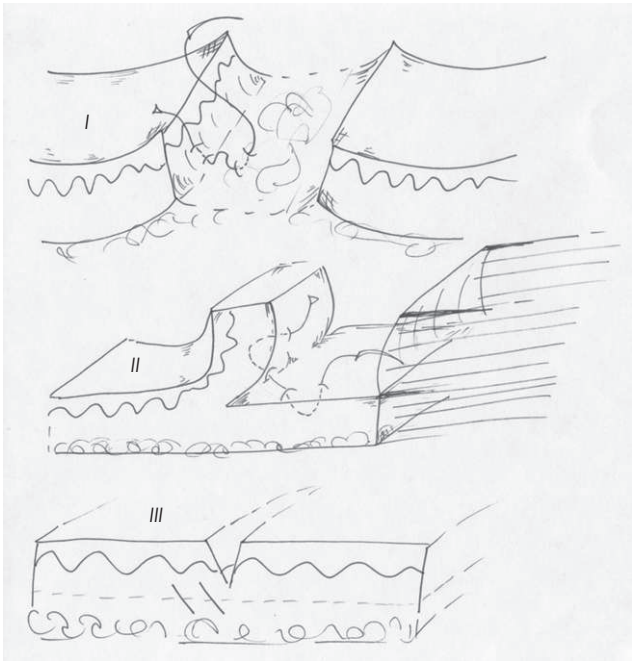

Fig 5: Illustration of a walking suture to allow tension releasing.

that side after the skin is stretched towards the centre of the wound. The undermined skin is moved slightly towards the centre of the wound as the suture is tightened and tied. Rows of sutures are placed in a similar manner in the undermined skin on both sides of the wound until the wound can be sutured with less tension.

A sutured stent is another helpful method to combat tension on the incision. Suturing a towel in a horizontal mattress fashion can aid healing by protecting the incision from the environment and decreasing tension on the incision line (**Fig 6**).

External devices that stretch the skin can be applied to skin on each side of the wound (or on each side of the mass to be removed) (Hirshowitz *et al*. 1993; Barnea *et al*. 2004). These external stretching devices, by applying steady traction to skin surrounding a large wound, permit the wound to be closed primarily without tension. Several systems (eg TopClosure®) have been used to aid closure of wounds in people and small animals (Pavletic 2000; Topaz *et al*. 2014), but we are not aware of reports describing the application of these external stretching devices to close wounds of horses. One of us (G.K.) has used the Top Closure® device to repair an incisional hernia and to close wounds of three horses (**Fig 7**), but the results were overall disappointing. Failure, however, was not due to malfunction of the device or inadequacy of the technique. In one case, the device was used to close an incisional hernia on the ventral midline of a horse, but the repair failed because the bands broke and because of lack of compliance by the client. In another case, the device was used to close two chronic cutaneous wounds, one over the fetlock and the other over a shoulder. The wounds contracted markedly, but did not close completely and eventually healed by second intension. In

Fig 6: Stent sutured using horizontal mattress, to a modified Forssell's incision (a) and a flank laparotomy (b) to decrease tension on the suture line, apply pressure and protect the incision.

Fig 7: A mass (exuberant granulation tissue) near the tarsus (a) Using Top Closure® system to enable closure of the wound resulted from removal of the mass (b).

another horse, the surgery went well but the horse succumbed to unrelated complications and in the fourth, the gap was so wide and the forces applied by movement so extensive that the wound opened shortly after closure. The human surgeon, who developed the device and helped to apply it to the wounds of two horses, opined that the device must be modified to be more resilient and increase its efficacy, if it is to be used in horses.

An improvised method for closing gaping wounds under tension is by incorporating buttons into the repair in both sides of the wound. The technique relies on repeated loops of suture across the wound, similar to the mattress sutures and NFFN. However, the buttons allow for distributing the pressure on the skin to a larger surface area and thus enable the skin to withstand further tension across the wound (**Fig 8**).

Another method of relieving tension on a sutured incision that does not involve stretching skin adjacent to cutaneous defect is to create one or more relaxing incisions adjacent and parallel to the defect. The width of the skin between the incision and the wound should be equal to the width of the wound when a single incision is used to relieve tension. Creating a relaxing incision on each side of the wound

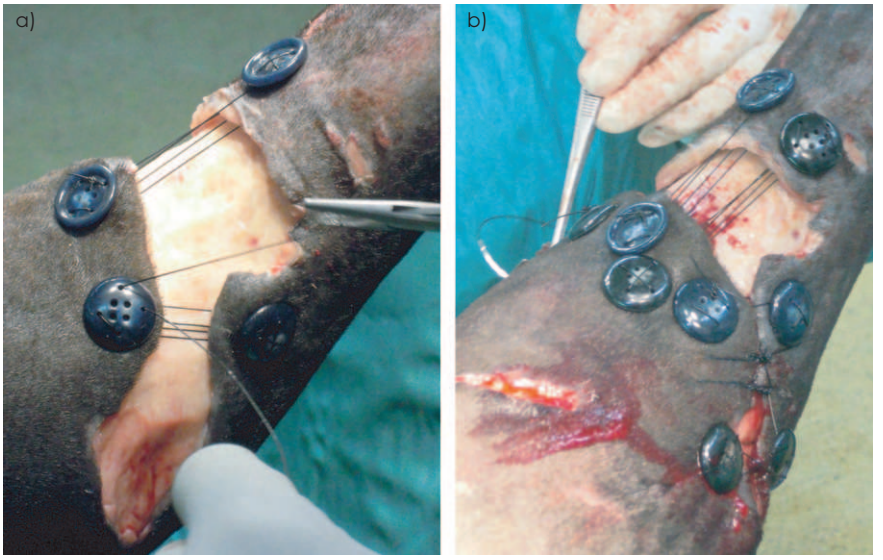

Fig 8: a) Initiating an improvised tension releasing method using buttons. b) The buttons' repair is nearly completed.

Fig 9: Multiple, staggered, short, tension-releasing incisions to allow closure of a distal limb laceration under significant tension.

Fig 10: a) One month after application of a full-thickness skin graft to a wound, on the forehead of a mule, created by removing a large sarcoid. b) A 3 months post-operative photograph of the accepted graft on the forehead. Pictures courtesy of Dr. J. Blake Everett.

results in two smaller wounds. The width of the skin between each of these incisions and the wound should be equal to the half of the width of the wound. Wounds created by relaxing incisions heal by second intention, and one large relaxing incision heals more slowly than two smaller relaxing incisions. Creating multiple, staggered, parallel, relaxing incisions on each side of the wound provides less relaxation but results in small wounds that heal much faster than one or two long, relaxing incisions and impart a better cosmetic appearance (**Fig 9**).

If techniques for decreasing tension described above appear to be insufficient to allow a wound to be closed primarily, a skin graft can be applied to the wound. The rapid healing achieved with a skin graft may make grafting more economical than allowing the wound to heal by second intention. A healed skin graft contains epidermis, dermis and adnexa, including hair follicles, so is more cosmetic and durable than is a large epithelial scar. The most practical type of graft that can be applied to fresh cutaneous wound is the full-thickness graft (Tóth *et al*. 2010). A full-thickness graft is most easily harvested from the cranial pectoral region—one of the few places on a horse where the skin is relatively mobile. The graft is usually harvested with the horse sedated, after desensitising the donor site with local anaesthetic solution. The donor site is sutured in one or two layers. Subcutaneous tissue is sharply excised to expose the dermal vasculature to permit plasmatic imbibition, inosculation and neovascularisation. The graft is attached to the recipient site with staples or sutures, after desensitising the recipient site with local or regional anaesthesia, or with cyanoacrylate glue. The owner should be informed that the epidermis may become necrotic and slough (**Fig 10**) but that sloughing of the epidermis has no effect on the final appearance of the graft.

To conclude, when a surgeon is attempting to close a gaping wound under tension, several techniques can be used, as described above. In cases when a significant gap is to be closed, one can either mobilise adjacent skin, by using skin flaps or recruiting skin from a distant body region by utilising skin grafts.

Authors' declarations of interest

No conflicts of interest have been declared.

Ethical animal research

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Authorship

E. Cypher contributed to the preparation of the manuscript and gave their final approval. J. Schumacher and G. Kelmer contributed to all stages of the manuscript preparation.

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Case Report

Tenectomy of the superficial digital flexor tendon as a treatment of suspected septic tendinitis and tenosynovitis of the digital flexor tendon sheath followed by rehabilitation with an orthotic device

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Keywords: horse; septic; superficial digital flexor tendon; tenectomy; orthotic; external support boot

Summary

A 15-year-old Sports horse gelding was referred for nonweightbearing lameness of the left hindlimb of one week's duration. Ultrasonographic and radiographic evaluations revealed severe subcutaneous swelling over the entire limb and a moderately distended digital flexor tendon sheath (DFTS) filled with a moderate amount of hypoechoic fluid interspersed with synovial thickening and fibrin-like material. The appearance of the superficial (SDFT) and deep (DDFT) digital flexor tendons was within normal limits. Septic cellulitis was diagnosed and managed medically. After 14 days, septic tenosynovitis of the DFTS, with septic tendinitis of the SDFT and DDFT became evident. Surgical resection of the intrathecal portion of the septic SDFT was performed via an open incisional approach to the DFTS. Post-operatively, a half-limb cast was placed on the operated limb for 10 weeks. This was followed by a 6-week rehabilitation period with the help of an articulated orthotic support boot. The horse recovered, regained long-term pasture soundness and is used for light pleasure riding. Ultrasonography performed 5 months after surgical removal of the SDFT demonstrated the presence of a flat, banana-shaped layer of fibrous tissue with heterogenous echogenicity, variable fibre orientation and irregular margins, in the location of the resected SDFT (**Fig 1**). This case demonstrates that tenectomy of the SDFT followed by the use of an orthotic boot support during the rehabilitation period may be a viable salvage procedure for refractory septic tendinitis in the DFTS and can have a positive outcome.

Key points

- Septic tendinitis is relatively common and may have life-threatening consequences.
- Tenectomy of the SDFT appears to be a viable option to treat chronic and severe septic tendinitis in the DFTS when infection cannot be controlled with medical treatment or tenoscopic lavage.
- The bilateral use of a custom-made equine support boot during the rehabilitation period prevented excessive loading of the injured tendon, the other components of the stay apparatus and the stay apparatus and the foot of the contralateral limb.

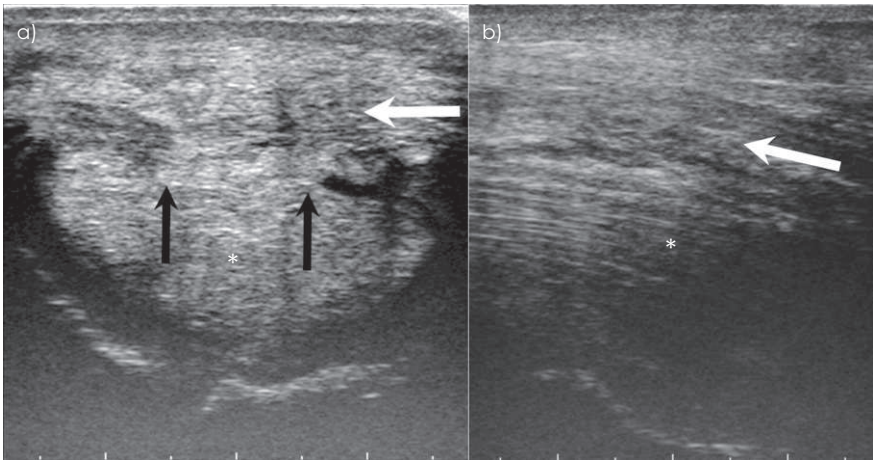

***Fig 1:** Transverse (a; lateral is to the left) and longitudinal (b; proximal is to the left) ultrasonographic images obtained at the level of the fetlock canal, 5 months after surgery. The heterogeneous connective tissue bridge replacing the SDFT is visible (white arrow). Adhesions (black arrows) are present between the SDFT and the DDFT (white asterisk).*

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Clinical Commentary

'Bridging the gap': A spontaneous demonstration of regenerative medicine?

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Keywords: horse; orthotic device; resection; superficial digital flexor tendon

A case report published in this issue of Equine Veterinary Education (Lenoir *et al*. 2022) documents the radical surgical resection of a portion of the superficial digital flexor tendon in an area that usually shows poor natural healing. This case report is interesting because the gap became filled with tissue with similarities to tendon on ultrasound and enabled the horse to regain soundness with the aid of an orthotic device.

The resection of the tendon was deemed necessary because of suspected infection although this was not possible to confirm with positive culture or histology. While infection is rare in tendon, it does carry a poor prognosis (Kidd *et al*. 2002) which, therefore, justifies radical debridement. However, this left a large gap between the two ends of the superficial digital flexor tendon. Gap healing of equine tendons is seen following tendon lacerations with the formation of bridging fibrous 'callus' (Jordana *et al*. 2011). However, this can be a protracted process and may ultimately become exaggerated with restrictive adhesion formation. Reflection of the tendon ends can also occur which can delay healing further, and so, there have been many attempts to assist healing, especially for the digital flexor tendons because of their importance in normal weight-bearing limb function. These approaches have included the use of a variety of biologic and synthetic implants to bridge the gap. The choice of a suitable material has progressed from inextensible carbon fibre (Vaughan *et al*. 1985), through artificial nonabsorbable materials (Gibson *et al*. 2002; Barrett *et al*. 2014; **Fig 1**), to long-lasting absorbable materials (Eliashar *et al*. 2001; Jenson *et al*. 2005), and even autologous tendon tissue (Valdes-Vazquez *et al*. 1996). Their role has been postulated to act as a scaffold to provide a conduit along which cells and healing vasculature can grow as well as maintain the tendon ends in alignment. This is in contrast to the use of scaffold in smaller animals where they can act as a robust mechanical 'bridge' because of the smaller forces involved. This is not possible to achieve in horses and, indeed, it has been our observation in the past, especially in hindlimbs supported with a distal limb cast post-operatively which has immobilised the fetlock but allowed hock and stifle flexion, that the implants have become detached from the transected tendon ends. This observation, the poor availability of appropriately sized, long-lasting but absorbable, implants, and the failure to show significant benefit over debridement alone in the few limited studies published, has meant that implants are now rarely used. As a result, clinicians have relied on simple debridement and natural repair while the region is protected from loading using external coaptation, as described in this case report.

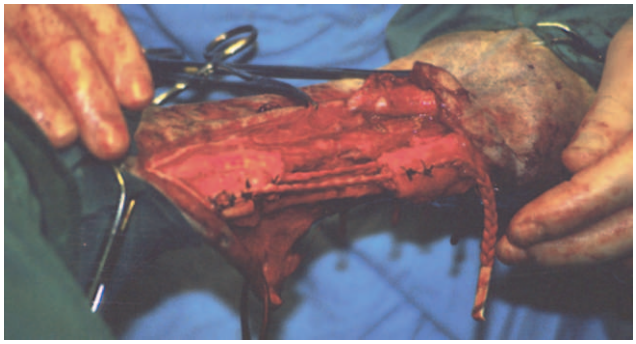

Fig 1: A nonabsorbable (terylene) implant has been used to bridge the large gap between tendon ends following blunt laceration in both digital flexor tendons.

What is, however, surprising in this case report is that this gap healing has occurred in a region which is particularly problematical for healing. Plantar to the fetlock, where the tendon is subjected to compression as well as tension, requires a more complex extracellular matrix. Moreover, its intrathecal location means that the tendon is surrounded by synovial fluid and lacks a paratenon. We have recently established that synovial fluid has toxic effects on the cells within tendon which helps explain why many tendon and ligament lesions that communicate with the synovial cavity of a tendon sheath, bursa or joint often fail to heal spontaneously (Garvican *et al*. 2017). The paratenon is considered to be a major player in extrinsic (coming from surrounding tissues) healing, which is believed to dominate extrathecal tendon repair, at least in experimental animal models (Kajikawa *et al*. 2007). The paratenon is continuous with the endotenon, or interfascicular matrix, which is believed to be the source of endogenous tendon stem cells and neovasculature (Cauvin 2000; Marr et al. 2017). However, the lack of a paratenon in intrathecal locations, means that, in the absence of adhesion formation, repair relies more heavily on intrinsic (from within the tendon) healing which is less effective and slower. Adhesions will enhance gap healing by providing a route for cells and vasculature to access the lesion, and by isolating the injury from the synovial environment, but they may also result in restriction of tendon movement, causing pain and lameness. Hence, it is impressive that the surgically created gap in the superficial digital flexor tendon within the digital flexor tendon sheath in this case became bridged with tissue without restrictive adhesion formation.

This could, therefore, be considered an example of tendon 'regeneration' at least on a limited functional level. Of course, this is not the same as suggesting that the bridging tissue consists of regenerated normal tendon, but it did demonstrate a similarity to tendon ultrasonographically. 'Regenerative medicine' has had the 'holy grail' of tissue regeneration as its goal for some time, which was the impetus for the first use of mesenchymal stem cells for the treatment of a tendon injury in 2003 (Smith *et al*. 2003). However, there has been little evidence that true regeneration has been achieved for any of the ever-expanding list of regenerative medicine products and devices that have become commercially available, even though such claims are often made. To a certain extent, this is because 'regeneration' is not well defined. It is important to differentiate normal repair from reformation of 'normal' tendon, although tendon does change with ageing. In this author's opinion, true regeneration should be defined, for tendon at least, by the restoration of three key elements – mechanics, structure *and* composition – to their pre-injury state, which does give a high bar to reach. Defining these characteristics for musculoskeletal tissues is also not always simple, and a spectrum ranging from nonfunctional repair tissue to regenerated tendon probably exists. The normal healing response in tendon is via a process of scarring with the production of fibrous tissue. This tissue is collagen-rich, like tendon, but with a different ratio between collagen types I and III and is more disorganised in structure, which results in different mechanical properties. It also has higher levels of noncollagenous proteins resulting in a higher tissue content of glycosaminoglycans. However, one of the most striking differences exists at an ultrastructural level where the collagen fibril populations are universally small in scar tissue while they are bimodal (mixed population of small and large fibrils) in normal mature (adult) superficial digital flexor tendon (but not all tendons). This latter characteristic was, therefore, used in an experimental study in horses to assess the ability of mesenchymal stem cells (MSCs) to induce tendon regeneration, but MSC-treated tendons still showed the same unimodal distribution of small collagen fibres similar to controls (Caniglia *et al*. 2012), indicating a failure of regeneration. However, that does not mean that they cannot still exert a beneficial effect and they have been shown to improve tissue composition and organisation as well as function (Smith *et al*. 2013). We now believe this effect to be due to modification of the inflammatory process rather than true regeneration which still results in a clinical benefit (reduced reinjury rate; (Godwin *et al*. 2012) but not by the recreation of normal tendon tissue. In the case described in this edition, not surprisingly, it was not possible to retrieve any of this 'regenerated' tissue for a more detailed analysis to determine if true tendon regeneration had occurred. The only possible evaluation of the nature of this tissue, other than through the observation of limb function and soundness, was with ultrasound. This showed an echogenic material similar in echogenicity to tendon with at least some evidence of a degree of longitudinally arranged fibres on longitudinal views (figure 6 in the case report). We have seen this occur previously in extrathecal locations, including in a case when both digital flexor tendon had been lacerated and the gap healed with one scar involving both tendons. Over time, however, two separate tendons, capable of moving independently, were restored (M. Schramme and R. Smith, unpublished observations), showing the remarkable propensity for the restoration of tissue function in some situations.

Mechanical loading of the gap tissue is believed to be an important driver for this functional restoration. However, in the horse, such loads can be both helpful and harmful. It is important to protect the neotendon from high damaging loads when it is forming, but a gradual increase in loading also provides an important stimulus for tissue differentiation. A cast, as used in this case report initially, is the only way to unload the gap in the early stages of healing but this does not allow gradual loading. It also unloads the other weight-bearing tendons and ligaments of the distal limb which weakens them, and has recently been shown to be deleterious to the other musculoskeletal tissues of the limb (Stewart *et al*. 2020). Therefore, it is important to consider alternative methods of controlling digital flexor tendon (or suspensory ligament) loading. Contrary to what is perceived by the horse-owning public, distal limb bandages fail to provide any significant support to the digital flexor tendons in the adult horse (Smith *et al*. 2002) and a more robust system is needed. Contoured palmar or plantar splints made from casting tape are effective and can be applied to the palmar/plantar aspect of a clinical bandage. They are useful to apply immediately after removal of the cast when a bandage is still required (Smith *et al*. 2002; Kuemmerle *et al*. 2018; **Fig 2**). However, they are difficult to maintain, can cyclically fail, and are likely to be less effective at controlling loading than specifically designed orthotic devices. The first

Fig 2: A contoured palmar splint used to provide significant fetlock support by being taped to the palmar aspect of a bandage. The splint can be fashioned on the opposite limb or else made by laying two rolls of four inch casting tape onto a precontoured plastic guttering. The angle should be slightly straighter than the normal fetlock angle in the horse to be effective at providing fetlock support.

of these devices (EqueStride™) was developed and tested in the early 2000s (Smith *et al*. 2002) and is still used for cases requiring fetlock support at the Royal Veterinary College Equine Referral Hospital. The case report in this issue used a newer orthotic device, the FastTrack™ boot designed at Tufts University and manufactured in the USA, to achieve the same goal. The case report shows how these devices can be particularly useful in the rehabilitation of these severe injuries, and clinicians should consider their use as part of a structured rehabilitation programme for cases with a significant loss of fetlock support.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this clinical commentary.

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Original Article

Standing computed tomography of the equine limb using a multi-slice helical scanner: Technique and feasibility study

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Keywords: arthrography CT; distal limb CT; fan Beam; horse foot CT; standing CT

Summary

Computed tomography (CT) is an important cross-sectional diagnostic modality for lameness localised to the equine distal limb. The necessity of general anaesthesia to perform CT scans has limited its use in the equine orthopaedic field. Therefore, many attempts have been made to perform CT of the distal limb in standing horses. This retrospective report aims to describe the technical set-up and the feasibility of using a multi-slice helical CT unit recently introduced into the equine market. The medical records of the patients undergoing a standing CT in the period between March 2019 and January 2020 were reviewed. The imaged anatomical region and the image quality were assessed. Thirty-two horses met the inclusion criteria, and the following anatomical areas have been imaged: front foot/pastern (n = 14), metacarpophalangeal joint (n = 11), front proximal suspensory ligament (n = 2), carpus (n = 2), metatarsophalangeal joint (n = 2) and tarsus (n = 1). In 97% of the cases, excellent imaging quality was obtained. Motion artefact is the main cause of poor image quality. The feet and the metacarpophalangeal region can be easily imaged. Imaging the proximal anatomical regions of the limb is more challenging but achievable.

Introduction

The use of computed tomography (CT) in equine veterinary medicine in a clinical setting was first documented in the late 1980s for the investigation of a brain abscess and an osteochondral cyst in the metacarpophalangeal region (Allen *et al.* 1987; Barbee *et al.* 1987a). To image these anatomical regions, it has been necessary to conduct the scans under general anaesthesia to position the anatomical region of interest in the CT scanner (Barbee *et al.* 1987b). However, the mortality rate associated with equine anaesthesia has been reported to range from 0.08% to 1.8% (Dugdale and Taylor 2016). A third of the deaths were attributed to limb or cervical fractures and post-anaesthesia myopathy. It is likely that at least some of the fractures occurred as a consequence of myopathy-induced pain or weakness (Dugdale and Taylor 2016).

The first attempt to perform a standing CT of the equine extremity dated back to 2002 (Desbrosse *et al.* 2008). Desbrosse and colleagues (2008) described the use of a small peripheral quantitative computerised tomography scanner, which is used for assessing bone mineral density. They used it on 47 clinical cases successfully to confirm a diagnosis or aid in surgical planning for conditions of the foot (Desbrosse *et al.* 2008). However, the procedure time was about 90 seconds per slice, and the entire scan protocol took 20 min to obtain ten slices. Not surprisingly, 11% of the slices were invalid due to the motion artefacts. A few years later, adaptation of a human CT machine for use in the standing sedated horse was designed and developed for imaging the head and cranial cervical spine (Dakin *et al.* 2014).

The helical CT units in the standing horse have been described using two distinct techniques, either with a sliding gantry or with a stationary gantry (Bregger *et al.* 2019). The CT table, with the 'patient', moves through the gantry bore in stationary system and vice versa in sliding system. In both systems, the patient has to be placed on a platform that is suspended by air castors (Bregger *et al.* 2019; Riggs 2019). These systems are commonly used for imaging the head and cranial cervical spine in standing horses. Recently, a new CT machine has become available on the market to perform the CT of the distal limb in standing horses. The aim of the current retrospective study was to demonstrate the feasibility of a helical multi-slice CT unit for imaging the limb of standing horses.

Materials and methods

The electronic medical records of the horses admitted for standing limb CT in the period between March 2019 and January 2020 at Tierklinik Lüsche GmbH, Germany were reviewed. The horses imaged for demonstration purposes were excluded. The data recorded included signalment, clinical presentation, the imaged anatomical region and diagnosis. The number of scan attempts to provide a diagnostic image quality was recorded. The image quality was evaluated subjectively using a 3-point visual grading system developed for that purpose (**Table 1** and **Fig 1**). Both bone and soft tissue reconstructed CT images were evaluated by a German board-certified radiologist (M.M.) who was aware of the case history. The images were reviewed once in a period of 3 days using the same workstation. A detailed description of the CT scanner and the needed technical installations, and the scanning procedure are provided.

Results

Thirty-two subjects met the inclusion criteria. They were 10 mares, 17 geldings and 5 stallions, with a mean age of 8.4 years (range 3–22 years). There were 29 Warmblood horses, 2 Haflingers and one donkey. For simplicity, we describe the included subjects as equines or horses. Three horses were excluded because they were used for demonstration purposes and training of the staff members.

TABLE 1: Visual grading system of the computed tomographic imaging of the distal limb in standing horses

Grade	Limitations for clinical use	Image quality and definition
1	No limitations	Excellent quality: no motion artefact at anatomical region of interest (**Fig 1a**)
2	Minimal limitations	Good quality: mild-to-moderate motion artefact (**Fig 1b**)
3	Image not usable, loss of information, image must be repeated	Poor image quality: severe motion artefact (**Fig 1c**)

The included horses were presented with the history of lameness (n = 29) or suspicion of bone pathology on a pre-purchase examination (n = 3). The anatomical regions of interest were foot/pastern (n = 14), metacarpo(tarso) phalangeal joint (n = 13), proximal suspensory ligament of front limb (n = 2; PSL), carpus (n = 2) and tarsus (n = 1). The majority of the scans were carried out in the front limbs (n = 28), and only three scans were on hindlimbs (two metatarsophalangeal regions and one tarsus). Sixteen patients had contrast-assisted CT (arthrography [n = 13] and venogram [n = 3]). A total number of 94 scan attempts were recorded for all included horses. The mean number of acquired scans per horse was three (range 1–7 scans) and for native CT two scans per horse. The horses that underwent contrast-enhanced CT showed a higher number of scan attempts (mean 5; range 4–7 scans). The radiological diagnoses included a space-occupying mass in a hoof (n = 5; **Fig 2**), chondropathy (n = 7; **Fig 3**), fissure fracture (n = 2), subchondral cystic lesions (n = 9, **Fig 4**), osteoarthritis (n = 3) and sesamoiditis (n = 1). In an additional five cases, no structural changes were identified. The image quality was assessed as grade 1 in 29 horses, grade 2 in two horses (tarsus and fore PSL) and grade 3 in one horse (fore PSL). Motion artefact was the cause of reduced image quality.

CT system

The CT scanner is a sliding helical multi-slice gantry and has 16 detector rows each is 0.5 mm wide (Aquilion LB)[1]. The gantry bore diameter is 90 cm, which provides a 70-cm scanning field of view (**Fig 5**). The tube is eccentric in position (away from CT table) and provides an output of 80–135 kV (20 kVp step) and mA of 50–400. The rotation speed per second ranges between 0.32 and 3. The maximal weight limit of the patient couch is 205 kg. The CT scanner is sliding on a special designed mobile platform, which provides the up and down movements. The platform is rectangular, measuring 2.3 × 3.9 m, and is positioned on a hydraulic lever system. It is installed in a pit in the ground (3.3 × 4 × 1.3 m) to allow bringing the gantry to the level of the distal limb. This feature enables imaging different sizes of horses in the standing position (**Fig 6**).

Scanning procedures

Prior to image acquisition, machine-specific calibration and warm-up protocols were performed, which lasted approximately 17 min. Thereafter, the patient data were acquired from the PACS and the CT platform positioned at the level of the anatomical region of interest. The scanning protocol was chosen prior to bringing the patient to the CT room. The platform has extra extensions, which provide patient stability during the scan (**Fig 5**). The head is positioned on a metal extension to support the head during scanning. This extension is long on one side to prevent the horse seeing the gantry when sliding away during the scan (**Fig 5B**). An additional U-form wood board attached to the CT table provides limb stability. Furthermore, it protects the CT

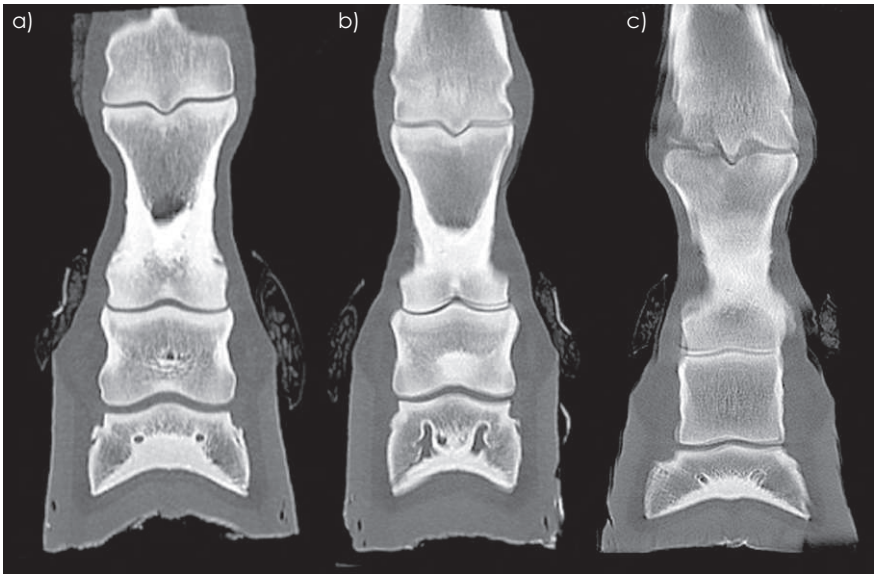

Fig 1: Multi-planar reformatted frontal reconstructed CT images using bone algorithm of the distal limb in standing horses. The images represent a grading system of image quality (Table 1). The image (a) represents excellent image quality with no motion artefact (grade 1). The image (b) shows mild-to-moderate motion artefact representing image quality grade 2. Image (c) has a severe motion artefact that significantly degrades the image quality (grade 3).

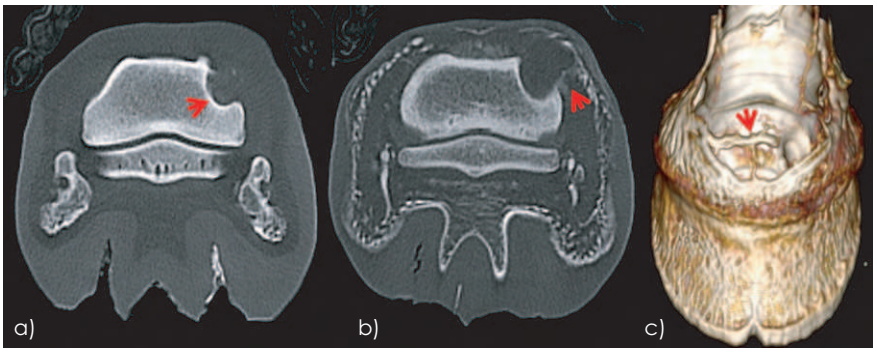

***Fig 2:** Multi-planar reformatted transverse CT image (bone window) of the left front foot of a 17-year-old mare. Lateral is to the right. There is moderate deformation of the lateral aspect of the middle phalanx (arrow in a) caused by a hypoattenuating mass. There is a partial contrast enhancement surrounding the mass (arrow in b). The 3D reconstruction shows the mass blood supply (arrow in c).*

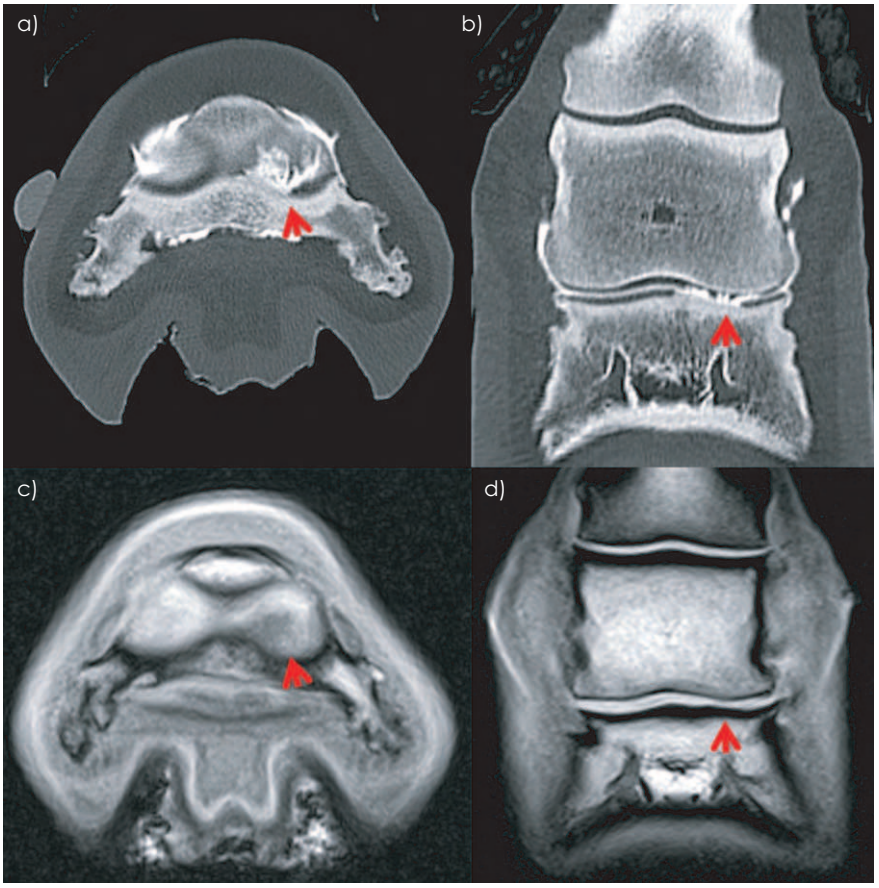

***Fig 3:** a) and b) are multi-planar reformatted arthrographic CT images (bone window) of the left front distal interphalangeal joint (DIP) of a 6-year-old gelding. There is pooling of the contrast agent in the cartilage with direct contact with subchondral bone of the medial aspect of the DIP joint (arrow). This may indicate a full-thickness cartilage erosion. The horse underwent standing low field MRI of the foot (c and d) post-CT, to assess the presence of fluid-based pathology in the subchondral bone plate. MRI showed mild-to-moderate thinning of the cartilage on the medial aspect of DIP (arrow), and the subchondral plate was normal. The severity of the chondropathy was less obvious on MRI versus CT (medial is to the right).*

machine if the horse retracts his limb during the scan (**Fig 5D**). To minimise the horse leaning against the gantry, additional ropes at the level of the horse's shoulder are fixed to side columns. They are attached to the platform frame providing the stability of the patient when the gantry slides away from the patient (**Fig 5F**). Sliding of the gantry during the scan creates a gap between the ground and platform (**Fig 6b**). The safety wood extension (**Fig 5E**) prevents the horse stepping in this and provides extra support to the CT table.

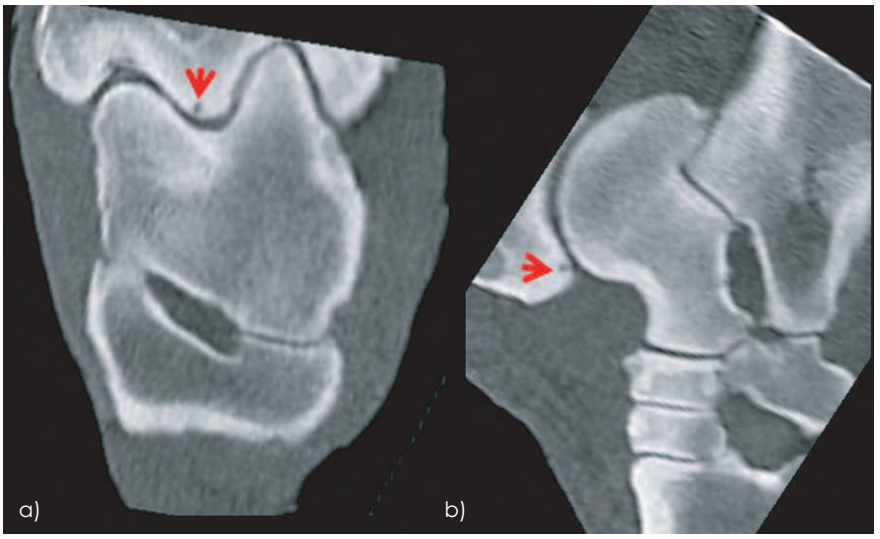

Fig 4: Multi-planar reformatted frontal (a) and sagittal (b) reconstructed CT images (bone window) of the right tarsus of a 6-year-old stallion. There is a circumscribed hypoattenuating zone on the cranial aspect of the distal intermediate ridge of the tibia (arrow). The image shows mild motion artefact. Note the flexed position of the tarsocrural joint due to the limb positioning. Right is lateral and caudal.

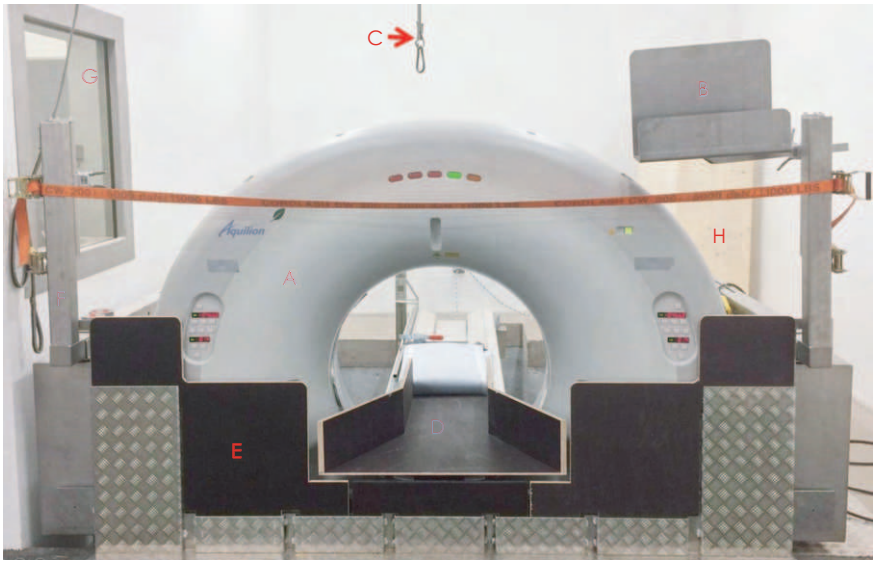

Fig 5: Multi-slice helical CT gantry (A) built over a platform (not seen on the image). The CT gantry is positioned for imaging metacarpophalangeal region. There are extensions attached to the platform to support the head during the scanning, reducing the motion artefact. B) (metal stand) and (C) (rope) provide head support during the scan. D is U-form wood board attached to the CT table to facilitate foot positioning. E is a safety wood wall to prevent dropping the horse limb in the gap created when the gantry slides away from the horse during the scan. Furthermore, it provides additional support to the CT table during loading of the horse limb. F is a side column attached to the platform for fixing a rope to prevent the horse leaning against the gantry. G is the lead window of the CT operating room to monitor the horse during the scan. H is a mobile lead shielded cabin. The gantry can be moved down in a pit in the ground to position the anatomical region of interest at the isocentre of the gantry.

Patient preparation and positioning

A clinical examination of the horse is always conducted prior to imaging. The shoe of the examined limb is removed if the foot is the anatomical region of interest. An intravenous injection of detomidine (10 μg/kg bwt; Domosedan 10 mg/mL)[2] and butorphanol tartrate (0.1 mg/kg bwt; Torbugesic Vet 10 mg/mL)[3] was administered prior to bringing the horse into the CT room. Every horse should be carefully positioned with the feet as close to the platform as possible. For imaging distal anatomical regions, such as the foot and metacarpophalangeal region, the horse is positioned at 90° to the platform in order to position the limb at the isocentre of the gantry. This is done in extension to avoid compression of the joint space in one side. In this case, the head is

supported using a rope from the CT room roof (**Figs 5C** and **6a**). For imaging the most proximal region such as the proximal suspensory ligament and carpus, the horse is positioned at an angel of 30–45° to the gantry, and therefore, the anatomical region of interest would be in the scanning field (**Fig 7**). The limb is attached to a rope, which is held by a person during the scan to provide the proper position of the limb. Imaging the hindlimb requires higher positioning of the platform, with the gantry isocentre at the level of the middle third of the third metatarsus of the contralateral limb (**Fig 8**). To facilitate this positioning, the horse is positioned at an angle of 90° to the platform and the head is supported by a stand. This requires personnel to hold the horse's head. The horse handler can be safely positioned behind a lead cabin (**Fig 5H**).

Image acquisition

The anatomical region of interest will dictate the extent of the scan. Pilot (scout) scans are not performed, since fast movement of the gantry might panic the horses. Also, the limb position is likely to change after the pilot scan. However, not performing the pilot view can lead to use of a wider field of view (FOV), which reduces the image resolution and increases the radiation exposure dose. We use 32 cm FOV from the metacarpo(tarso)phalangeal region through the foot. For imaging most proximal anatomical regions, such as carpus and tarsus, we use the 55 cm FOV. The scanning protocol is summarised in **Table 2**.

Discussion

The current report describes the use of a multi-slice helical CT scanner for the distal limb in standing horses. We were able to achieve diagnostic image quality in 97% (31/32) of the horses. In some horses, up to seven scan attempts have been carried out. These horses underwent a contrast CT, which requires additional scans. The main cause of the motion in horses was the slipping of the limb on the CT table due to the patient leaning against the gantry. However, the platform extensions have greatly reduced the motion artefact. During training, stocks were used for positioning the horses (three horses excluded from this study), to scan the limb. This procedure was time-consuming. Furthermore, the stocks interfered with proper positioning of the limb, particularly for imaging the proximal anatomical regions such as the carpus. Therefore, we do not use it in clinical cases and it has been replaced by platform extensions. No horses reacted adversely to the technique. We were able to easily scan the front feet and the metacarpophalangeal region with good image quality. The images of the proximal anatomical region were more predisposed to motion artefact. However, we imaged these regions in five horses. In three cases (not included in this study), we attempted to image the tarsal region in standing patients, but flexion of the limb was painful; therefore, the CT was carried out under general anaesthesia. Horses with painful responses to limb flexion should be heavily sedated or imaged under general anaesthesia. The acquisition time needs to be kept as short as possible to minimise the motion artefact in the standing horse. Therefore, we use a 1 mm slice thickness and rotation speed of 0.75 s, which enables us to scan a range of 30 cm in 15 seconds.

Arthrography was performed in 38% of the patients. We were able to diagnose chondropathy in different joints (**Fig 3**). However, other diagnostic imaging modalities such as low field magnetic resonance are considered insensitive to diagnose cartilage damage (Smith *et al.* 2012; van Zadelhoff *et al.* 2020). We did not compare the diagnostic accuracy of CT, which is beyond the scope of the current study. One of the advantages of this CT unit is that the limb can be positioned on a partially non-weightbearing limb and thus

Fig 6: a) Positioning of a horse (600 kg, 170 cm height) to scan the metacarpophalangeal region. The gantry slides away from the patient during the scan creating a gap. b) Positioning of a donkey (250 kg, 120 cm height) to scan the foot region. The safety wood wall (Fig 5E) was removed to illustrate the gap made by sliding the gantry away from the patient during the scan.

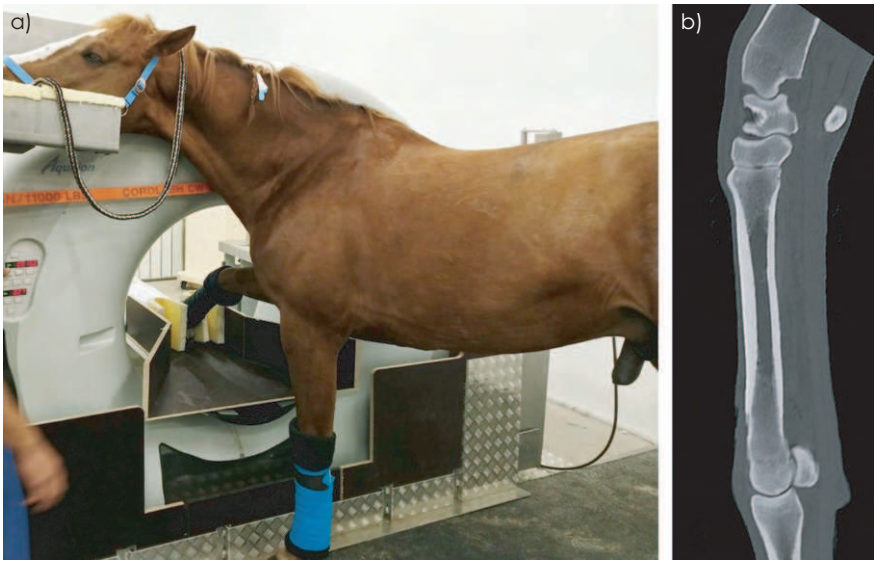

Fig 7: a) Positioning the horse for imaging the carpus and metacarpus region. The horse is positioned at an angle of 30–45° to the platform, which enables scanning the proximal anatomical regions. b) Multi-planar reformatted sagittal CT image (bone window) illustrates the imaged anatomical region. Note there is a mild-to-moderate motion artefact in the distal metacarpal region.

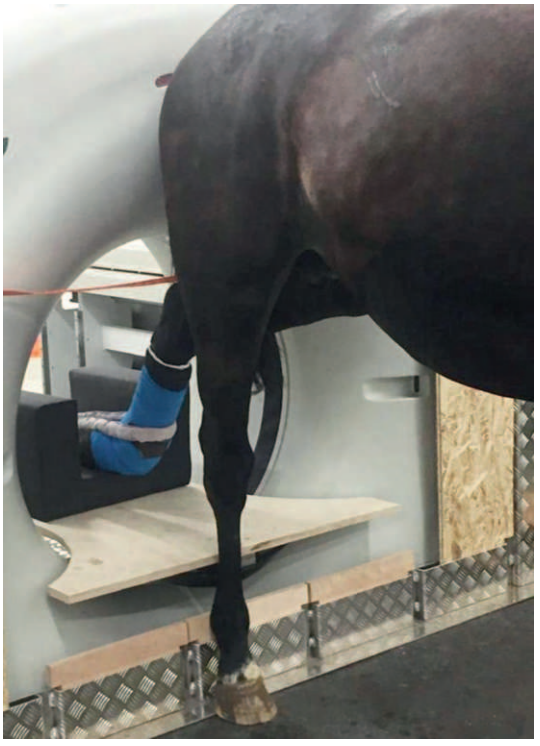

Fig 8: Positioning the horse for imaging the distal hindlimb. The horse is positioned at an angle of 90° to the platform.

TABLE 2: CT scanning protocol of the distal limb in standing horse

Parameter	Value
Kilovoltage (kV)	120
Milliampere (mA)	200
Rotation time (s)	0.75
Field of view (mm)	230–550
Slice thickness (mm)	1

reduce the mechanical compression on the joint space. This also enhances distribution of the contrast agent. Furthermore, flexion of the joint such as a metacarpo(tarso)phalangeal can expose the cartilage surface to more contrast agent and thus provide accurate diagnosis. Venogram CT scans have been carried out in three horses diagnosed with a space-occupying mass lesion in the hoof, facilitating the surgical planning (**Fig 2**). Intra-arterial enhanced contrast CT has been reported to have high sensitivity (93%) for diagnosing soft tissue lesions in the equine foot (van Hamel *et al.* 2014). This technique is usually carried out under general anaesthesia since it requires a consistent infusion contrast agent prior to and during the image acquisition. Recently, ultrasound-guided injection of median and cranial tibial arteries in standing sedated horses has been described (Spriet *et al.* 2015; Torrent *et al.* 2019). We did not attempt to perform intra-arterial enhanced contrast CT since extra equipment, such as saline chaser, is required for providing a constant infusion of the contrast agent, which may not be practicable in standing horses. Moreover, positioning of the limb with an intra-arterial catheter can be a potential risk factor for complications such as arterial thrombi and bleeding.

Radiation safety is one of the most concerning issues in equine standing CT. It is recommended to wear 0.5 mm lead protective clothes, when holding horses for scans (Dakin *et al.* 2014; Davies *et al.* 2019). In this study, there was no horse holder in the CT room during the imaging of the front limbs, the limb was held with a long rope from the operating room. For imaging the hindlimb, the horse's head is supported

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with a stand, and personnel hold the rope from an adjacent lead shielded cabin. This set-up has been used and recommended in standing CT of the equine head (Dakin *et al.* 2014). It has been reported that the estimated dose for the personnel under these circumstances ranged between 0 and 5 μSv per scan (Dakin *et al.* 2014).

More recently, cone beam CT units have been introduced to the equine market for performing the CT in standing patients. Despite improved spatial resolution and isotropic voxel dimensions, cone beam CTs possess disadvantages compared with multi-slice systems, including increased motion susceptibility (long acquisition time), decreased contrast resolution and Hounsfield unit variability (Nelson *et al.* 2017). Regarding the image quality, multi-slice CT shows a greater ability to produce clear and anatomically correct images, and with better soft tissue differentiation compared with the cone beam CT (Nelson *et al.* 2017).

Optimisation and development of this CT unit is still in progress. Since the motion artefact was the most common reason for poor image quality and scans repeating, we hope for motion correction software to be adapted in the future. In human medicine, a rigid motion correction method has been used to eliminate or reduce the motion artefact by 90% in the multi-slice helical system (Kim *et al.* 2015).

The current report showed that a multi-slice helical CT scanner built over a platform facilitates scanning the distal limb of standing horses with a good diagnostic image quality. Imaging of the feet and metacarpo(tarso)phalangeal region of both front and hindlimbs can be performed easily. Although more prone to movement artefact, image acquisition with diagnostic quality of the proximal limb is also achievable in some cases. We believe this technique could improve the assessment of distal limb pathology.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This is a retrospective designed study. No names or patient-owner data have been used.

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Manufacturers' addresses

[1]Toshiba, Berlin, Germany
[2]Orion Pharma, Hamburg, Germany
[3]Zoetis GmbH, Berlin, Germany

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Original Article

Gait abnormalities and ridden horse behaviour in a convenience sample of the United Kingdom ridden sports horse and leisure horse population

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Keywords: horse; saddle; noseband; lameness; musculoskeletal pain; Ridden Horse Pain Ethogram

Summary

The objectives of this study were to compare horses' gaits in hand and when ridden; to assess static and dynamic saddle fit for each horse and rider; to apply the Ridden Horse Pain Ethogram (RHpE) and relate the findings to gait abnormalities consistent with musculoskeletal pain, rider position and balance and saddle fit; and to document noseband use and its relationship with mouth opening during ridden exercise. Data were acquired prospectively from a convenience sample of horses believed by their owners to be working comfortably. All assessments were subjective. Gait in hand and when ridden were evaluated independently, by two assessors, and compared using McNemar's test. Static tack fit and noseband type were recorded. Movement of the saddle during ridden exercise, rider position, balance and size relative to the saddle was documented. RHpE scores were based on assessment of video recordings. Multivariable Poisson regression analysis was used to determine factors which influenced the RHpE scores. Of 148 horses, 28.4% were lame in hand, whereas 62.2% were lame ridden (P<0.001). Sixty per cent of horses showed gait abnormalities in canter. The median RHpE score was 8/24 (interquartile range 5, 9; range 0, 15). There was a positive association between lameness and the RHpE score (P<0.001). Riding School horses had higher RHpE scores compared with General Purpose horses (P = 0.001). Saddles with tight tree points (P = 0.001) and riders seated at the back of the saddle rather than the middle (P = 0.001) were associated with higher RHpE scores. Horses wearing crank cavesson compared with cavesson nosebands had higher RHpE scores (P = 0.006). There was no difference in mouth opening, as defined by the RHpE, in horses with a noseband with the potential to restrict mouth opening, compared with a correctly fitted cavesson noseband, or no noseband. It was concluded that lameness or gait abnormalities in canter may be missed unless horses are assessed ridden.

Introduction

It is well recognised that a horse's gait may appear different when ridden compared with in hand (Licka *et al*. 2004; Marqués *et al*. 2014; Dyson and Greve 2016), but there has been no large-scale comparative study. It is becoming increasingly evident that there is a lack of recognition of lameness and other pain-related gait alterations by riders and trainers in the sports horse population, with variable estimates of 47–69% of horses experiencing musculoskeletal pain (Greve and Dyson 2014; Marqués *et al*. 2014; Dyson and Greve 2016; Pfau *et al*. 2016; Rhodin *et al*. 2016; Wilson *et al*. 2016; Dittmann *et al*. 2020). A Ridden Horse Pain Ethogram (RHpE) has been developed to help identify horses with musculoskeletal pain (Dyson *et al*. 2018a). Further evaluation of a broad cross section of sports horses would potentially help to demonstrate the usefulness of this tool. The prevalence of ill-fitting saddles was reported, and the importance of correct saddle fit for equine musculoskeletal health was highlighted by Greve and Dyson (2014, 2015a); however, this was restricted to saddle fit for the horse and not the rider. Correct saddle fit for the rider is considered important both for optimal force distribution and enabling the rider to ride in balance (Dyson *et al*. 2019; Bondi *et al*. 2020; Roost *et al*. 2020). There has been considerable debate about the use, design and fit of nosebands, the possible discomfort imposed by nosebands and the relationship between mouth opening and nosebands (Fenner *et al*. 2016; Doherty *et al*. 2017; Uldahl and Clayton 2019). However, there has been no large-scale study relating noseband use to oral behaviour.

The objectives of this study were to compare horses' gaits in hand and when ridden; to assess static and dynamic saddle fit for each horse and each rider; to apply the RHpE and relate the findings to gait abnormalities consistent with musculoskeletal pain, rider position and balance and saddle fit; and to document noseband use and its relationship with mouth opening during ridden exercise.

Materials and methods

Study population

This was a cross-sectional study, performed at 10 venues. Data were collected prospectively from a convenience sample of horses, recruited from professional and amateur

riders, by personal invitation or by response to a social media request. Age, breed (Warmblood or Warmblood cross, Thoroughbred or Thoroughbred cross, Cob, Irish Sports Horse, Pony, Other), sex (mare or gelding/stallion), and work discipline (Dressage, Show Jumping, Eventing, General Purpose [including unaffiliated competition, pleasure riding, hunting and showing], Riding School and Other [including Racing, Western performance and Endurance]) were recorded. The horses were in regular work and presumed by their owners, of variable skill and experience (pleasure riders to 5* 3-day event riders), to be working comfortably.

Tack assessment

Static fit of the saddle was assessed by S.D. (Diplomate of the European College of Sports Medicine and Rehabilitation) after tacking up to determine, both without and with a rider, if there was appropriate clearance of the summits of the spinous processes by the pommel and gullet, if the tree points were too tight, if the saddle was positioned too close to the scapulae, if the saddle bridged, and if the seat of the saddle was horizontal, tipped backwards or tipped forwards (Harman 2004; Society of Master Saddlers 2007; Dyson *et al*. 2015; Bondi *et al*. 2020). The type of noseband (cavesson, crank cavesson, flash, crank flash, grackle, drop, Micklem, **Supplementary Item 1**) and the correctness of fit (ISES 2012), or the absence of a noseband, was recorded.

Gait evaluation

The presence or absence of lameness when trotted in hand on a hard surface was determined after tacking up by S.D. (Dyson 2011). After preliminary warm-up, horses were observed ridden in walk, rising trot (including 15 diameter circles) and canter (including 20 m diameter circles) on the left and right reins for approximately 10 min in an indoor or outdoor arena of approximately 20 m × 60 m. Lameness (Dyson 2011) or gait abnormalities in canter (close spatial and temporal separation of the hindlimbs during stance; short stepping, stiff and stilted; lack of a suspension phase; rushed and unbalanced; lifting of the forehand and wide spatial separation of the hindlimbs during stance, Greve and Dyson 2019) while being ridden were determined by a veterinarian, a graduate of 4 years, undergoing specialist training (J.R.).

Saddle movement and rider assessment

Dynamic fit of the saddle to the horse and rider during ridden exercise was determined by a British Horse Society (BHS) Instructor, with specialist knowledge of saddle fit (A.B.). Dorsoventral movement ('bouncing') of the saddle, side-to-side oscillation of the saddle, or the saddle persistently slipping to one side were documented (Greve and Dyson 2013, 2014; Bondi *et al*. 2020). Suitability of the size of the saddle for the rider (correct, or too small), rider position in the saddle (in the middle, or on the back of the saddle [caudal half; the rider's pelvis was caudal to the middle of the saddle]) (Dyson *et al*. 2019) and balance of the rider relative to the horse's movement (in balance, or not in balance) (Walker *et al*. 2020) were also assessed. Both assessors (the veterinarian and the BHS Instructor) stood in standardised locations, in the corner of an arena, so that horses and riders were observed from behind, in front and the side.

Video recording and application of the RHpE

Video footage was acquired from the same positions with a high-definition video camera (Panasonic HDC-SD600[1]) for retrospective assessment and application of the RHpE (Dyson *et al*. 2018a). The RHpE was applied by S.D., without knowledge of either horse identification or the results of ridden gait assessments, at least 3 months after live horse data acquisition, to minimise bias from observations made at the time of data acquisition.

Feedback was provided to all riders about saddle fit and movement, gait abnormalities and rider position.

Data analysis

Data were collected and stored in a Microsoft Excel[2] (Office 365) spreadsheet and imported into Stata[3] (IC v.13.0) for descriptive and statistical analyses. Normality was assessed visually via histograms overlaid with kernel density plots and the Shapiro–Wilk test for normality. Two new variables were created. Rider score (0–3) was based on the rider's seat position, size in relation to the saddle and balance (no abnormalities [0], one abnormality [1], two abnormalities [2] or three abnormalities [3]). Overall lameness status was based on a combination of in hand and ridden assessments (not lame, mild [grade ≤ 2/8, Dyson 2011], moderate [≥3/8 < 5/8] or severe [≥5/8] lameness) and represents the most severe observation. Age, rider score and total RHpE score were summarised as medians (interquartile range [IQR]; range). The remainder of the variables were categorical and were described as proportions (%) with corresponding 95% confidence intervals (CI).

Comparison of lameness and gait abnormalities in hand and when ridden

Paired data on in hand and ridden lameness assessment for each horse were compared using McNemar's exact conditional test without continuity correction. The null hypothesis is that lameness will be present or absent at the same frequencies during ridden and in hand assessment. The relationship between the presence of canter abnormalities and lameness in hand or ridden was assessed using the chi-squared (χ^2) test.

Noseband type and fit

The relationship between mouth opening (defined in the RHpE as mouth opening and/or shutting repeatedly with separation of teeth, for ≥10 s) and noseband type was assessed using the chi-squared test or Fisher's exact test when the frequency of observations was <5.

Factors associated with higher Ridden Horse Pain Ethogram scores

The outcome for each horse was their total RHpE score and was calculated as the sum of the total number of observed predefined behaviours, out of a possible 24, during the 10 min ridden observation period. The relationship between the RHpE score and categorical variables was initially assessed using the Mann–Whitney *U* test for variables with two categories and the Kruskal–Wallis test for variables with more than two categories. The Spearman rank correlation coefficient was used to assess correlations between RHpE score and either age or rider score. Significance was set at

P<0.05; P-values were not adjusted for multiple comparisons (Perneger 1999).

Univariable Poisson regression, with robust standard errors and adjusting for clustering at venue level, was used to calculate incident rate ratios (IRR) and 95% CIs in order to identify factors associated with higher rates of pain-related behaviours and thus higher RHpE scores (Cameron and Trivedi 2009). Robust standard errors were used to control for mild violations of the underlying assumption that the mean and variance of the outcome variable distribution are equal. Variables with Wald P<0.25 following univariable analysis were selected for multivariable Poisson regression modelling. Manual, forward selection was used to build the final multivariable Poisson regression model, with stepwise addition of variables in order of most to least significant based on their Wald P-values. Variables were retained in the final model where Wald P<0.05. Variables not retained in the final model were forced back into the model one at a time to establish if any confounders or interactions had been missed. The fit of the model to the data was assessed using the goodness-of-fit chi-squared test.

Results

Data were available for 151 horse and rider combinations from 10 venues. One horse was excluded following in hand assessment due to grade 5/8 forelimb lameness, thus unless stated otherwise, the data represent 150 horse and rider combinations. Two additional horses, which showed mild lameness in hand, were withdrawn from ridden exercise because they immediately displayed grade 6/8 lameness and were not included in further gait analysis.

Descriptive statistics

All descriptive data are presented in **Table 1**. The horses consisted of 66.0% (n = 99) geldings, 33.3% (n = 50) mares and one stallion and had a median age of 10 years (IQR 8, 14 years; range 3, 27 years). Breed data were available for 149 horses, consisting of 26.9% (n = 40) Warmbloods and Warmblood crosses, 18.8% (n = 28) Cobs, 17.4% (n = 26) Thoroughbreds and Thoroughbred crosses, 16.8% (n = 25) Irish Sports Horses, 10.7% (n = 16) ponies and 9.4% (n = 14) other breeds. The most common work disciplines included General Purpose (n = 85; 56.7%), Riding School (n = 22; 14.7%), Eventing (n = 19; 12.7%) and Dressage (n = 17; 11.3%), with fewest horses in the Show Jumping (n = 4) and Racing/ Endurance/Western (n = 3) disciplines.

Of 151 horses, 29.1% (n = 44) showed lameness in hand. Of 148 horses evaluated ridden, 62.2% (n = 92) exhibited lameness. The median lameness score was 2/8. The total proportion of horses that were lame in hand or while ridden was 79.1% (n = 117/148). More than half of the horses (59.6%, n = 84/141) had gait abnormalities in canter. The median RHpE score for the horses was 8 out of 24 (IQR 5–9; range 0–15).

Saddle fit was likely to compromise performance in 84.0% (n = 126) of the horses. Detailed assessment of static saddle fit identified 74.7% (n = 112) of horses had tree points that were too tight, 27.3% (n = 41) had pommels that were too low, 16.7% (n = 25) had saddles that bridged, and 8.0% (n = 12) had tree points too close to the scapulae. The seat position of the majority of saddles was horizontal (n = 112), while 21.3% (n = 32) tipped backward and six tipped forward. Dynamic assessment of saddle fit identified that 57.7% (n = 86/149) of saddles oscillated from side to side, 53.0% (n = 79/149) of saddles bounced dorsoventrally and 45.0% (n = 67/149) of saddles slipped to one side.

Noseband type was recorded for all 151 horses. The most common type of nosebands used included cavesson (40.4%, n = 61), crank flash (13.9%, n = 21), grackle (12.6%, n = 19), crank cavesson (10.6%, n = 16) and Micklem (7.9%, n = 12) nosebands. Less used noseband types included flash (5.3%, n = 8) and drop (3.3%, n = 5) nosebands. Nine horses (6.0%) did not wear nosebands.

The median rider score was 2 (IQR 0, 2), with one-third of riders displaying two abnormalities (33.3%, n = 50). The most common abnormality observed was the rider being seated on the back of the saddle rather than the middle (56.7%, n = 85), followed by the rider being out of balance (54.0%, n = 81), and the rider being too big for the size of the saddle (45.3%, n = 68).

Comparison of lameness and gait abnormalities in hand and when ridden

From the same sample of 148 horses, 62.2% were considered lame when ridden, but only 28.4% were considered lame when assessed in hand (difference + 33.8%, 95% CI 22.9, 44.6%; P<0.001). Thirteen horses were considered lame in hand but not when ridden, while 63 horses were considered lame when ridden but not when assessed in hand. Gait abnormalities in canter were not related to in hand lameness ($\chi^2 = 1.2$, P = 0.28), or lameness when ridden ($\chi^2 = 3.3$, P = 0.07), when these were assessed individually. However, a combination of in hand or ridden lameness was related to a higher proportion of gait abnormalities in canter ($\chi^2 = 13.8$, P<0.001).

Noseband type and fit

Although the prevalence of mouth opening, as defined by the RHpE, was generally lower when nosebands with the potential to restrict mouth opening (crank cavesson, crank flash, grackle, Micklem, drop and flash nosebands) were used (30.9%), compared with when a correctly fitted cavesson noseband or no noseband was used (37.3%), this difference was not statistically significant ($\chi^2 = 0.7$, P = 0.41).

Factors associated with higher Ridden Horse Pain Ethogram scores

A Poisson regression model with robust standard errors, including venue (n = 10) as the only explanatory variable, revealed a significant effect of venue on RHpE scores (P = 0.01). The subsequent Poisson regression models were, therefore, adjusted for venue-level clustering. The results of the univariable Poisson regression analysis are presented in **Table 2**. Fourteen variables were selected for inclusion in the building of the multivariable model.

The final multivariable Poisson regression model identified six variables related to breed, work discipline, lameness status, saddle fit, rider position and noseband type that were significantly associated with RHpE scores (**Table 3**). Irish Sports Horses had higher RHpE scores compared with Cobs (P = 0.02). Riding School horses had higher RHpE scores compared with horses used for General Purpose (P = 0.001). Although horses used for Racing, Endurance or Western had lower RHpE scores compared with horses used for General Purpose, this finding was based on only three observations.

TABLE 1: Description of horse signalment, work discipline, gait, rider and tack variables collected from a convenience sample of 151 horses enrolled in a study to determine the relationship between Ridden Horse Pain Ethogram scores, gait and behaviour. One horse was withdrawn after in-hand assessment and two horses were withdrawn from ridden exercise because of lameness severity

Variable	Number (n)	Percentage (%)	95% Confidence interval (%)
Horse			
Sex (n = 150)			
Gelding	99	66.0	58.4, 73.6
Mare	50	33.3	25.8, 40.9
Stallion	1	0.7	0.0, 2.0
Breed (n = 149)			
Warmblood/Warmblood cross	40	26.8	19.7, 34.0
Cob	28	18.8	12.5, 25.1
Thoroughbred/Thoroughbred cross	26	17.4	11.4, 23.5
Irish Sports Horse	25	16.8	10.8, 22.8
Pony	16	10.7	5.8, 15.7
Other	14	9.4	4.7, 14.1
Work discipline (n = 150)			
General purpose	85	56.7	48.7, 64.6
Riding school	22	14.7	9.0, 20.3
Eventing	19	12.7	7.3, 18.0
Dressage	17	11.3	6.3, 16.4
Show jumping	4	2.7	0.1, 5.2
Racing/Endurance/Western	3	2.0	0.0, 4.2
Gait			
Lameness in hand (n = 151)			
No	107	70.9	63.6, 78.1
Yes	44	29.1	21.9, 36.4
Forelimb lameness	13*		
Hindlimb lameness	36*		
Lameness ridden (n = 148)			
No	56	37.8	30.0, 45.7
Yes	92	62.2	54.3, 70.0
Forelimb lameness	34*		
Hindlimb lameness	98*		
Lameness in hand or ridden (n = 148)			
No	31	20.9	14.4, 27.5
Yes	117	79.1	72.5, 85.6
Lameness status (n = 148)			
Not lame	31	20.9	14.4, 27.5
Mild lameness	16	10.8	5.8, 15.8
Moderate lameness	99	66.9	59.3, 74.5
Severe lameness	2	1.4	0.0, 3.2
Gait abnormality in canter (n=141)			
No	57	40.4	32.3, 48.5
Yes	84	59.6	51.5, 67.7
Tack			
Potential for saddle fit to compromise performance (n = 150)			
No	24	16.0	10.1, 21.9
Yes	126	84.0	78.1, 89.9
Saddle tree points too tight (n = 150)			
No	38	25.3	18.4, 32.3
Yes	112	74.7	67.7, 81.6
Saddle tree points too close to scapulae (n=150)			
No	138	92.0	87.7, 96.3
Yes	12	8.0	3.7, 12.3
Saddle pommel too low (n = 150)			
No	109	72.7	65.5, 79.8
Yes	41	27.3	20.2, 34.5
Saddle bridges (n = 150)			
No	125	83.3	77.4, 89.3
Yes	25	16.7	10.7, 22.6
Saddle seat position (n = 150)			
Horizontal	112	74.7	67.7, 81.6
Tips forward	6	4.0	0.9, 7.1
Tips backward	32	21.3	14.8, 27.9

TABLE 1 Continued

Variable	Number (n)	Percentage (%)	95% Confidence interval (%)
Saddle bounces dorsoventrally (n = 149)			
No	70	47.0	39.0, 55.0
Yes	79	53.0	45.0, 61.0
Saddle oscillates from side to side (n=149)			
No	63	42.3	34.3, 50.2
Yes	86	57.7	49.8, 65.7
Saddle slips to one side (n = 149)			
No	82	55.0	47.0, 63.0
Yes	67	45.0	37.0, 53.0
Noseband type (n = 151)			
Cavesson	61	40.4	32.6, 48.2
Crank cavesson	16	10.6	5.7, 15.5
Crank flash	21	13.9	8.4, 19.4
Flash	8	5.3	1.7, 8.9
Grackle	19	12.6	7.3, 17.9
Micklem	12	7.9	3.6, 12.3
Drop	5	3.3	0.5, 6.2
None	9	6.0	2.2, 9.7
Rider			
Rider seat position (n = 150)			
Middle	65	43.3	35.4, 51.3
Back	85	56.7	48.7, 64.6
Rider size in relation to saddle (n = 150)			
Suitable	82	54.7	46.7, 62.6
Too large	68	45.3	37.4, 53.3
Rider balance (n = 150)			
In balance	69	46.0	38.0, 54.0
Out of balance	81	54.0	46.0, 62.0
Rider score (n = 150)			
No abnormalities (0)	41	27.3	20.2, 34.5
1 abnormality (1)	22	14.7	9.0, 20.3
2 abnormalities (2)	50	33.3	25.8, 40.9
3 abnormalities (3)	37	24.7	17.8, 31.6

*Some horses were lame on more than one limb.

The incident rate ratio of RHpE scores for horses with mild lameness was 1.4 times higher (P = 0.001) than for nonlame horses and 2.4 times higher (P < 0.001) for horses with moderate-to-severe lameness than for nonlame horses, which was in keeping with the initial Kruskal–Wallis test findings (**Fig 1**). Saddles with tree points that were too tight (P = 0.001) and riders seated at the back of the saddle rather than in the middle (P = 0.001) were also associated with higher RHpE scores. Finally, horses wearing crank cavesson nosebands had higher RHpE scores compared with horses wearing correctly fitting cavesson nosebands (P = 0.006). The goodness-of-fit chi-squared test indicated the Poisson model was an adequate fit for the data (goodness-of-fit χ^2 = 64.3, P = 1.00).

Discussion

Frequency of lameness and comparison of in hand and ridden assessments

In the current study, 79% of all horses showed lameness either in hand or ridden, although only 29% were lame in hand, one of which was not assessed ridden because of the severity of lameness and two of which were withdrawn during ridden exercise. The participants were volunteers and, despite including a broad range of work disciplines and rider expertise, the horses and riders were not necessarily representative of the United Kingdom (UK) horse-rider population. Gait in hand and ridden were assessed independently by two observers, without knowledge of each other's findings.

Direct comparison of the frequency of occurrence of lameness among other studies of riding horses, in work and assumed to be working comfortably, is not straightforward because the circumstances under which horses were examined varied, as did the proportions of different work disciplines and levels of performance. Forty-seven per cent of 506 UK sports horses evaluated in hand and ridden showed lameness, or gait abnormalities in canter consistent with musculoskeletal pain (Greve and Dyson 2014). Fifty-three per cent of 201 Swedish riding horses exhibited measurable asymmetry of gait when trotted in hand (Rhodin *et al*. 2016). Sixty-four per cent of 57 Danish dressage and showjumping horses showed lameness under one or more circumstances (in hand [26%], on the lunge on soft and/or firm surfaces [44%] or ridden [47%]) (Dyson and Greve 2016). Twenty-two of 33 horses (67%) examined in Canada and Argentina showed lameness in hand (Marqués *et al*. 2014). Of 237 Swiss riding horses, 54% were lame in hand (Dittmann *et al*. 2020). Of 60 horses in the UK, which were only evaluated ridden, including 11 riding school horses, 73.3% were lame (Dyson and Pollard 2020). In a study of Swedish riding school horses, evaluated in hand and on the lunge in trot and canter, up to 87% of 99

TABLE 2: Univariable Poisson regression, including robust standard errors and clustering at venue level, of signalment, work discipline, gait abnormalities, rider and tack variables associated with Ridden Horse Pain Ethogram scores in a convenience sample of 148 horses evaluated moving in hand and ridden

Variable	Coefficient	Robust standard error	Incident rate ratio (IRR)	IRR 95% CI	Wald P-value
Horse					
Age (continuous)	−0.002	0.01	0.998	0.98, 1.01	0.82
Breed					**0.20**
Cob	Reference		Reference		
Warmblood/Warmblood cross	0.01	0.06	1.0	0.9, 1.1	0.81
Thoroughbred/Thoroughbred cross	0.12	0.09	1.1	0.9, 1.3	**0.17**
Irish Sports Horse	0.04	0.12	1.0	0.8, 1.3	0.74
Pony	0.13	0.09	1.1	0.9, 1.4	**0.17**
Other	0.13	0.15	1.1	0.8, 1.5	0.41
Sex					**0.02**
Gelding/stallion	Reference		Reference		
Mare	0.10	0.04	1.1	1.0, 1.2	
Work discipline					<**0.001**
General purpose	Reference		Reference		
Dressage	−0.33	0.11	0.7	0.6, 0.9	**0.002**
Show jumping	0.05	0.12	1.0	0.8, 1.3	0.70
Eventing	−0.07	0.09	0.9	0.8, 1.1	0.39
Riding school	0.16	0.07	1.2	1.0, 1.3	**0.01**
Racing/Endurance/Western	−0.45	0.11	0.6	0.5, 0.8	<**0.001**
Gait					
Lameness in hand					0.69
No	Reference		Reference		
Yes	−0.04	0.09	1.0	0.8, 1.2	
Lameness ridden					**0.02**
No	Reference		Reference		
Yes	0.28	0.12	1.3	1.1, 1.7	
Lameness in hand or ridden					<**0.001**
No	Reference		Reference		
Yes	0.83	0.1	2.3	1.9, 2.8	
Lameness status					<**0.001**
Not lame	Reference		Reference		
Mild lameness	0.33	0.09	1.4	1.2, 1.7	**0.001**
Moderate lameness	0.89	0.11	2.4	2.0, 3.0	<**0.001**
Severe lameness	0.74	0.10	2.1	1.7, 2.6	<**0.001**
Lameness status (recategorised)					<**0.001**
Not lame	Reference		Reference		
Mild lameness	0.33	0.10	1.4	1.2, 1.7	**0.001**
Moderate-to-severe lameness	0.89	0.11	2.4	2.0, 3.0	<**0.001**
Gait abnormality in canter					**0.02**
No	Reference		Reference		
Yes	0.22	0.09	1.2	1.0, 1.5	
Rider					
Rider seat position					**0.24**
Middle	Reference		Reference		
Back	0.08	0.07	1.1	0.9, 1.3	
Rider size in relation to saddle					0.67
Suitable	Reference		Reference		
Too large	0.04	0.09	1.0	0.9, 1.2	
Rider balance					**0.002**
In balance	Reference		Reference		
Out of balance	0.21	0.07	1.2	1.1, 1.4	
Rider score (0–3) (continuous)	0.07	0.03	1.1	1.0, 1.1	**0.03**
Rider score					**0.001**
No abnormalities (0)	Reference		Reference		
1 abnormality (1)	0.04	0.11	1.0	0.8, 1.3	0.69
2 abnormalities (2)	0.02	0.11	1.0	0.8, 1.3	0.86
3 abnormalities (3)	0.22	0.09	1.3	1.0, 1.5	**0.02**

TABLE 2 Continued

Variable	Coefficient	Robust standard error	Incident rate ratio (IRR)	IRR 95% CI	Wald P-value
Tack					
Potential for saddle fit to compromise performance					**0.21**
No	Reference		Reference		
Yes	0.09	0.07	1.1	1.0, 1.3	
Saddle tree points too tight					0.43
No	Reference		Reference		
Yes	0.07	0.09	1.1	0.9, 1.3	
Saddle tree points too close to scapulae					0.60
No	Reference		Reference		
Yes	−0.04	0.08	1.0	0.8, 1.1	
Saddle pommel too low					0.84
No	Reference		Reference		
Yes	0.01	0.04	1.0	0.9, 1.1	
Saddle bridges					**0.22**
No	Reference		Reference		
Yes	0.07	0.06	1.1	0.96, 1.2	
Saddle seat position					0.57
Horizontal	Reference		Reference		
Tips forward	−0.13	0.12	0.9	0.7, 1.1	
Tips backward	−0.004	0.10	1.0	0.8, 1.2	
Saddle bounces dorsoventrally					0.77
No	Reference		Reference		
Yes	0.02	0.06	1.0	0.9, 1.2	
Saddle oscillates from side to side					**0.18**
No	Reference		Reference		
Yes	−0.08	0.06	0.9	0.8, 1.0	
Saddle slips to one side					**0.18**
No	Reference		Reference		
Yes	0.11	0.08	1.1	0.9, 1.3	
Noseband type					**<0.001**
Cavesson	Reference		Reference		
Crank cavesson	−0.0005	0.16	1.0	0.7, 1.4	1.00
Crank flash	−0.17	0.8	0.8	0.7, 1.0	**0.02**
Flash	−0.22	0.20	0.8	0.5, 1.2	0.27
Grackle	−0.12	0.08	0.9	0.8, 1.0	**0.12**
Micklem	−0.14	0.08	0.9	0.7, 1.0	**0.06**
Drop	−0.22	0.27	0.8	0.5, 1.4	0.42
None	−0.02	0.10	1.0	0.8, 1.2	0.88
Noseband type (recategorised)					**0.07**
Cavesson/none	Reference		Reference		
Crank cavesson, crank flash, flash, crackle, micklem and drop	−0.12	0.07	0.9	0.8, 1.0	

P-values < 0.25 are highlighted in bold.
CI, confidence intervals.

horses had gait abnormalities reflecting musculoskeletal pain (Egenvall *et al*. 2010). It was notable that in the current study Riding School horses had higher RHpE scores than General Purpose horses. In a previous unrelated study, Riding School horses had a higher median RHpE score compared with horses from other work disciplines (Dyson and Pollard 2020).

Compared with some other studies, the proportion of horses in the current study that were lame in hand was relatively small; this may be because 18% of the lame horses exhibited bilateral forelimb or hindlimb lameness when ridden. Such horses may have had short-stepping, but symmetrical gaits in hand. In addition, the lameness seen ridden was often low grade (median 2/8, Dyson 2011).

The current study highlighted the importance of ridden exercise for lameness detection, validating previous observations in which 26% of horses were lame in hand, compared with 47% when ridden (Dyson and Greve 2016); 12% of these horses were only lame when ridden. In a smaller study of 13 horses in regular work, seven horses were nonlame both in hand and ridden, three horses (23%) were nonlame in hand, but lame ridden (left hindlimb), and three horses exhibited lameness both in hand and ridden (Marqués *et al*. 2014). Recognition that a horse may be nonlame in hand, but lame when ridden, is of vital importance, either when examining horses as part of a prepurchase examination, or when investigating a horse with a history of either poor performance or a change in behaviour. In this study, the relationship between lameness seen in hand was variable and unpredictable. It is also notable that 60% of horses had gait abnormalities in canter, which were not necessarily

TABLE 3: The final multivariable Poisson regression, including robust standard errors and clustering at venue level, of signalment, work discipline, gait, rider and tack variables associated with Ridden Horse Pain Ethogram scores in a convenience sample of 148 horses

Variable	Coefficient	Robust standard error	Incident rate ratio (IRR)	IRR 95% CI	Wald P-value
Breed					
Cob	Reference		Reference		
Warmblood/Warmblood x	0.07	0.05	1.1	1.0, 1.2	0.17
Thoroughbred/Thoroughbred x	0.10	0.07	1.1	1.0, 1.3	0.18
Irish Sports Horse	0.11	0.05	1.1	1.0, 1.2	**0.02**
Pony	0.02	0.08	1.0	0.9, 1.2	0.78
Other	0.15	0.08	1.2	1.0, 1.4	0.07
Work discipline					
General purpose	Reference		Reference		
Dressage	−0.07	0.05	0.9	0.9, 1.0	0.13
Show jumping	−0.14	0.10	0.9	0.7, 1.1	0.18
Eventing	0.12	0.07	1.1	1.0, 1.3	0.11
Riding school	0.12	0.04	1.1	1.1, 1.2	**0.001**
Racing/Endurance/Western	−0.32	0.08	0.7	0.6, 0.9	<**0.001**
Lameness status					
Not lame	Reference		Reference		
Mild lameness	0.31	0.09	1.4	1.1, 1.6	**0.001**
Moderate-to-severe lameness	0.87	0.12	2.4	1.9, 3.0	<**0.001**
Rider seat position					**0.001**
Middle	Reference		Reference		
Back	0.08	0.02	1.1	1.0, 1.1	
Saddle tree points too tight					**0.001**
No	Reference		Reference		
Yes	0.07	0.02	1.1	1.0, 1.1	
Noseband type					
Cavesson	Reference		Reference		
Crank cavesson	0.16	0.06	1.2	1.0, 1.3	**0.006**
Crank flash	−0.05	0.07	0.9	0.8, 1.1	0.47
Flash	−0.13	0.12	0.9	0.7, 1.1	0.28
Grackle	0.09	0.05	1.1	1.0, 1.2	0.06
Micklem	−0.6	0.09	0.9	0.8, 1.1	0.50
Drop	0.06	0.07	1.1	0.9, 1.2	0.39
None	0.09	0.07	1.1	1.0, 1.3	0.21

P-values < 0.05 are highlighted in bold.
CI = confidence intervals.

associated with lameness at trot, highlighting the importance of the assessment of canter in ridden horses.

Saddle fit

There was a disturbingly high proportion of saddles (84%) that were considered to fit inadequately, and which may adversely influence performance. This proportion was higher than in two previous UK studies (Greve and Dyson 2014; Dyson and Pollard 2020). In 40% of 506 sports horses, there were abnormalities of saddle fit identified by a veterinarian who had undergone specialised training in saddle fit (Greve and Dyson 2014). Saddle fit was assessed by a Society of Master Saddlers qualified saddle fitter in 60 sports horses, and 47% had ill-fitting saddles that may compromise performance (Dyson and Pollard 2020). However, in a study of 237 Swiss horses, 74% had ill-fitting saddles assessed by experienced veterinarians, with a higher proportion in leisure horses (81%) compared with competition horses (68%) (Dittmann *et al*. 2020). Adequate room underneath the pommel is a feature that can readily be assessed by a rider (Harman 2004) yet was inadequate in 27% of horses in the current study, clearly reflecting the lack of awareness of a high proportion of riders, despite their willingness to be involved in the study. Better education of riders is obviously required.

Previous smaller studies did not show a significant effect of an ill-fitting saddle on the RHpE score (Dyson *et al*. 2020; Dyson and Pollard 2020). However, in the current, larger study tight tree points (seen in 75% of horses) were significantly positively associated with the RHpE score. This highlights the importance of assessing saddle fit in all horses, especially those undergoing investigation for poor performance. We have previously demonstrated the importance of regular saddle-fit assessment and appropriate adjustment for the maintenance of optimal thoracolumbar muscle function and equine performance (Greve *et al*. 2015; Greve and Dyson 2015a,b).

Rider position

In the current study, 57% of riders sat on the back rather than in the middle of the saddle. This may be because the saddle was too small relative either to the rider's leg length, or to the size of their seat, as observed in 45% of riders. Alternatively, it could be the result of the saddle being the wrong shape for the rider, the stirrup bars being in an inappropriate position, or because the rider had an inherently poor position (Schleese 2014). In a previous pilot study on saddle fit for riders (n = 34), the saddle was too small in 41% (Dyson 2017). Sitting on the back of the saddle will potentially increase forces transmitted

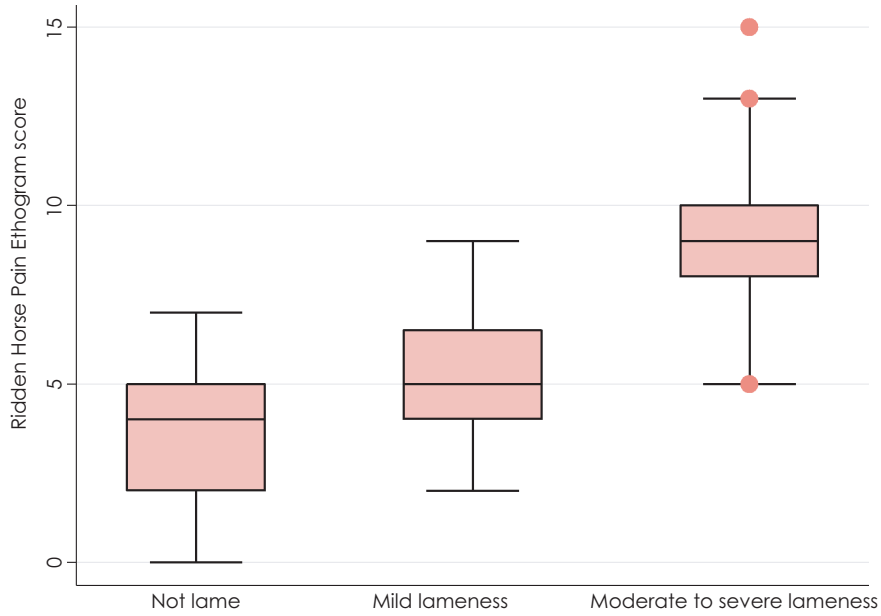

Fig 1: Median Ridden Horse Pain Ethogram scores (0–24) of 148 horses compared with lameness status, assessed both in hand and ridden. Mild lameness ≤ 2/8; moderate or severe lameness ≥ 3/8 (Dyson 2011). Boxes represent medians and interquartile ranges, whiskers represent the range and individual points are outliers.

through the caudal half of the saddle (Roost *et al*. 2020), an effect which could be potentially compounded if the rider is out of balance (54% of riders in the current study), the saddle seat tips backwards (21% of saddles in the current study), or if the saddle moves excessively during ridden exercise (dorsoventral 53%, side to side 58%, saddle slip 45%, in the current study). However, we did not assess left-right asymmetry of the rider in the current study, which can also have a major impact on force distribution under the saddle (Gunst *et al*. 2019). Despite this limitation, the importance of rider position and the horse's performance is highlighted by the positive relationship between the rider being on the back of the saddle and the RHpE score.

The RHpE score and musculoskeletal pain

We have previously demonstrated that a RHpE score ≥ 8/24 is highly likely to reflect the presence of musculoskeletal pain, although some lame horses score < 8/24 (Dyson *et al*. 2018a, b, 2020; Dyson and Van Dijk 2020; Dyson and Pollard, 2020), as seen in the current study. Moreover, there was a positive relationship between lameness severity and the RHpE score. Fifty-six horses (37.8%) had a RHpE score < 8, of which 33 (58.9%) were nonlame. The gait assessment in the current study was limited to subjective evaluation, but included assessment of variations in canter, which cannot currently be assessed objectively.

Twenty-two horses had a symmetrical gait in trot and a RHpE score ≥ 8, of which 16 (72.7%) showed gait abnormalities in canter. Gait abnormalities in canter were significantly associated with the RHpE score in the univariable analysis, but not in the final model, as in a previous study (Dyson and Pollard, 2020). However, 5/22 horses (22.7%) (H1-5) had, based on the definitions, both a symmetrical gait and normal canter, but a RHpE score ≥ 8. It is also necessary to consider gait abnormalities not included in the definitions which may reflect discomfort (e.g. a short-stepping gait), rider size relative to the saddle, their position in the saddle and balance, and saddle fit for the horse, and their effect on performance and behaviour, bearing in mind that both tight tree points and the rider sitting on the back of the saddle had a significant positive association with the RHpE score. The rider of H1 sat on the back of the saddle, was too large for the saddle and was not in balance; the tree points were tight, and the saddle oscillated. The rider of H2 sat on the back of the saddle was too large for the saddle and was not in balance. The rider of H3 was not in balance; the horse had a short-stepping gait; the seat of the saddle tipped forwards and the saddle bridged and oscillated. Horse 4 was reluctant to canter; the tree points were tight, there was dorsoventral bounce of saddle, which oscillated and slipped to one side. The rider of H5 sat on the back of the saddle and was not in balance; the horse exhibited poor hindlimb impulsion; the tree points were tight, the pommel was too low, and the saddle oscillated and slipped to one side. These five horses illustrate the need to evaluate the horse, saddle, rider combination when considering reasons for equine poor performance.

Nosebands

The use of nosebands which by their design and/or tight fitting have the potential to restrict mouth movement, or predispose to oral lesions, is a controversial issue (Fenner *et al*. 2016; Doherty *et al*. 2017; McGreevy *et al*. 2017; Uldahl and Clayton 2019). In the current study, noseband fit was not quantified, but all horses were observed closely during tacking up, as part of a related study, with subjective assessment of tightness. Noseband fit was evaluated by one observer; it was possible to insert two fingers between the cavesson nosebands and the nasal bones. All the nosebands with the potential to limit mouth opening were fitted snugly; it would not have been possible to insert the purpose-designed taper gauge (ISES 2012; Doherty *et al*. 2017), or a single finger

(Uldahl and Clayton 2019). However, there was no significant difference in mouth opening, as defined by the RHpE, in horses with a noseband with the potential to inhibit mouth opening (crank cavesson, flash, crank flash, grackle, drop, Micklem) versus no noseband or a correctly fitted cavesson noseband. Thus, horses could still open their mouths with separation of the teeth, despite a noseband designed to restrict mouth opening. This means that the use of such nosebands, depending on how tightly they are applied, may permit some movement, so that they can theoretically function as training aids, that is if the mouth opens, pressure on the face increases, whereas with the mouth closed there is immediate reduction of pressure, thereby conforming with the principle of training by negative reinforcement (Cooper 1998). However, the effectiveness of these nosebands as training aids is questionable.

The use of a crank cavesson noseband, but not a crank flash noseband, was significant in the multivariable analysis for the RHpE score, despite being used in only 11% of horses. This association does not necessarily imply a causal relationship. The lack of association of the use of a crank cavesson noseband with the RHpE score in the univariable analysis indicates that there is a likely complex interaction of rider position, saddle fit, breed, work discipline and lameness on the effect of a crank cavesson noseband.

The reasons for choice of the type of noseband used are variable. In a questionnaire survey of 3040 riders, the reasons for noseband use were diverse and included stopping the horse putting its tongue over the bit or opening the mouth, 'it was the noseband which came with the bridle', and improving the horse's appearance, but no specific reason for the selection of a crank-type noseband was determined (Weller *et al*. 2020). Two studies, one conducted on a treadmill in 10 nonridden horses (Pospisil *et al*. 2014) and a second involving six ridden horses (Randle and McGreevy 2013), showed that with increased tightness of a cavesson noseband there was a reduction in rein tension. It was concluded that noseband tightness may influence the horse's sensitivity to the bit; however, the evidence is incomplete and further investigation of noseband design and application is required.

There are limited data concerning the potential adverse effects of a crank cavesson noseband. In a study involving 12 naïve horses, after application of a crank cavesson noseband fitted tightly, with data collected over a period of 10 min while standing still, there were significant increases in heart rate and eye temperature and decrease in heart rate variability compared with baseline (Fenner *et al*. 2016). These results were interpreted as an indication of a physiological stress response, not observed when the same noseband was fitted more loosely. Whether or not the same response would be observed in non-naïve horses, or horses being ridden, has not been determined. Focal high pressures were measured at consistent locations under crank cavesson nosebands (Murray *et al*. 2015). In a cross-over design study, 12 competition horses showed increased carpal and tarsal flexion when ridden in a bridle in which the crank cavesson noseband and headpiece were modified to reduce pressures at peak sites compared with their conventional bridles (Murray *et al*. 2015). Whether or not such gait alteration would be sustained over time has not been determined.

It is perhaps more pertinent to determine why ridden horses open their mouths, so that riders may choose to use a crank cavesson noseband. There is a higher frequency of occurrence of mouth opening in lame versus nonlame horses (Dyson *et al*. 2017, 2018a,b) and, in a small subset of lame horses, mouth opening was more common when the horses were ridden compared with being lunged wearing a bridle, suggesting that it was related to the presence of the rider (Dyson *et al*. 2017).

Conclusions

This study clearly demonstrated that lameness or gait abnormalities in canter may be missed unless horses are evaluated ridden. It further validated the RHpE as a valuable tool for recognising the presence of musculoskeletal pain or discomfort. The results indicated that there may be a contributory causal association between either tight tree points or the rider sitting on the back of the saddle and a high RHpE score. Further investigation is needed to determine the role of nosebands in equine performance. There was a disturbingly high frequency of occurrence of ill-fitting saddles for both horses and riders, thus demonstrating that further education of the equestrian community is required in order to improve ridden horse welfare and performance.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The study was approved by the Clinical Ethical Review Committee of the Animal Health Trust (AHT 26 2019). The horse owners gave informed consent for inclusion of their horses in the study.

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Authorship

S. Dyson was responsible for study design and contributed to study execution, data analysis and interpretation, and preparation of the manuscript. A. Bondi and J. Routh contributed to study execution. D. Pollard contributed to data analysis and interpretation, and preparation of the manuscript. All authors gave their final approval of the manuscript.

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Image Article

Use of serial standing computed tomography for diagnosis, treatment and monitoring of a horse with acute myonecrosis of the head

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Keywords: horse; computed tomography; myonecrosis; myositis; *Prevotella intermedia*; *Peptostreptococcus asaccharolyticus*

Summary

An 11-year-old American Quarter Horse gelding was referred to the JT Vaughan Large Animal Teaching Hospital at Auburn University, College of Veterinary Medicine, for investigation of acute and severe right-sided facial swelling and nasal discharge. Standing computed tomographic (CT) examination of the head identified severe soft tissue swelling surrounding the right mandible, emphysema within the soft tissues tracking along fascial planes and right-sided caudal and rostral maxillary sinusitis. Using CT identification and ultrasound guidance, several targeted fasciotomies were created into the right masseter, cranial cervical musculature, supraorbital space and caudo-medial aspect of the mandible. The right-sided sinusitis was treated by right conchofrontal sinus trephination and lavage. Aerobic and anaerobic cultures obtained from the fasciotomy sites and conchofrontal sinus both yielded *Prevotella intermedia* and *Peptostreptococcus asaccharolyticus*. During hospitalisation, serial, standing CT examinations were performed for monitoring case progression and guiding further fasciotomies in the face of continued myonecrosis. Follow-up CT performed at 1 month showed resolution of the emphysema and presence of chronic right ventral conchal sinusitis. The sinusitis was treated by fenestration of the right ventral concha with a diode laser via the nasal passage.

Introduction

Severe, acute subcutaneous emphysema progressing to oedema and necrosis of the soft tissues following breach of the epithelium by anaerobic bacteria, usually a *Clostridium* species, is a relatively rare but potentially life-threatening phenomenon. A 2003 review of 37 cases of clostridial myonecrosis determined that the majority of instances occurred following an intramuscular injection, with a small number occurring in association with a wound (Peek *et al*. 2003). The resultant myonecrosis surrounded the respective injection site, commonly the cervical or gluteal musculature. These anatomical areas contain relatively few large neurovascular structures, allowing the treating clinician to perform fasciotomies to aerate the offending bacteria and drain the accumulated purulent material without the need for meticulous surgical planning. The following case report describes the use of serial, standing computed tomography (CT) examinations to guide diagnosis, fasciotomies and treatment monitoring of severe, acute myonecrosis of the head. Serial CT examinations allowed for the precise planning for multiple fasciotomies in a region where the surgical anatomy is daunting in both complexity and importance.

Case history

An 11-year-old American Quarter Horse gelding was referred to Auburn University JT Vaughan Large Teaching Hospital for investigation of acute and severe right-sided facial swelling and malodorous nasal discharge. One day prior to presentation, the patient presented to the referring veterinarian with depressed mentation, right-sided facial swelling and a fever of 40°C. A complete blood count revealed lymphopenia (340 cells/uL) and hyperfibrinogenaemia (5.1 g/L). Skull radiographs identified rounding of tooth root 108 and fluid opacity within the right side of the rostral and caudal maxillary sinuses. An oral examination was unremarkable. Despite treatment with flunixin meglumine (1.1 mg/kg bwt i.v.), phenylbutazone (2.2 mg/kg bwt i.v.), dexamethasone (0.01 mg/kg, bwt i.v.), dimethyl sulphoxide (0.1 g/kg bwt i.v.), dipyrone (30 mg/kg bwt i.v.) intravenous fluid therapy and enrofloxacin (7.5 mg/kg bwt i.v.), there was progression of the facial swelling and loss of airflow of the right nostril.

Clinical findings

At presentation, the gelding was bright, alert and responsive. The rectal temperature was elevated at 39.1°C, the heart rate was elevated at 56 beats/min and the respiratory rate was slightly increased at 24 breaths/min. The horse's mucous membranes were pink and moist with a normal capillary refill time of less than 2 s. The right side of the face was profoundly swollen, including the right peri- and retro-orbital space with resultant exophthalmos and chemosis. The swelling extended from the level of the throat latch rostrally to the right nostril, including the soft tissues overlying the vertical and horizontal rami of the right mandible (**Fig 1**). Airflow was not appreciated through the right nostril. Abundant malodorous, mucopurulent right-sided nasal discharge was noted. The left nostril had appropriate airflow and was free from discharge. The mandibular lymph nodes were bilaterally enlarged. Absence of the right palpebral reflex was detected on cranial nerve examination but was considered to be due to severe head swelling and not due to cranial nerve deficit

Fig 1: Side photograph of an 11-year-old American Quarter Horse gelding at presentation for treatment of acute and severe right-sided facial swelling and nasal discharge. Note the severe swelling of the right periorbital space, eyelids, across the lateral surface of the ventral head and labial commissure. Foetid right-sided nasal discharge was present.

because other reflexes associated with the facial nerve were intact.

Initial investigation and treatment

Initial diagnostics included complete blood count, serum biochemistry, transcutaneous ultrasonographic examination of the thorax and abdomen (Aplio i700 TUS-AI700; Canon)[1], upper airway endoscopy and ophthalmological examination of the right eye. A mild lymphopenia, moderate thrombocytopenia and moderate hypomagnesaemia were identified (1100 lymphocytes/µl, 6700 platelets/µl and 0.45 mmol/L magnesium, respectively). Mild comet-tail artefacts along the right cranioventral lung field were identified by thoracic ultrasonography, consistent with mild pleural roughening. The remainder of the ultrasonographic examination was unremarkable. Upper airway endoscopy identified thick purulent discharge at the right nasomaxillary aperture. No other abnormalities of the guttural pouches, pharynx or the proximal trachea were identified. Ophthalmological examination confirmed exophthalmos and chemosis of the right side, but no other abnormalities of either eye were detected. Sedated oral examination using a dental camera[2] did not identify any foreign body or penetrating wound in the oral mucosa. Chronic buccal ulceration associated with sharp points was noted on the left side. Infundibular caries of teeth 109 and 110 were noted. No teeth were loose or fractured.

Advanced imaging

A standing sedated CT examination of the head and cervical region was performed using a 16-slice CT scanner (GE LightSpeed VCT CT System, 160 mA, 120kV)[3], and images were reconstructed in both bone and soft tissue algorithms at a slice thickness of 5.0 mm. Severe soft tissue swelling contouring the right mandible abaxially from the first premolar to the atlas was identified, extending across the entire abaxial aspect of the right maxillary bone. Numerous coalescing gas bubbles were present throughout the soft tissue swelling and were noted tracking along multiple fascial planes (**Fig 2**). The swelling along the axial aspect of the right vertical mandible caused mild axial compression of the nasopharynx and axial deviation of the guttural pouch. This swelling extended into the right caudal periorbital space, where pinpoint areas of gas within the right orbital fissure were observed. A mild, focal area of irregular periosteal response was noted along the medial contour of the right horizontal mandible. Fluid and soft tissue attenuating material was present within the right rostral and caudal maxillary sinus, the right sphenopalatine sinus, right dorsal and ventral conchal bulla. Infundibular gas and rounding of the apical roots were noted in teeth 109 and 110. No foreign body or evidence of a penetrating wound could be identified.

Surgical treatment

Based on the CT, a diagnosis of myonecrosis of the right side of the head with right-sided secondary sinusitis was made, though whether dental disease or other penetrating injury was implicated could not be determined. The anatomical regions on CT containing the greatest emphysema were selected as fasciotomy sites. Fasciotomies were performed under standing sedation and local anaesthesia; one into the supraorbital adipose tissue, three across the lateral aspect of the mandible (i.e. into the masseter, ventral to the approximated location of the facial nerve) and one at the caudo-medial aspect of the horizontal ramus of the mandible. Ultrasonographic guidance was used to guide the fasciotomy at the medial aspect of the mandible to avoid penetration of the facial artery or linguofacial vein. Purulent discharge along with necrotic muscle and adipose tissue was obtained from the fasciotomy sites and a sample submitted for aerobic and anaerobic culture. The sites were lavaged with sterile polyionic solution. A Penrose drain was placed connecting the rostral and caudal lateral masseter incisions and secured in place. The right conchofrontal sinus was opened with a ¾" Horsley's trephine and a sample of the purulent discharge within the sinus was submitted for culture (separate from the fasciotomy culture). The sinus was lavaged and a 20 French Foley catheter left in situ for serial lavage.

Case progression and post-operative treatment

Treatment was initiated with potassium penicillin (44,000 iu/kg bwt q. 6 h, i.v.), metronidazole (15 mg/kg bwt q. 8 h, per os) and flunixin meglumine (1.1 mg/kg bwt q. 12 h, i.v.). Initially, the gelding had persistent tachycardia (60 beats/min) and additional pain relief was provided (morphine, 0.1 mg/kg bwt q. 8 h, i.v.). The gelding had a recurring fever responsive to flunixin meglumine administration. Fasciotomy sites were lavaged twice daily with a dilute betadine solution. The sinus was flushed once a day with a balanced ionic solution until resolution of the purulent sinus material and removal of the Foley catheter (3 days). Repeat bloodwork performed at 48 h

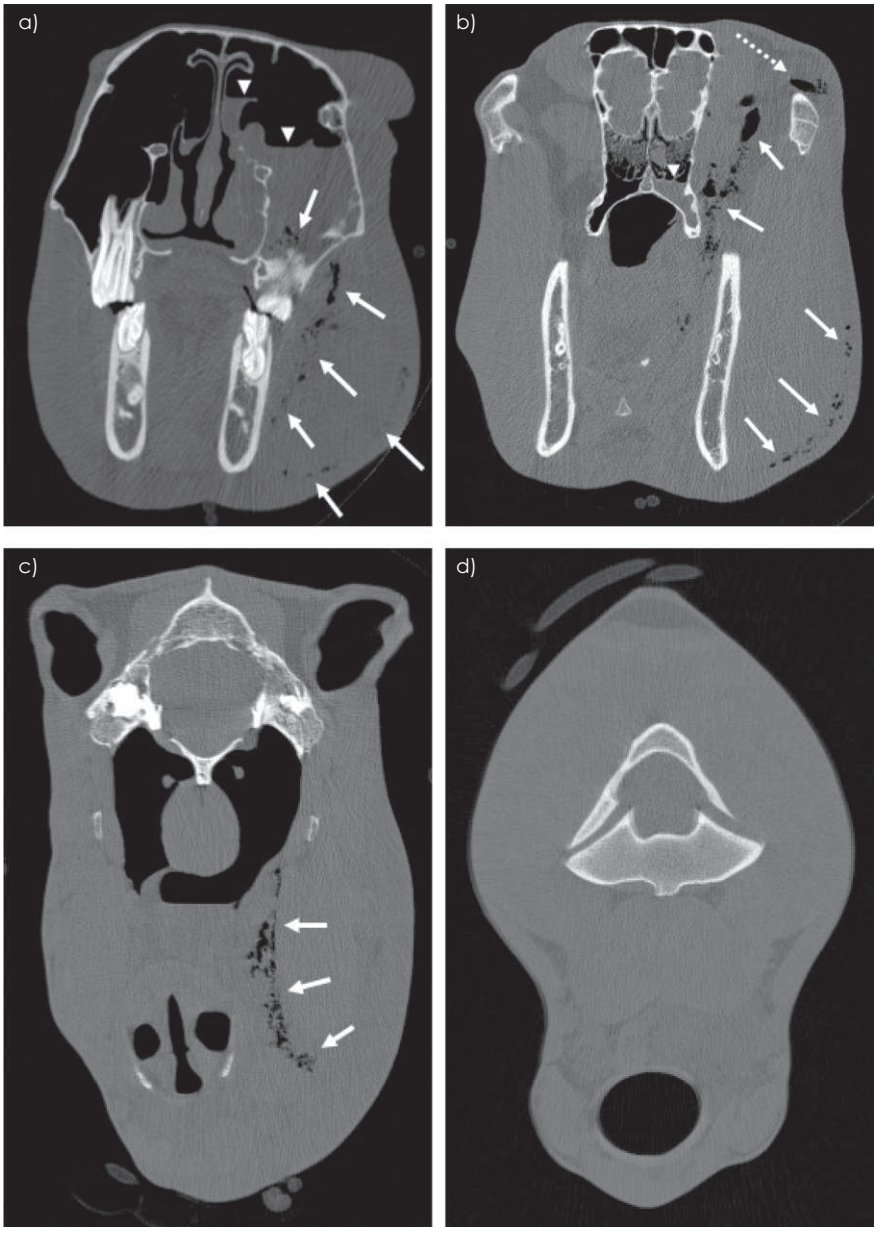

Fig 2: Initial computed tomography examination of the head. Transverse plane images, a) at the level of the 3rd molar (rostral), b) at the ethmoidal conchae just caudal to the orbits (orbital), c) at the level of the guttural pouches (caudal) and d) at the C1-C2 articulation (cervical). Enlargement of the soft tissues is seen across the right side of the head, with emphysema present contouring the abaxial (a, b) and axial (b, c) aspects of the mandible (white arrows). Additionally, there is gas within the periorbital space (b – dashed arrow) and soft tissue/fluid attenuation present within the right conchofrontal (a), caudal maxillary (a) and sphenopalatine (b) sinuses (arrowheads). There is marked swelling of the nasopharynx (b) and deviation of the larynx (c). The emphysema was limited to the head region and did not extend into the cervical musculature (d).

showed a persistent mildly elevated fibrinogen (6 g/L), improved thrombocytopenia (81,000 platelets/μl) and resolution of the previous lymphopenia (2200 lymphocytes/μl).

Second CT examination and further surgical treatment

At Day 4 post-fasciotomy, the gelding was persistently tachycardic and had an intermittent fever (highest temperature 39.0°C), despite a decrease in the facial swelling and improvement in the palpebral reflux. Subsequently, a second CT to evaluate the response to treatment was performed. This showed a significant improvement in the emphysema abaxial to the right mandible within the masseter muscle, but more emphysema present axial to the horizontal ramus and within the right periorbital space (**Fig 3**). Additionally, new, pathological emphysema tracts were identified along the ventrolateral cervical soft tissues, dorsal and lateral to the cranial trachea. Based on these findings, which were felt to indicate

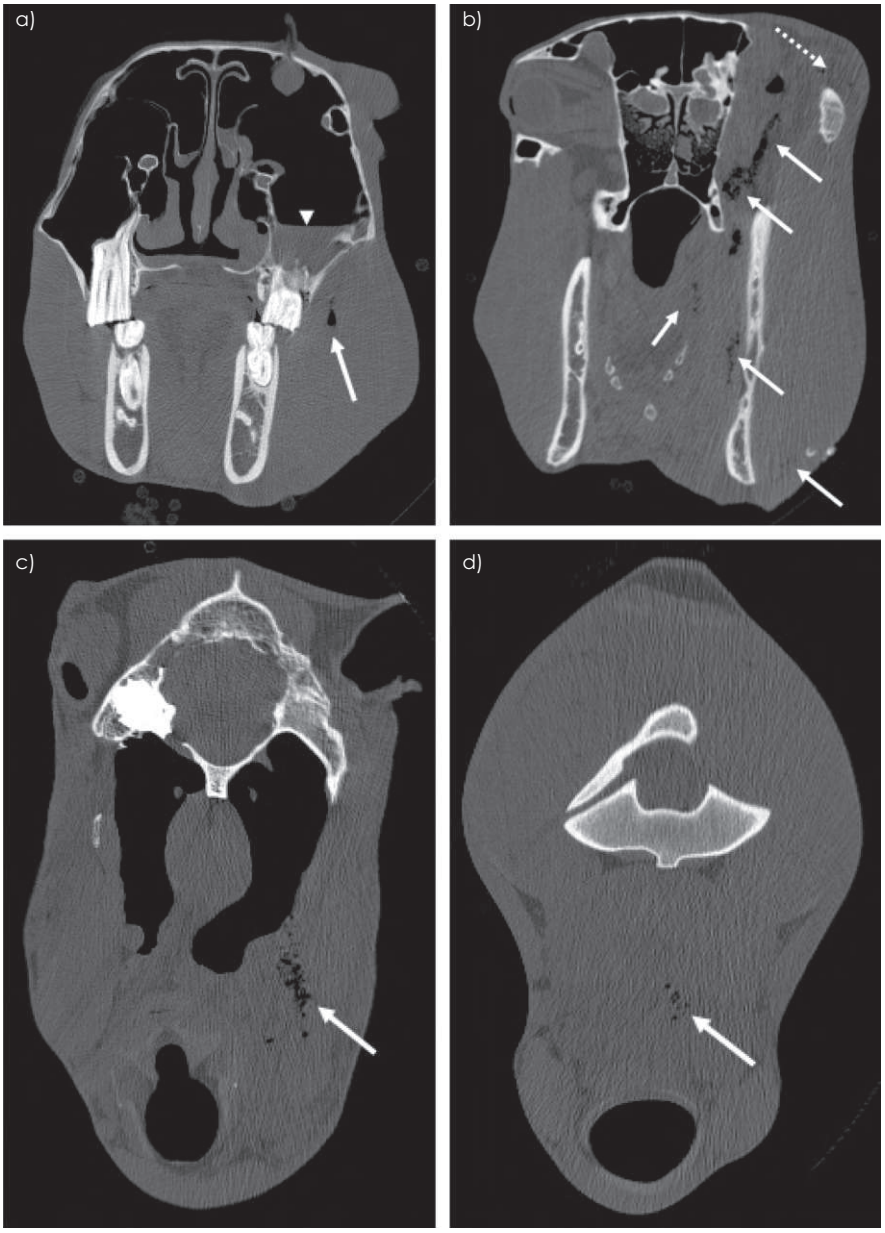

Fig 3: Second computed tomography examination of the head performed 4 days post-fasciotomy (5 days after the first study). Images a) (rostral), b) (orbital), c) (caudal) and d) (cervical) are transverse plane images that correspond to the images in Figure 2. There is less gas present (white arrows) within the soft tissues rostrally (a) and the soft tissue/fluid opacity (arrowhead) previously identified within the caudal maxillary sinus is reduced (a). The gas (white arrows) contouring the abaxial aspect of the mandible is also greatly reduced (b), however, it persists axially (b, c) and within the supraorbital space (b – dashed arrow). The second CT identified new regions of emphysema caudally within the cranioventral cervical soft tissues, consistent with infectious tracts and progression of the pathology (d).

progression of the disease process, additional fasciotomies were performed. Using ultrasound guidance to avoid the parotid gland and major vasculature, a fasciotomy was made into the cranial cervical musculature, just caudal to the angle of the mandible. More necrotic, purulent material, similar to that identified during the first procedure, was identified and removed. The periorbital incision was extended deeper towards the retrobulbar space, liberating more dark necrotic adipose tissue. The previous fasciotomies were cleaned, digitally stretched and lavaged with isotonic fluids.

Microbial culture result and case progression

Culture results from both the sinus and mandibular fasciotomy site were available after 1 week of treatment and both revealed heavy growth of *Prevotella intermedia* (Gram-negative) and *Peptostreptococcus asaccharolyticus* (Gram-positive). Due to the presence of a mixed bacterial growth, gentamicin (6.6 mg/kg bwt q. 24 h, i.v.) was added to the treatment protocol. Additionally, due to lack of detectable *Clostridium* species, the improvement in clinical signs and the

risk of antibiotic-associated enterocolitis, the dose of penicillin was lowered to 22,000 iu/kg bwt i.v. q. 6 h. Due to progressive inappetence, the route of administration of the metronidazole was switched from per os to per rectum at a dose of 20 mg/kg q. 8 h (Steinman *et al*. 2000). Over the following 2 weeks of hospitalisation, the gelding slowly improved. The facial swelling decreased, the heart rate and rectal temperature normalised and the appetite improved.

The gelding underwent CT examination every 4–5 days to monitor the progress of the emphysema. The studies showed gradual improvement. The fasciotomies were allowed to close by second intention. Antibiotic therapy was transitioned from intravenous penicillin/gentamicin to Trimethoprim-sulfamethoxazole (30 mg/kg bwt q. 12 h, per os) on Day 21, due to satisfactory clinical and imaging improvement. At 30 days post-presentation, the facial swelling was considered to have resolved. A complete blood count performed at this time showed no abnormalities. The gelding was discharged at 25 days post-presentation for further care at the farm, with instructions to clean the healing fasciotomy sites and to return for a repeat oral examination and head CT in 30 days.

Follow-up

The gelding presented for follow-up at 30 days. At this time, the fasciotomy sites were well-healed and the soft tissue swelling of the head had resolved (**Fig 4**). There was no history of recurrence of the right-sided nasal discharge. Oral examination was unchanged from the previous examination. Follow-up standing CT revealed resolution of the soft tissue thickening and no evidence of emphysema (**Fig 5**). There was soft tissue attenuating signal consistent with inspissated purulent debris in the right ventral conchal sinus. The previously described dental abnormalities were unchanged.

Fig 4: Side photograph of the gelding at the 30 day recheck showing resolution of the soft tissue swelling and good healing of the fasciotomies. The right-sided nasal discharge was also resolved at this time.

At this time, resting upper airway endoscopy was performed and was unremarkable. Treatment of the chronic sinusitis was discussed with the owner, who expressed a reluctance to perform sinoscopy for cosmetic reasons. Trans-endoscopic fenestration of the right ventral concha with a contact diode laser via the nasal passage was performed following local desensitisation with 2% mepivacaine. Thick purulent material was flushed from the sinus via a chambers catheter inserted into the opening. The gelding was discharged with instructions to monitor for recurrence of the nasal discharge.

Discussion

In this report, myonecrosis of the soft tissues of the head with concurrent sinusitis was caused by *Prevotella intermedia* and *Peptostreptococcus asaccharolyticus*. How the bacteria were able to enter and establish infection in these tissues remains unclear, since no penetrating wound or foreign body was identified and the case resolved without removal of any tooth. Due to their ability to express potent virulence factors such as endotoxin and collagenases, *Prevotella* species are frequently identified in cases of severe periodontitis in man and in veterinary species (Borsanelli *et al*. 2017). Kennedy *et al*. (2016) assessed the oral microbiome of horses with and without periodontal disease and found that affected horses had a different, more diverse microbiome, with *Prevotella* species being the most prevalent. Bailey and Love (1991) isolated bacteria from the pharyngeal tonsillar surface of horses with and without lower respiratory tract or oral bacterial infections and identified *Peptostreptococcus* species in both normal and diseased horses, suggesting that this species is an opportunistic pathogen of the pharynx. The horse described in this report had infundibular caries of 109 and 110 and though the emphysema and other clinical signs resolved without tooth removal, it is possible that the compromised oral health of the horse contributed to the pathogenesis of the myonecrosis, perhaps following a small penetrating wound of the oral mucosa. The affected teeth were not removed as there was concern that standing removal of the teeth would require performance of a maxillary nerve block, which given the location of the myonecrosis was contraindicated.

At presentation, the differential diagnoses were periodontal disease, neoplasia, mandibular fracture or abscess, sialadenitis or sialolithiasis, *Streptococcus equi equi* infection, snake bite and myositis. The initial CT examination was most consistent with that of anaerobic myositis as there was extensive emphysema within markedly swollen soft tissues with gas bubbles tracking along the fascial planes. No discrete abscess or neoplasm could be identified and, coupled with the acute presentation, these were considered less likely. The gas identified on CT did not appear to extend into or originate from the parotid gland. The tooth roots, although not normal, did not appear to be abscessed. The upper airway endoscopy performed at admission determined the guttural pouches were free of empyema. No external wound or puncture marks were identified on the skin, thus following the advanced imaging the diagnosis of myonecrosis, presumed to be due to *Clostridial* species, was most likely (Peek *et al*. 2003).

Most cases of *Clostridial* myonecrosis occur in the cervical or gluteal musculature, a direct consequence of the

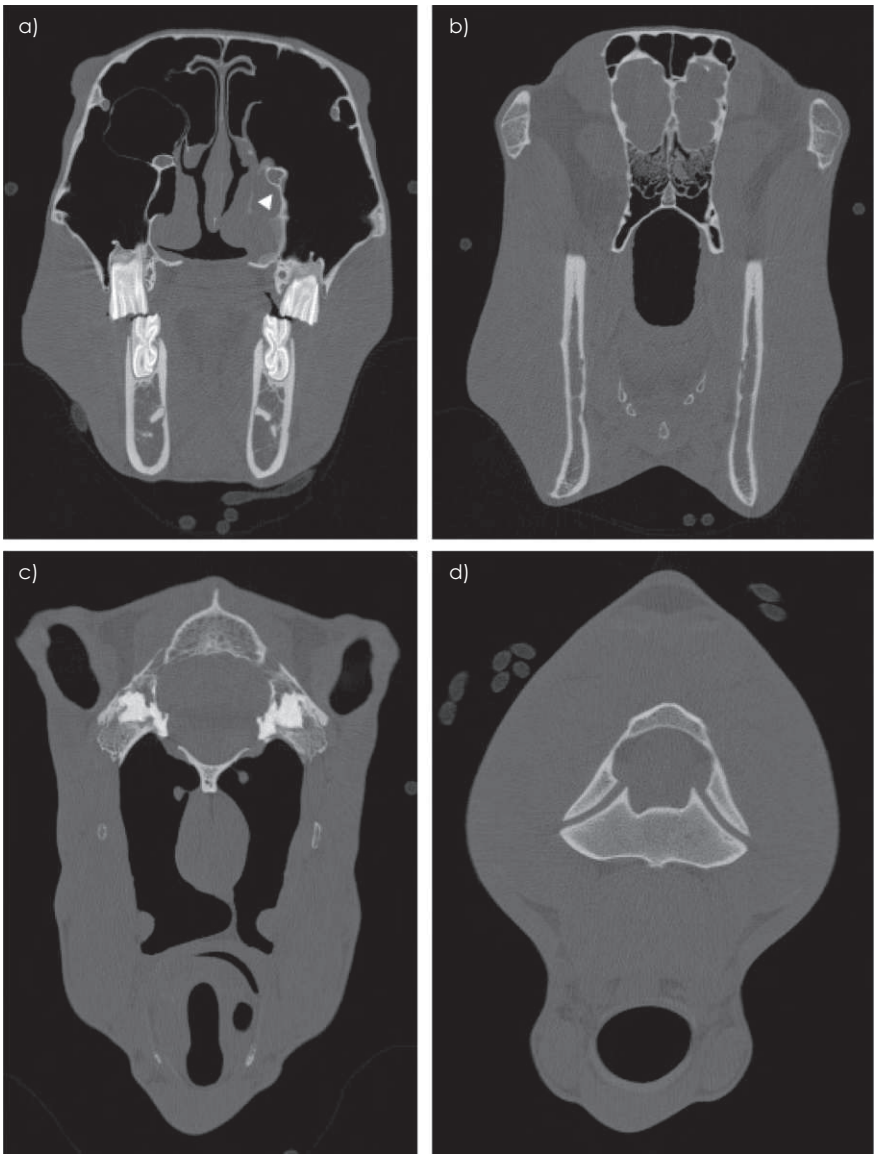

Fig 5: Follow-up CT examination of the head performed 30 days after discharge (55 days post-presentation). Transverse images a) (rostral), b) (orbital), c) (caudal) and d) (cervical) correspond to the images in Figures 2 and 3. There is resolution of the previously identified emphysema. There is moderate thickening of the soft tissues of the ventral conchal sinus consistent with chronic sinusitis (arrowhead).

common aetiology of post-intramuscular injection (Peek *et al*. 2003). In both of these regions, the clinician is quickly able to perform a therapeutic fasciotomy to expose the causative anaerobic bacteria to air. In the cervical region, the fasciotomies are made dorsal to the vertebral column and ventral to the nuchal ligament, while in the gluteal region the position of the sciatic nerve should be avoided. In direct contrast, the head presents a particular anatomical challenge. The abundance of vital structures in the affected region made the prospect of performing fasciotomies in this region daunting. The CT helped to target the guide and minimise the number of incisions required, while also helping to approximate the position of the distorted anatomy. The extension of the emphysema to the cranial cervical musculature observed on the second CT increased concern for development of ataxia and for long-term consequences of the infection such as right laryngeal neuritis/chondritis. Fortunately, following the second fasciotomy procedure and the addition of gentamicin to the treatment protocol, the infection began to resolve, as demonstrated by the slow resolution of the emphysema identified by CT and by improvement of clinical signs and attitude.

As well as aiding in diagnosis, surgical planning and clinical monitoring of the infection, the serial CT examinations were helpful for communication with the owner. The extensive gas bubbles within the soft tissues were easy for the owner to recognise and aided in their understanding of the case. Although not inexpensive, the owner felt the evidence of improvement that the CTs provided was of great emotional value, particularly as visitation of the gelding was not permitted due to the hospital policy instated during the COVID-19 outbreak. The availability of a standing head CT

was fundamental; if CT had required general anaesthesia, the number of examinations performed would have been lower due to the risk of general anaesthesia. If standing CT is unavailable, the authors suggest using serial ultrasonographic or radiographic studies to evaluate the effected anatomy with the understanding of the limitations of these modalities when compared with CT.

In conclusion, this report describes an unusual case of myonecrosis of the right side of the head and cervical region with concurrent sinusitis due to *Prevotella intermedia* and *Peptostreptococcus asaccharolyticus* infection. CT examinations aided in the diagnosis, surgical treatment and monitoring of the horse, and provided a large amount of visual evidence for the owner, aiding in client understanding. The authors suggest using antimicrobial coverage for Gram-negative as well as Gram-positive anaerobic organisms as part of the antimicrobial treatment plan for myonecrosis cases that may have originated from the oral cavity.

Authors' declaration of interests

No conflicts of interest have been declared.

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Authorship

S. Boorman wrote the article. J. Hamersky provided the imaging reports and figures. All authors contributed equally to the diagnosis and management of the case. All authors edited the article and gave final approval.

Manufacturers' addresses

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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: Photographs of cavesson, crank cavesson, flash, crank flash, drop, grackle and Micklem nosebands.

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Review Article

Performance and rideability issues in horses as a manifestation of pain: A review of differential diagnosis and diagnostic approach

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Keywords: horse; pain; poor performance; rideability issues; differential diagnosis; diagnostic approach

Summary

Nonspecific performance and rideability issues are more likely a manifestation of pain in the ridden horse rather than a true behavioural problem. A systematic and thorough investigation focusing on the potential presence of pain-related conditions is thus crucial in horses with such complaints. It can, however, be challenging to determine whether the complaint is indeed related to pain, where the pain is located, and what the underlying cause is. This review describes the challenges of pain recognition in ridden horses and summarises the recently developed ridden horse ethograms that might enable pain to be assessed in an objective, valid and reliable way. Furthermore, the differential diagnosis and diagnostic approach to horses presenting potentially pain-related performance and rideability issues are discussed.

Introduction

In recent years, societal concern about animal welfare has increased, and one frequently discussed topic in the animal welfare debate is the welfare of the ridden horse. Addressing this contentious issue, the International Federation for Equestrian Sports (FEI) has produced a code of conduct for the welfare of the horse that requires all stakeholders to '*acknowledge and accept that at all times the welfare of the horse must be paramount*' and that the '*welfare of the horse must never be subordinated to competitive or commercial influences*' (Fédération Equestre Internationale 2020). The competition in modern equestrian sports is hard, and for horse and rider to succeed, it requires that both rider and horse perform to the best of their ability. Combined with an increased focus on equine welfare from all stakeholders, even subtle changes in performance and behaviour are often recognised and investigated. Performance and rideability issues are thus common presenting complaints in equine practice, and the types of clinical problems that may be encountered include poor performance, subtle lameness, alteration in gait, stiffness, bucking, rearing, unwillingness to work, and/or otherwise resistant or evasive behaviour (Dyson 2010a, 2016a). All of these types of ridden behaviours may be expressions of pain but are unfortunately sometimes ascribed to the horse being 'bad-tempered' (Jonckheer-Sheehy *et al*. 2012; Hall *et al*. 2013; Dyson *et al*. 2018a). However, most horses have a compliant demeanour, leaving only a very small minority of cases to be attributed to a genuine behavioural issue. This emphasises the importance of recognising and investigating all behavioural and performance issues as potential manifestations of pain. The diagnostic investigation can be challenging since the clinical manifestations are often nonspecific and include a broad list of differential diagnoses. The differential diagnosis can be largely divided into conditions causing either musculoskeletal pain, oral pain or visceral pain. The standard diagnostic work-up should always include a thorough medical history and a complete physical examination, which, depending on the clinical presentation, may be followed by an orthopaedic examination, oral examination and/or various diagnostic tests (Dyson 2010a, 2016a, 2016b; Davidson 2015). Cases that remain undiagnosed after a standard work-up should be subjected to further examination focusing on the potential presence of visceral pain associated with various types of internal medical issues (Lindegaard *et al*. 2009). Establishing whether the complaint is indeed pain-related might prove particularly challenging, and the work-up may call for alternative methods and tools for such investigations.

The present review aims to describe objective means of identifying behavioural signs indicative of pain in ridden horses and to discuss potential diagnoses and the diagnostic approach to horses with performance or rideability issues suspected to be related to pain.

Recognition of pain in ridden horses

Pain negatively influences the quality of equine performance and rideability, and impairs the welfare of the ridden horse. Thus, it is of great importance for all stakeholders in the equestrian businesses that equine pain is identified and managed appropriately. The first step towards successful alleviation of pain is the recognition of its presence, which, however, might pose a significant challenge (Gleerup *et al*. 2015; Gleerup and Lindegaard 2016).

The recognition of pain in prey animals, such as the horse, is complicated by the behavioural evolution of prey species to suppress expressions of pain as a survival strategy (Hall *et al*. 2013). Furthermore, the assessment of pain in horses is confounded by the subjective nature of pain resulting in many different manifestations of pain. These challenges contribute substantially to human error when assessing equine pain and increase the risk of equine pain going unnoticed. For instance, subtle performance and behavioural changes in ridden horses are not always recognised by the owners, riders or trainers as a potential manifestation of pain, but may instead be ascribed to either riding or training problems or the horse being 'bad-tempered' (Jonckheer-Sheehy *et al*. 2012; Hall *et al*. 2013; Greve and Dyson 2014; Dyson

and Greve 2016; Dyson *et al*. 2018a). When pain is neglected as a possible cause for why the horse resists commands or does not perform according to expectations, the horse risks being coerced to perform through more intense or punitive training measures (Jonckheer-Sheehy *et al*. 2012; Dyson *et al*. 2018a). Furthermore, when the presence of pain long predates its recognition, it entails the failure of timely initiation of appropriate treatment and thus potential deterioration of the underlying problem (Mullard *et al*. 2017). In order to protect the welfare of the ridden horse, education of the equestrian population to recognise and acknowledge signs of equine pain, and respond to these signs appropriately, is required.

An increased focus on animal welfare has engendered much effort to be invested in the field of objective pain assessment in horses. In furtherance of valid and reliable pain assessment tools, several facial expression ethograms (Dalla Costa *et al*. 2014; Gleerup *et al*. 2015; van Loon and van Dierendonck 2015) and composite face and body ethograms (Bussières *et al*. 2008; Graubner *et al*. 2011; van Loon and van Dierendonck 2015; Gleerup and Lindegaard 2016) have been developed to make pain evaluation in stabled/nonridden horses with various painful conditions as objective and consistent as possible. There is, however, increasing awareness that pain in some cases is only evident during ridden exercise, highlighting the importance of a ridden evaluation during the diagnostic work-up of horses with a suspected pain-related problem. Especially, musculoskeletal pain has been specifically linked to ridden work, as it has often been reported that horses can exhibit lameness or other gait abnormalities when ridden while appearing sound during movement in hand (Dyson and Greve 2016; Dyson 2016a, 2017; Dyson *et al*. 2018a). Other types of pain (e.g. oral pain or visceral pain) could, however, also sometimes be exacerbated by ridden work and thus be less apparent in the stabled/nonridden horse (Christoffersen *et al*. 2007; Pehkonen *et al*. 2019). That being said, the assessment should still include an evaluation of the potential implications of behavioural events outside of the ridden work; chronic pain could, for instance, be expressed as resentment of being tacked up (Dyson 2016a) or as aggression towards humans (Fureix *et al*. 2010). Assessment of pain in ridden horses is complicated by the diversity of pain manifestations related to the underlying clinical problem, the horse's temperament and subjective perception of pain, and discipline in which the horse is used (Dyson 2016a). Furthermore, the accuracy of the subjective assessment of pain in ridden horses is limited since it is prone to experiential bias. Equine veterinarians that are unexperienced and/or have had little training in assessing pain-related behaviour in ridden horses might fail to recognise pain as a cause of performance and rideability issues. Thus, there is a need for an evidence-based understanding of how pain in the ridden horse can be assessed in a valid and reliable way. Recent studies have developed and applied ethograms that could be used to facilitate identification of pain in ridden horses (Hall *et al*. 2013; Dyson *et al*. 2017; Mullard *et al*. 2017; Dyson *et al*. 2018a, 2018b). The composite ethogram developed by Hall *et al*. (2013) describes behavioural features of general pain and pain originating from specific locations that may be expressed in ridden horses (**Table 1**). In continuation hereof, Dyson *et al*. (2018a) developed the ridden horse ethogram that is specifically related to musculoskeletal pain and includes an adaptation of the facial expression of ridden horse (FEReq) ethogram (Dyson *et al*. 2017; Mullard *et al*. 2017) together with further features of general body language and behaviour while ridden (**Table 2**). Providing further validation of the ridden horse ethogram, its application was able to differentiate between lame horses before and after diagnostic analgesia and nonlame and lame horses, although there were some overlap and marked diversity among lame horses in the occurrence of behavioural features (Dyson *et al*. 2018b). Furthermore, a new study by Dyson *et al*. (2019) tested the inter-observer reliability of the ridden horse ethogram and confirmed that veterinarians can, with appropriate training, apply the ethogram with consistency to differentiate between nonlame and most lame horses. These studies accentuate that the application of an ethogram may improve the accuracy of pain assessments in ridden horses by providing veterinarians with a valuable tool for the identification of pain in horses presented with performance or rideability issues, and in turn help them to communicate a potential pain problem in the horse more effectively to their clients. Ultimately, this could help lead to an increased understanding among the equestrian population of signs of pain in the ridden horse which would undoubtedly improve the welfare of many horses.

TABLE 1: Behavioural features of different types of pain in ridden horses (adapted from Hall *et al*. 2013)

Pain type	Behavioural features
General pain	Restlessness, agitation, rigid stance, reluctance to move, fixed stare, dilated nostrils, clenched jaw
Abdominal pain	Vocalisation (deep groaning), kicking at abdomen, flank watching, stretching, dullness, depression
Orthopaedic pain	Weight shifting between limbs, limb guarding, abnormal weight distribution, rotating limbs and abnormal movement, reluctance to move
Head and dental pain	Head-shaking, abnormal behaviour in response to wearing a bit, tilted head carriage

Pain-related causes for performance and rideability issues

Poor performance and other rideability issues can be caused by a myriad of different clinical pain conditions, which can largely be divided into three groups: musculoskeletal pain, oral pain and visceral pain (Jeffcott 1980; Jeffcott *et al*. 1982; Dyson 2002, 2009, 2016a; Christoffersen *et al*. 2007; Franklin *et al*. 2008; Girodroux *et al*. 2009; Lindegaard *et al*. 2009; Anthony *et al*. 2010; Jonckheer-Sheehy *et al*. 2012; Barstow and Dyson 2015). Thus, it is necessary to consider a rather broad and disparate range of differential diagnoses, especially when presenting complaints are nonspecific and subtle (**Table 3**).

The most common cause of performance loss or riding problems in equestrian activities is musculoskeletal problems causing lameness or pain originating from the vertebral column (Jeffcott 1980, 1982; Gaughan 1996; Dyson and Murray 2003; Girodroux *et al*. 2009; Jonckheer-Sheehy

TABLE 2: Behavioural features that can reflect musculoskeletal pain in ridden horses (adapted from Dyson *et al.* 2018a)

Area	Behavioural features
Face	
Ears	Ears rotated back or flat >5 s
Eyes	Eyelids closed or half-closed for 2–5 s, sclera exposed, intense stare for >5 s
Mouth	Mouth opening and shutting repeatedly for >10 s, tongue exposed and/or moving in and out, bit pulled through the mouth on one side
Body	
Head	Repeated changes in head position (up/down), head tilting, head in front or behind of vertical for >10 s, regular changes in head position (tossed or twisted from side to side)
Tail	Tail clamped tightly to middle or held to one side, tail swishing
Gait	
Changes or abnormalities	A rushed gait, irregular rhythm, repeated changes in speed, gait too slow, moves on three tracks, canter repeated leg changes, repeated strike off wrong leg, spontaneous changes in gait, stumbling, toe dragging
Obedience	Sudden changes in direction against rider direction, reluctant to move forward, rearing, bucking or kicking backwards (one or both hindlimbs)

TABLE 3: Pain-related aetiologies to consider in the differential diagnosis of nonspecific performance and rideability issues in horses

Pain type	Differential diagnosis	References
Musculoskeletal pain		
Lameness	Bilateral foot, fetlock, carpal or distal hock joint pain Bilateral proximal suspensory desmitis	Dyson (2002), Dyson (2009), Dyson (2010a)
Back pain	Impinging dorsal spinous processes Osteoarthritis of the thoracic and/or lumbar facet articulations Sacroiliac joint region pain	Jeffcott (1980), Walmsley *et al.* (2002), Dyson and Murray (2003), Girodroux *et al.* (2009), Barstow and Dyson (2015)
Muscle pain	Muscle cramps Muscle strains Muscle trauma Sporadic exertional rhabdomyolysis Chronic exertional rhabdomyolysis Chronic exertional myopathies Aorta-iliac thrombosis (TAI)	Brama *et al.* (1996), Rijkenhuizen *et al.* (2009), Valberg (2018), Rijkenhuizen and Pokar (2019)
Miscellaneous	Temporomandibular joint disease	Jørgensen *et al.* (2015)
Oral pain		
Bit and tack-related pain	Oral ulcerations Aggravation of existing dental disorders	Tell *et al.* (2008), Björnsdóttir *et al.* (2014), Cook and Kibler (2019), Pehkonen *et al.* (2019), Uldahl and Clayton (2019), Thomas (2020)
Dental disorders	Soft tissue injuries caused by sharp enamel points Presence of the first premolar teeth Abscessed teeth Periapical infection Dental fractures Periodontal disease Abnormalities of eruption Malocclusions	Griffin (2009), Anthony *et al.* (2010), Bryant (2014), Pehkonen *et al.* (2019), Thomas (2020)
Visceral pain		
Gastrointestinal pain	Equine gastric ulcer syndrome (EGUS) Inflammatory disorders Parasite infestation Intestinal ulceration Intestinal spasms Mesenteric tension Neoplasia Partial obstruction of the intestinal lumen (i.e. sand impaction, adhesions, stricture, intussusception, enterolithiasis or intra-abdominal abscesses)	Vatistas *et al.* (1999), Jonsson and Egenvall (2006), Archer (2008), Franklin *et al.* (2008), Sykes *et al.* (2015), Coté (2019)
Urogenital pain	Referred pain syndrome Ovarian pain associated with impending ovulation Postcastration complications in geldings (i.e. neuroma formation or spermatic cord adhesions)	Cox and DeBowes (1987), Echte *et al.* (2006), Christoffersen *et al.* (2007), Chenier (2008), Lindegaard *et al.* (2009), Dyson (2010b), Weaver (2011)

et al. 2012; Barstow and Dyson 2015; Dyson 2016a). Lameness-associated performance problems are most frequently caused by bilateral foot, fetlock, carpal, or distal hock joint pain or bilateral proximal suspensory desmitis (Dyson 2002, 2009, 2010a). Common causes of back pain that instigate performance problems include impinging dorsal spinous processes, osteoarthritis of the thoracic and/or lumbar articular process articulations, and sacroiliac joint region pain (Jeffcott 1980; Walmsley *et al*. 2002; Dyson and Murray 2003; Girodroux *et al*. 2009; Barstow and Dyson 2015). Another very important cause that is likely to affect equine performance is muscle pain that can be either focal (i.e. muscle cramps, strains or trauma) or generalised (i.e. sporadic or chronic exertional rhabdomyolysis or chronic exertional myopathies) (Valberg 2018). A potentially under-recognised cause of exercise-associated hindlimb muscle pain and lameness is aorta-iliac thrombosis (TAI), which is a progressive vascular disease characterised by thrombus formation of the caudal aorta or iliac arteries and subsequent impairment of blood supply to the large muscles of the hindlimbs (Brama *et al*. 1996; Rijkenhuizen *et al*. 2009; Rijkenhuizen and Pokar 2019). Another musculoskeletal disorder to consider in the differential diagnosis is temporomandibular joint disease, which reportedly may present with nonspecific symptomatology such as obscure performance and riding problems (Jørgensen *et al*. 2015).

Oral pain is also a well-accepted potential cause for performance and rideability issues. Horses are often able to mask signs of oral pain by adapting their eating patterns and behaviour until the underlying disorder becomes too advanced to cope with (Moine *et al*. 2017). However, signs of oral pain may become evident when the horse is ridden, which may be related to the impact of bits and bridles (Thomas 2020). The use of bits might either be the primary cause of oral pain (Cook 2003; Cook and Kibler 2019) or aggravate existing dental problems (Pehkonen *et al*. 2019; Thomas 2020). There is evidence that horses ridden with a bit and bridle have a higher prevalence of oral ulcerations compared with unridden horses and that bit type influences the location and severity of lesions (Tell *et al*. 2008; Björnsdóttir *et al*. 2014). In another study, however, the prevalence of oral lesions did not differ between different types of bit or bitless bridles but was associated with overtightened nosebands (Uldahl and Clayton 2019). There is widespread anecdotal evidence that common equine dental problems (such as soft tissue injuries caused by sharp enamel points, presence of the first premolar teeth, abscessed teeth, dental fractures, periodontal disease, abnormalities of eruption and malocclusions) might cause significant pain and in turn could be linked to impaired performance and occurrence of undesirable behaviours during ridden work (Griffin 2009; Anthony *et al*. 2010; Bryant 2014; Thomas 2020). In accordance herewith, a recent study established a link between bit-related behavioural problems and dental pain caused by periapical infection in cheek teeth of horses (Pehkonen *et al*. 2019). Similar to these findings in horses, studies in human athletes have provided evidence that dental disease had substantial negative impact on their sports performance (Needleman *et al*. 2013, 2016).

Visceral pain, originating from abdominal or pelvic viscera, is the third main type of cause to consider in the differential diagnosis of performance and rideability issues in horses. The gastrointestinal tract is presumably the most frequent source of visceral pain in horses, wherefore this type of abdominal visceral pain has received the most research and clinical attention (Robertson and Sanchez 2010). There are various gastrointestinal problems that may result in chronic intermittent colic and adversely affect equine performance and behaviour. A well-known example is equine gastric ulcer syndrome (EGUS), for which there is evidence of a significant association with poor performance (Vatistas *et al*. 1999; Jonsson and Egenvall 2006; Franklin *et al*. 2008; Sykes *et al*. 2015). The underlying mechanism has not yet been established, but it has been proposed that decreased performance may arise as a direct consequence of the gastric pain per se (Vatistas *et al*. 1999; Andrews 2008; Sykes *et al*. 2015), or potentially because of referred pain that might also cause other types of aversion, such as reaction to the girth (Millares-Ramirez and Le Jeune 2019). There has also been reported an association between EGUS and behavioural changes such as nervousness, aggression and self-mutilation (McDonnell 2008; Sykes *et al*. 2015), why it is reasonable to expect that EGUS may also affect the horse's rideability by causing behavioural problems during ridden work. Other possible causes for chronic abdominal pain related directly to the gastrointestinal tract include inflammatory disorders, parasite infestation, ulceration, intestinal spasms, mesenteric tension, neoplasia and partial obstruction of the intestinal lumen due to, for example, sand impaction, adhesions, stricture, intussusception, enterolithiasis or intra-abdominal abscesses (Archer 2008; Coté 2019). As a direct consequence of the inflicting pain, all of these disorders have the potential to adversely affect performance and rideability. Although less common, chronic visceral pain may also originate from other abdominal or pelvic organs such as the peritoneal cavity, liver, biliary tracts, pancreas, organs of the urinary system and organs of the reproductive system (Archer 2008; Coté 2019). Research is generally lacking in regard to confirmation of a potential association between these causes for abdominal and pelvic pain and the occurrence of performance and rideability issues, but since the pain has an independent impact on performance and behaviour regardless of the underlying cause, such an association is considered very plausible. Of these less common causes, it is especially referred urogenital pain causing hypersensitivity/hyperalgesia in the lower back, flanks and/or hindquarters that have been established as a potential cause of performance and behavioural changes in horses (Christoffersen *et al*. 2007; Lindegaard *et al*. 2009). The phenomenon of referred pain is well-established in human medicine where several specific somatic areas of referred pain have been linked to specific visceral organs, for example epigastric region for the stomach, lumbar region/flank for the urinary tract and lowest abdominal quadrants for the reproductive organs (Giamberardino *et al*. 2010; Kaufman and Jones 2018). This can be explained on the basis of convergence of somatic and visceral afferents on the same secondary neuron within the dorsal horn of the spinal cord, which can cause the brain to misinterpret the visceral nociceptive input as somatic in origin since the nociceptive system is primarily accustomed to somatic inputs (Giamberardino 1999; Dunckley *et al*. 2005; Christoffersen *et al*. 2007; Lindegaard *et al*. 2017). Performance and behaviour problems in mares have also been linked to ovarian pain that occasionally occurs in association with impending ovulation (Cox and DeBowes 1987; Chenier 2008;

Dyson 2010b; Weaver 2011). An example of performance-limiting urogenital problems in geldings is post-castration complications such as formation of painful neuromas at the testicular nerves or painful adhesions of the spermatic cord stump which has been suggested as the cause for inguinal pain and unexplained hindlimb lameness (Echte *et al*. 2006; Bengtsdotter *et al*. 2019).

Lastly, it is important to recognise that behavioural and performance issues are not necessarily related to an underlying clinical condition in the horse, but may be due to a riding or training problem or simply lack of athletic ability, which should also always be taken into consideration in the clinical assessment (Dyson 2010a, 2016a).

Diagnostic approach

Nonspecific performance and rideability issues in horses encompass a broad and disparate differential diagnosis. Navigating the diagnostic challenge and establishing an accurate diagnosis are therefore dependent on the use of a systematic diagnostic approach. Important steps in the process of diagnosing horses with performance or behaviour problems include obtainment of a comprehensive history, performing a complete clinical examination, performing various diagnostic tests, and referring or consulting with other equine clinicians (Davidson 2015; Dyson 2016a, 2016b). When signs are suspected to be pain-related, particular emphasis should be placed on delineating the cause of pain as musculoskeletal, oral or visceral in origin, with focus on ruling out the most common aetiologies before considering more rare causes. **Figure 1** presents the proposed diagnostic methods and tools for the evaluation of pain-related causes of performance and rideability issues in horses.

Musculoskeletal pain is the most common cause for poor performance and rideability issues, underlining the importance of a thorough orthopaedic examination (Gaughan 1996; Dyson 2010a, 2016a, 2016b; Davidson 2015). Gait evaluation is a key aspect of the orthopaedic examination and should include an assessment of the horse moving in hand, on the lunge, and ridden, as well as an assessment of the response to flexion tests (Ross 2010; Dyson 2010a, 2016a). The ridden examination is indispensable, since many performance problems and lamenesses are invariably worse or only apparent when the horse is ridden (Dyson and Murray 2003; Licka *et al*. 2010; Dyson 2010a, 2016a; Dyson and Greve 2016). Ideally, the horse should be assessed ridden by the regular rider in its usual tack, performing the specific manoeuvres or movements with which the rider is experiencing difficulties, in order to achieve complete insight of the presenting complaint (Dyson 2010a, 2016a). The gait evaluation requires a great understanding of the biomechanics of equine locomotion and an ability to recognise low-grade gait abnormalities or other behavioural changes that are a manifestation of pain (Gaughan 1996; Dyson 2010a). This is particularly important since subjective lameness evaluation is prone to experiential bias and has a relatively low inter-observer reliability, especially for horses presenting only mild lameness (Fuller *et al*. 2006; Keegan *et al*. 2010). Recently developed wireless inertial sensor systems that objectively identify and quantify lameness could potentially serve as a helpful complementary tool to detect subtle lameness (McCracken *et al*. 2012; Keegan *et al*. 2013). Findings on the clinical evaluation may raise suspicion of potential pain sources, which can then be investigated further by using diagnostic analgesia techniques (e.g. perineural nerve blocks, intrasynovial joint/sheath/bursa blocks or local infiltration) to truly authenticate and localise the site of pain (Dyson 2010a; Barker 2016; Brown *et al*. 2020). Once the site of pain has been identified, appropriate diagnostic imaging is often required to establish a definitive diagnosis (Dyson 2016a). However, it is important to realise that some anatomical areas are difficult or even impossible to block, sometimes rendering diagnostic analgesia inconclusive. Therefore, in cases where a thorough investigation has led no closer to a diagnosis, a nuclear scintigraphic examination of the horse might be helpful in localising the site of pain. Determining the clinical significance of the results of scintigraphic examination can, however, be challenging, primarily because a negative result does not preclude significant pathology and because increased radiopharmaceutical uptake is not necessarily synonymous with pain (Archer *et al*. 2007; Dyson 2010a, 2016a). The results of scintigraphic examination must therefore be carefully interpreted in conjunction with findings from the clinical examination and other diagnostic tests (Archer *et al*. 2007; Dyson 2010a). In underperforming horses that appear clinically normal, it might also be valuable to assess the response to systemically administered analgesic drugs to try to establish if the complaint is indeed pain-related (Dyson 2010a, 2016a; Gleerup 2019). The concept of 'systemic analgesic testing' has become relatively common within the last 5–10 years and is based on the same concept as diagnostic analgesia used in standard orthopaedic work-up. However, to the authors' knowledge, no studies have investigated or documented the use of systemic analgesic testing for diagnostic purposes, and therefore, its application and interpretation warrant some discussion. Generally, systemic analgesic testing will be applied in horses with a longstanding problem, wherefore it might take time to achieve a response. The authors recommend systemic treatment with flunixin meglumine or meloxicam for 10–14 days prior to concluding that the test was negative. If the performance improves and/or the behavioural problem disappears with systemic analgesia, it is a strong indication that the problem is pain-related. The negative response to this test is, however, still inconclusive, since the type of analgesia, the dosing regimen and/or the duration may be insufficient to alleviate the pain. Performing a neurologic examination is another important part of the work-up since many causes of lameness have both a musculoskeletal component and a neurologic component (Maas 2008). Hence, it is often indicated to perform various neurologic tests that assess strength and proprioceptive functions, such as sway reaction tests and limb placement tests, as well as tests that exaggerate subtle neurologic deficits, such as walking with the head elevated, backing and turning in tight circles (Reed 2003; Furr and Reed 2015). In most cases of musculoskeletal causes of poor performance and rideability issues, blood work will provide ambiguous results, except for cases of recurrent exertional rhabdomyolysis which can be verified by abnormally high concentration of serum aspartate aminotransferase (AST) and increased creatine kinase (CK) after exercise compared with before exercise (Martin *et al*. 2000; Dyson 2010a, 2016b; Valberg 2018).

As mentioned earlier, oral pain can also be a significant cause of poor performance and behavioural changes in

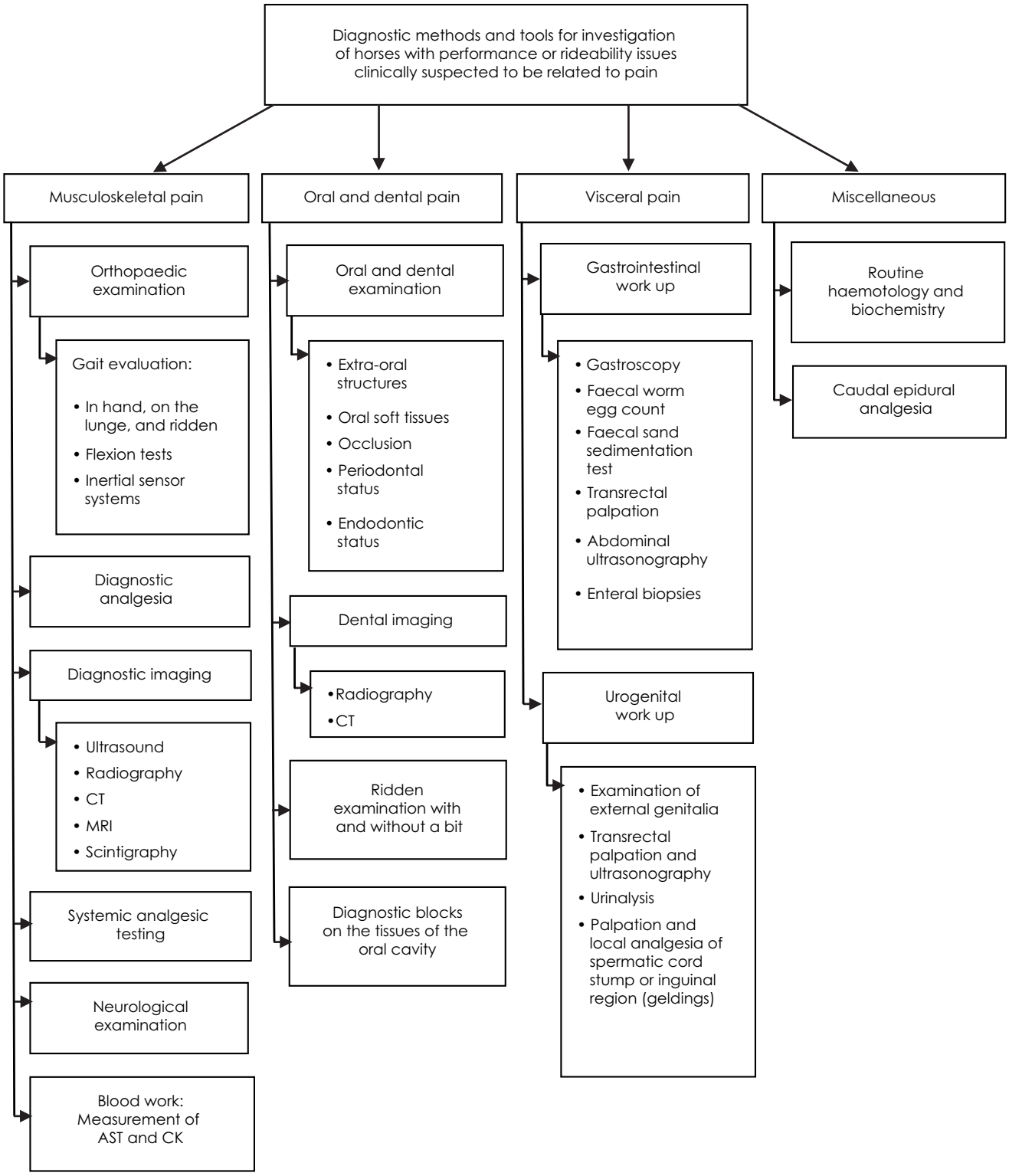

Fig 1: Diagnostic methods and tools for the evaluation of horses presenting with poor performance or rideability issues clinically suspected to be related to pain of either musculoskeletal, oral or visceral origin.

horses, wherefore a comprehensive oral and dental examination may be required in the diagnostic work-up. The identification of oral and dental abnormalities requires a complete evaluation of extra-oral structures, oral soft tissues, occlusion, periodontal status and endodontic status (Henry and Rice 2017). To aid diagnosis of disorders involving the apical regions and reserve crowns, dental imaging such as radiography or computed tomography may also be

indicated (Tremaine and Casey 2012; Henry and Rice 2017). The effect of oral and dental disorders on the horse's performance and rideability can be convincingly established if the treatment proves to be successful in reducing signs, bearing in mind that correction of dental abnormalities may not immediately influence the movement or rideability of the horse (Moine *et al*. 2017). The potential presence of bit-induced pain might be relevant to investigate further by comparing the ridden horse's behaviour with and without a bit (Cook and Kibler 2019). In some instances, it could also be valuable to perform diagnostic nerve blocks on the tissues of the oral cavity prior to a ridden examination to test its results on the horse's performance and rideability (Foster 2013). However, this could potentially cause the rider to have less control of the horse and should therefore be reserved as a diagnostic procedure of last resort and only be performed with extreme caution (Foster 2013).

Since EGUS is a highly prevalent disease in adult horses, performing a gastroscopy is often worthy of inclusion in the standard work-up if history and/or clinical examination does not negate its relevance to the problem. The presence, severity or location of gastric ulcers in horses may, however, not necessarily correlate with the clinical presentation (Sykes *et al*. 2015), wherefore the likely effect of EGUS on performance and rideability first can be fully appreciated after an assessment of response to treatment (Murray 1991; Franklin *et al*. 2008).

A minor fraction of horses with poor performance or rideability issues remain undiagnosed after a standard work-up. These horses merit further examination focusing on the potential presence of visceral pain associated with various other types of internal medical issues, for example disorders involving the gastrointestinal or the urogenital system causing primary and/or referred pain (Lindegaard *et al*. 2009). Such an investigation must be tailored to the individual horse based on clues obtained from the history and the clinical examination. Visceral pain is often diffuse, poorly localised and can be referred to distant somatic sites (Dunckley *et al*. 2005; Christoffersen *et al*. 2007; Lindegaard *et al*. 2009), which may complicate the establishment of a diagnosis. However, certain patterns of referred pain could prove useful in a diagnostic setting as it might be indicative of a specific organ system as the originating site of pain (Kaufman and Jones 2018). For instance, hypersensitivity and/or hyperalgesia in the lower back, flanks and/or hindquarters have been linked to referred urogenital pain in horses (Christoffersen *et al*. 2007; Lindegaard *et al*. 2009). It is reasonable to assume that other visceral pain conditions in horses could also cause referred pain manifested as hypersensitivity/hyperalgesia in specific somatic areas, for example gastric ulcers causing girthiness (Lindegaard *et al*. 2017; Millares-Ramirez and Le Jeune 2019). Thus, referred pain should be considered in horses exhibiting hypersensitivity/hyperalgesia, and specific referral patterns could potentially help point to the site of visceral pain.

Initial diagnostic testing for visceral pain conditions often includes routine haematologic and biochemical blood tests with measurement of inflammatory markers, electrolytes and organ-specific enzyme activities, which may, however, prove unrewarding. The diagnostic work-up of horses with suspected pain-related chronic gastrointestinal disorders may additionally include faecal worm egg count, faecal sand sedimentation test, transrectal palpation, abdominal ultrasonography and/or enteral biopsies (Archer 2008). In cases of suspected urogenital disorders, the basic diagnostic work-up may generally include the examination of the external genitalia, transrectal palpation and ultrasonography of the internal urogenital system, and a urinalysis (Christoffersen *et al*. 2007; Wilson 2007). In geldings exhibiting worsened performance or rideability issues after castration, it may also be relevant to include an evaluation of the potential presence of painful spermatic cord adhesions or neuromas by assessing response to palpation and local analgesia of the spermatic cord stump or inguinal region (Echte *et al*. 2006; Bengtsdotter *et al*. 2019).

The diagnostic work-up of some particularly difficult cases may require alternative diagnostic methods and tools. Even when the most common diagnoses have been ruled out during standard work-up, it does not assure that the presenting problem is not associated with pain. As a means of determining whether the signs are related to pain, caudal epidural analgesia could potentially be used as a valuable complementary diagnostic tool; if the horse's signs are reduced or eliminated by the epidural analgesia, it confirms an underlying pain-related condition localised to the structures analgised by the epidural analgesia. A comparison of the ridden horse's behaviour, performance and rideability before, during and after the epidural treatment should be assessed as objectively as possible, for example by comparing pain scores from an applied ridden horse ethogram (Dyson *et al*. 2018a, 2018b). To function as a diagnostic tool, it is required that the epidural drugs do not affect mentation or locomotor function; such side effects will complicate the assessment of analgesia-related improvements of performance and rideability and cause a potential hazard for the rider, thereby dismissing it as a safe and valuable diagnostic tool. Epidural co-administration of 0.1 mg/kg methadone and 0.1 mg/kg morphine diluted with saline to a total volume of 4.4 mL/100 kg has shown great potential for diagnostic use as it provides efficient analgesia at the coccygeal, perineal, sacral, lumbar and thoracic regions without accompanying adverse effects on mentation and locomotor function (Kjærulff *et al*. 2021). Due to the extensive regional analgesia obtained, many internal medical issues causing visceral pain, as well as some causes of musculoskeletal pain, are likely amenable to epidural administration of methadone and morphine. Thus, epidural analgesia could prove useful in confirming the presence of an underlying pain-related disorder in difficult cases of poor performance or rideability issues, where a comprehensive investigation has led no further to a diagnosis or where diagnostic analgesia cannot be performed, either because the horse's temperament does not allow it or because the source of pain is inaccessible. The diagnostic potential of epidural analgesia in equine medicine is intriguing but is still an area that requires further research into its role in the work-up of horses presented with performance or rideability issues before implementation.

Discussion and conclusion

As described, changes in horses' ridden performance or behaviour are more often caused by various pain-related conditions than attributed to true behavioural problems. Failing to recognise and investigate performance or rideability issues as potential manifestations of pain thus constitutes a major threat to ridden horses' health and

welfare. Recognition of pain in ridden horses can be challenging, but the quickly evolving field of equitation science holds great promise for facilitating pain recognition by means of recently developed ethograms (Hall *et al*. 2013; Dyson *et al*. 2018a). When pain is suspected as the underlying cause of nonspecific performance or rideability issues, the further investigation requires consideration of various possible musculoskeletal, oral and visceral pain conditions. While many underlying pathologic conditions may be relatively straightforward to diagnose when paying careful attention to the history and following a systematic diagnostic plan, there also exist cases that remain undiagnosed after a standard work-up. These cases require that the clinician carefully combines the information retrieved from the history, the understanding of the specific demands of the relevant discipline, and what that specific horse cannot or will not do with a deep knowledge of anatomy and biomechanics in order to imagine which anatomical areas and pathologic processes might be involved. We believe that many causes of pain and poor performance described in humans may also exist in horses. Therefore, successful diagnosis in difficult cases with rare aetiologies requires that the clinician is open-minded to new and unconventional diagnostic approaches while still adhering to a systematic diagnostic approach focusing on ruling out the most common aetiologies before considering more rare ones. We hope that this review will provide useful inputs to the, at times, complex challenges associated with the interpretation and investigation of performance and rideability issues in horses.

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