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EQUINE VETERINARY EDUCATION

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The official journal of the
American Association of
Equine Practitioners, produced
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'Like having another truck in the practice': A Q&A with Dr. Mike Pownall
on implementing telemedicine in your practice

Surgical correction of entrapment of the large colon and caecum through
a mesoduodenal rent with standing laparoscopic repair in a mare

Comparison of visual lameness scores to gait asymmetry in racing
Thoroughbreds during trot in-hand



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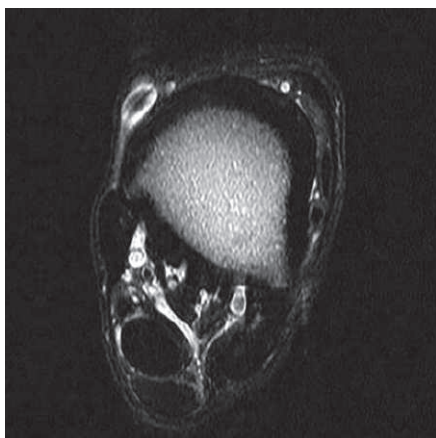
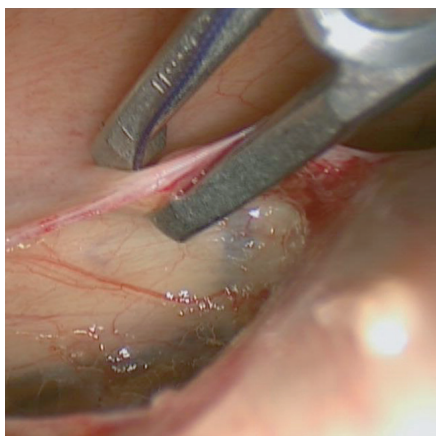
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American Association of Equine Practitioners

4033 Iron Works Parkway
Lexington, KY 40511
TEL (800) 443-0177 • (859) 233-0147
FAX (859) 233-1968
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Address advertising inquiries to Dana Kirkland
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'Like having another truck in the practice'

A Q&A with Dr. Mike Pownall on implementing telemedicine in your practice



Dr. Mike Pownall

With the phrase “social distancing” now firmly entrenched in the vernacular, the COVID-19 pandemic could serve to create increased awareness and adoption of telemedicine in the equine veterinary profession.

The AVMA defines telemedicine as use of a tool to exchange medical information electronically from one site to

another to improve a patient's clinical health status.

Examples include using Skype or a mobile app to communicate with a client and visually observe the patient for a post-operative follow-up examination and discussion. It is important to remember that telemedicine should be conducted within an existing Veterinarian-Client-Patient relationship and in compliance with the laws and regulations within the state in which one is licensed to practice.

Among the equine practices already employing telemedicine as a component of patient care is McKee-Pownall Equine Services near Toronto, Ontario. Co-founder Dr. Mike Pownall recently took time to discuss what he has learned from his telemedicine experience and offer tips to those thinking of getting started.

Which services in equine practice have you found to be well suited for telemedicine?

I look at telemedicine almost like having another truck in the practice. It's another means to reach our client. In our practice, the areas I've found telemedicine to be most effective are:

- Seeing gait abnormalities on videos of horses in motion, either at the home farm or at a competition.
- Doing progress checks of something I've already seen—maybe we sent the client home with instructions but it's been difficult or cost-prohibitive for them to ship back in, so they send us a video to look at it or we can do a livestreaming event.
- Consulting with other vets in the practice. Maybe an associate is at a farm and there's a mystery lameness that we all want to have a look at it. This is a great example of how a senior clinician can tag team with a junior clinician on a case in a live telemedicine scenario.

What situations, in your experience, are not suited for a telemedicine consult or evaluation?

Whenever we have to do a physical exam or anything that requires our hands being on the horse to assess it or to auscultate lungs or heart, telemedicine just can't help us. Our best digital tool is our fingers; if we can't use them, it's hard to be really confident in what you're assessing.

For a practitioner who has never used telemedicine with clients, how should he or she get started?

I think for somebody just starting, if they have an iPhone, they can just FaceTime, which is a great intro. The person on the other end can just show the horse in action, and then the vet and the trainer or owner can have a conversation. I think FaceTime is easiest.

As a practice gets more comfortable with it and they want to record what they're doing as part of the medical record, then they may want to look at Skype or Zoom. Zoom is a fantastic technology that we've been using. The ability to record is huge, the sound quality is amazing, and you can have a number of people on the call. Let's say you're doing a pre-purchase exam or maybe the scenario is a trainer at the farm is showing the horse off, the owner who is elsewhere can be on the call, and the vet can be there—so all three people can be on and you are able to record the examination so you have it as part of your medical records. It's just very easy to have that interaction with a client on a case, charge them appropriately and then save it to the medical record.

I think this is an opportunity for us to really demonstrate the value of our time and knowledge.

How do you save/archive the photos or messages that a client sends you about a case?

If it's an iPhone, you can save to your photos library and then just send the photos to somebody in the office who can collect and upload them to the patient file. Veterinarians can really get inundated with that stuff, so having somebody in the office who can manage it or be the quarterback for all the veterinarians makes it easier.

How do you bill for a telemedicine call? Do you have a different fee structure?

My attitude is all we sell as veterinarians is our time and our knowledge. I recommend charging what you charge for an exam. I don't think you should be discounting it. If we're taking 20 minutes to look at a horse and discuss the options with a client in terms of a progress exam, we could be spending that time on the road—as equine practitioners, we have so much windshield time we cannot bill for.

I think we are in a position like with dentistry years ago when a lot of vets said I don't want to be bothered with dentistry but all of a sudden we realized it was something we needed to add to our portfolio of services. We were scrambling. I think we're facing a very similar scenario now. It's sort of casting a reset to how we're doing things, so it's the perfect opportunity to start talking about telecommunications and the price we charge for it.

continued on page IV

Q&A with Dr. Mike Pownall, *continued*

On a phone consult, one of the things we try to do is bill it on a 10-minute increment. Then it's really up to the client with how detailed they want to get. In general, I think what happens—and it's just a practice management challenge—is we have a hard time saying no to clients, and what should've been a 5- or 10-minute phone conversation ends up being 20 minutes and we're not really charging for it. I think if we're trying to charge for the knowledge we have, bill it in blocks. This is when staff training comes in.

Are there any lessons learned from your telemedicine experiences that you want to share?

A couple of years back, I was on call for a horse show. I received a call around 10 p.m. about a dark bay horse that got a cut in a fleshy area just above the hock. I asked the owner to send me a picture, which he did. I looked at it and it was literally just an abrasion, a flesh wound. I told him I could come out now but I'd have to charge an emergency fee; or one of my associates would be on-site in the morning and could look at it. I was comfortable telling him he didn't need me to look at it. My associate

looked at it the next morning. When I talked to him later and asked if it was just an abrasion, he said no, it was a penetrating wound that went in about 3 inches and he had spent a bit of time flushing it because there was debris in there.

This really highlighted to me the dangers of relying only on 2-dimensional images; we don't have that perception of what really is going on there. It's a very flat perception often hindered by shadow, hair coat, and color of the horse. I was mortified that I missed it because, on the surface, it looked so obvious, but in reality, there was a lot more going on. Lesson learned. Don't rely on photos in those situations.

Any final thoughts?

I think this is an opportunity for us to really demonstrate the value of our time and knowledge. The convenience factor is huge—a client doesn't have to wait, they're not paying a call fee, we don't have to drive—so absolutely charge at least what you'd charge to do the equivalent examination.

Manage the COVID-19 pandemic with an AAEP assist

As the COVID-19 pandemic continues to spread throughout much of the world at press time for this issue, the AAEP in mid-March added a COVID-19 resources page to its website to help members stay current with changing federal and state health recommendations that may affect veterinary practice.

Resources on the page are updated as necessary and include a variety of information to help you and your practice navigate these challenging and uncertain times:

- Tips to mitigate the risk of exposure during client interactions
- A sample client letter from Grand Prix Equine

- Links to resources and information from the Centers for Disease Control and Prevention and the AVMA
- Equine Disease Communication Center resources
- A list of products effective against COVID-19 from the American Chemistry Council
- Telemedicine resources, including tips on how to implement

If you have a question about COVID-19 as it relates to your practice, contact Keith Kleine, staff liaison to the Infectious Disease Committee, at kkleine@aaep.org or (859) 233-0147.

Keep learning with free convention videos

While COVID-19 restrictions have affected in-person learning, the AAEP is providing members with complimentary access to the online video recordings of all AAEP Convention sessions from 2012-2019.

Although viewing these video sessions does not qualify for CE credit, it will help veterinarians and students stay current on best practices and new research in equine medicine as well as help maintain some semblance of normality as we try to navigate these unusual times.

Access the recordings at aaep.digitellinc.com/aaep/login. If you do not already have a Digitell account, you will be asked to establish one and select a password. Click on "Archived Sessions" to view the video options.



5 things to know about AAEP this month

1. Access resources to help you and your practice stay current with fast-changing federal and state health recommendations during the COVID-19 pandemic at aaep.org/resources/covid-19-resources-veterinarians.
2. The AAEP has re-established document retrieval services for members seeking veterinary articles and mediated database searches. Learn more at aaep.org/members/document-retrieval-service.
3. Registration is open at aaep.org/meetings for the Summer Focus Conference & Labs, featuring tracks devoted to Podiatry and Sport Horse Pre-Purchase Exam.
4. Graduate students, fellows and residents have until June 1 to submit grant proposals for up to \$20,000 in research funding from The Foundation for the Horse.
5. With its 2020 allotment, the Unwanted Horse Veterinary Relief Campaign has provided more than 39,000 doses of core vaccines for horses in need since its inception.

Updated guidelines for veterinarians working horse shows now available



The AAEP has published a revised edition of the *Veterinarian's Guide to Equestrian Competition Official Duties*, which details best practices and protocols for practitioners working in an official capacity at sanctioned horse shows.

The comprehensive set of guidelines includes modifications recommended by the Performance Horse Committee. The PDF document defines the roles and responsibilities of competition veterinarians; presents a 14-point list of guidelines to follow; and provides guidance on biosecurity planning, treatment of acutely injured horses, recommended veterinary equipment and medications to have on hand, lameness grading scale and protocols for examining a collapsed or fallen horse.

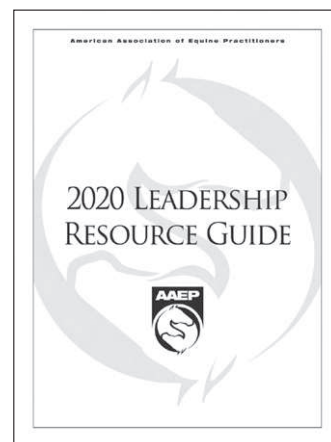
The guidelines are accessible at aaep.org/guidelines/competition-duties-veterinarians and on the AAEP's Publications App, available free by searching "AAEP Publications" at the App Store or Google Play.

View ethical guidelines and more in *Leadership Resource Guide*

The AAEP's 2020 *Leadership Resource Guide*, which contains the AAEP's Ethical and Professional Guidelines, council and committee listings, and other information that appeared in the front section of the discontinued membership directory, is now available on the AAEP's website and Publications App.

The handy 44-page guide, available as a PDF, also includes listings of the board of directors, staff, award recipients, student chapters and AVMA representation, along with a compendium of equine and veterinary organizations. AAEP's disciplinary procedures, articles of incorporation and bylaws are also presented.

The *Leadership Resource Guide* is accessible at aaep.org/newsroom/publications and on the AAEP Publications App. As a reminder, a member lookup feature that allows you to search the AAEP's membership database by name is also available on the app and at aaep.org/dashboard/directory.



AAEP re-establishes document retrieval services benefit

Without institutional support for accessing veterinary literature, the road to discovery often leads to detours and dead ends. Whether seeking a specific article to assist with a case or simply following a trail of medical curiosity, you can now enlist the help of the AAEP, which has re-established document retrieval services for members at no cost.

Request a mediated database search on a particular veterinary topic by contacting Megan Gray, member concierge, at membership@aaep.org.

For copies of articles, book chapters and conference papers, email membership@aaep.org and include the following required information:

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New EVE podcast features interview with Dr. Sue Dyson



In the latest episode of the *Equine Veterinary Education* podcast, Dr. Sue Dyson discusses her paper, "An investigation into the occurrence of, and risk factors for, concurrent suspensory ligament injuries with hindlimb proximal suspensory desmopathy." The paper is accessible at <https://beva.onlinelibrary.wiley.com/doi/10.1111/eve.13187>.

The bottom line: age, bodyweight:height ratio and breed influenced the risk for concurrent lesions of the SL ligament. Further prospective studies in young horses are warranted. Download or listen to the 29-minute episode at equineveterinaryeducation.podbean.com.

UHVRC distributes 7,000 core vaccines to horses in need



A Place for Peanut Equine Therapy and Rescue, a Cypress, Texas, nonprofit horse sanctuary whose rescues are predominantly miniature horses, is among 216 nonprofit equine rescue and retirement facilities to

receive free vaccines in 2020 through the Unwanted Horse Veterinary Relief Campaign (UHVRC).

In its 12th year of partnership between the AAEP and Merck Animal Health, the UHVRC provided 7,000 doses of core vaccines to protect horses from eastern equine encephalitis (EEE), western equine encephalitis (WEE), equine rhinopneumonitis (EHV-1 and EHV-4), influenza, tetanus, rabies and West Nile Virus. Since its inception, more than 39,000 doses of core vaccines have been distributed to protect horses in need.

"We are run on 100% donations and volunteers so receiving vaccinations for our 20-plus rescue horses is a huge savings for us and ensures our horses are adopted out healthy," said Megan Cardet, founder and owner of A Place for Peanut. "This donation is a huge blessing!"

Dr. Kurt Heite, of Brazos Valley Equine Hospitals, coordinated the facility's application for free vaccines. The annual application deadline is Jan. 31. Learn more at uhvrc.org.



"Thor," a 2-year-old Belgian described as "the biggest teddy bear who will make a great therapy horse or pet," is among the rescues at A Place for Peanut to receive core vaccines through the UHVRC.

Employing a somatic approach to trauma healing

By Aimee M. Eggleston Ahearn, DVM

Many of us experience trauma in our lives: the death of a parent, child or partner; sexual, physical or emotional abuse; natural disasters; or childhood trauma. I lost my father in 2007 to an aggressive cancer; I almost lost my husband to a bicycling accident 10 years later. These traumas have impacted my family and I directly, intensely and in ways subtle and almost unknowable. Somatic therapy has helped to minimize the effects of my traumas.

In November 2017, while enjoying a couple of child-free days with my husband, Tim, at the AAEP Annual Convention in San Antonio, Texas, my world came crashing down. I was almost completely suffocated in the wake of a horrible trauma that had left Tim, father of our 7-year-old daughter, partner in our equine veterinary practice and the love of my life, fighting for his life. He had gone for a bike ride, literally an everyday occurrence, and never came back. He texted me throughout his 70-mile ride, the last time with about 25 miles to go. The next time I saw him, he was fighting for his life in the intensive care unit at the region's Level 1 trauma center, University Health Center. The next time he could communicate with me was two days later, weakly writing on a dry erase board.

We “made it through” the life-threatening days in the ICU and the months of physical healing at home. Ultimately though, my family, Tim and I were on our own to restart our normal, routine lives. We had to care for our daughter, run a household, run our business and see patients. I am the only doctor in our veterinary practice: if I don't work, our business doesn't get paid. Now, on top of usual financial burdens and worries, there were daunting health care bills to pay. I thought I was “OK,” that I was “strong.” I felt that I had no choice. I told myself that I was fine, pushing away the truth that I wasn't. I could and would plow through. I had done it before when I suddenly lost my dad to a horrible and painful lung cancer 10 years prior.

Despite my dogged, stubborn mindset, Tim and I came to recognize that I needed help. But how do you get help and from whom? A significant failure of our healthcare system is that once a disease is diagnosed or injury treated, the patient is often left to navigate alone. We felt alone. I got the help I needed because I was lucky. My dentist reached out to me during a regular cleaning appointment in the spring of 2018. She knew of Tim's accident and, on her own, took the time to tell me about a mental health professional she had used. This doctor utilized techniques of



Dr. Aimee Eggleston Ahearn

somatic therapy, namely one called Eye Movement Desensitization and Re-processing (EMDR). I made an appointment not because I knew anything about EMDR, but because I knew I was struggling.

Somatic therapy studies the relationship between the mind and body regarding the psychological past. Past traumas disrupt the autonomic nervous system (ANS); therefore, trauma symptoms are the effects of instability of the ANS. According to somatic psychologists, our bodies reflect past traumas in our body language, posture and expressions. In some cases, past traumas manifest as physical symptoms like digestive, physical, sexual or immune dysfunction; in other cases, as mental health symptoms like depression, anxiety and/or addiction. The goal of somatic therapy is to aid the ANS' return to homeostasis in the aftermath of a traumatic event.

I am pleased to report somatic therapy has helped me. Specifically, I feel less occupied and burdened with the trauma and experience significantly less stress and anxiety thinking and speaking about it. While my husband's accident and my father's death will remain large parts of my life, somatic therapy has meant that these traumas no longer run my life.

If you need help dealing with a personal trauma or simply want to learn more about somatic therapy, the Wellness area of the AAEP website offers a two-part article series entitled “A Somatic Therapy Approach to Well-Being” authored by Trudi Howley, MS, SEP, CPC a somatic psychotherapist and lifelong equestrian. Access the articles at aaep.org/wellness/emotional-social-wellness.



Dr. Eggleston Ahearn and her husband Tim own Eggleston Equine LLC in Woodstock, Conn. She serves on the AAEP's Wellness Committee.

Podiatry, sport horse pre-purchase exam in focus at summer meeting

SUMMER FOCUS

Conference & Labs

Learn to effectively manage the common problem of foot-related lameness or raise the standard of your pre-purchase examination for sport horse clients through lectures and field sessions at the AAEP's Summer Focus Conference & Labs.

The conference will be held July 27–29 in the heart of horse country—Lexington, Ky.—at the Embassy Suites hotel, with field sessions at Rood & Riddle Equine Hospital and Spy Coast Farm. Profiles of each track follow:

TRACK 1 Podiatry

Veterinarian-farrier collaboration is essential for successful treatment of many of the causes of foot-related lameness. However, both professions face an inherent learning curve with therapeutic trimming and shoeing: besides the need to understand the complexities of hoof biomechanics and the effects of interventional methods on the foot structures, much of the information on the topic remains subjective, controversial or unclear.

During the Podiatry track, a small but elite team of veterinary podiatrists, sports medicine experts and farriers will bridge the information gap so that veterinarians and farriers not only share a similar level of practical knowledge but can collectively apply that knowledge to manage common to complicated podiatry cases.

Practical takeaways include:

- Integrating biomechanics, locomotion and gait analysis into trimming/shoeing decisions
- Using radiographs to assist with trimming/shoeing
- Utilizing a digital venogram to treat and manage laminitis
- Managing foot soundness of performance horses and Thoroughbred racehorses
- Strengthening the veterinarian-farrier relationship

The meeting will conclude with a day of demonstrations at Rood & Riddle Equine Hospital during which the experts will teach podiatry techniques on live horses, advancing your understanding of:

- Venograms/tenotomy laminitis
- Quarter crack repair and glue-on shoes
- Performance horse shoeing (negative palmar angle)
- Racehorse shoeing

Presenters:

Veterinarians:
Dr. Hilary Clayton
Dr. Scott Morrison
Dr. Ric Redden

Farriers:
Ronald Aalders
Stuart Muir
Mitch Taylor



Summer Focus Conference & Labs Platinum Sponsor:



CE Hours: 26.5

TRACK 2 Sport Horse Pre-Purchase Exam

A proper and thorough pre-purchase exam is fundamental to providing relevant 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?

During the Sport Horse Pre-Purchase Exam track, 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.

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

The meeting will conclude with an optional half-day of wet labs at Spy Coast Farm that will refine your examination skills on live horses at stations devoted to:

- Progression of an effective pre-purchase exam
- Image acquisition of common areas of difficulty
- Application and evaluation of dynamic gait analysis
- Cardiac evaluation at rest and after exercise

Presenters:

Veterinarians:

Dr. Kent Allen	Dr. Mary Durando
Dr. Mark Baus	Dr. Kit Miller
Dr. Stephanie Bell	Dr. Rick Mitchell
Dr. Jeff Berk	Dr. Steve Reed
Dr. Vern Dryden	Dr. Brett Woodie

Others:

Mike Casey (attorney)
 Anna Ford (New Vocations
 Racehorse Adoption
 Program)
 Mike Meuser (attorney)



CE Hours: Lectures – 15; Lectures + Labs – 23

Attendance is limited so register early

The AAEP-member registration rate is:

- \$650 for the Podiatry track, which includes both lectures and live demonstrations
- \$550 for the Sport Horse Pre-Purchase Exam track lectures and \$200 for the optional wet labs

Wet lab attendance is capped at 48 participants while lecture sessions for both tracks are limited to 100. All spots will be filled on a first-come basis.

Register for the meeting and book your hotel room at aaep.org/meetings.

AAEP-member researchers awarded grants from Grayson-Jockey Club



Dr. Sherry Johnson

Ten AAEP members are among the equine veterinary researchers who recently received project funding from Grayson-Jockey Club Research Foundation. Among the 10 is Colorado State University Ph.D. student Dr. Sherry Johnson, who received the Storm Cat Career Development Award for her project, "Validation of Blood Flow

Restriction Training in Horses." The award is intended to promote development of promising investigators through a one-year salary supplement of \$15,000.

Other members to receive research funding are:

Dr. Teresa Burns – *AMPK Agonist Combination Therapy & ID in Horses*

Dr. Noah Cohen – *Anti-Pnag Plasma for Preventing R. Equi Foal Pneumonia*

Dr. Laurent Couëtill – *Asthma, Performance and Omega-3s in Racing Thoroughbreds*

Dr. Sushmitha Durgam – *SDFT Adaptation in Thoroughbred Racehorses*

Dr. David Freeman – *Effect of NSAIDs on Anion Transport in the Equine Colon*

Dr. Heidi Reesink – *Bisphosphonates and Fatal Musculoskeletal Injury*

Dr. Lauren Schnabel – *Enhancing the Efficacy of MSCs for Tendon Healing*

Dr. Mats Troedsson – *Protein Based In Vivo Diagnostic for Endometrial Biofilm*

Dr. Stephanie Valberg – *Novel Treatment for Recurrent Exertional Rhabdomyolysis*

Visit <https://tinyurl.com/gjcfund20> for more information, including descriptions of each research project.

Benefit: Enlist colleagues' expertise in AAEP's online communities

Whether seeking advice on a difficult case, perplexed by an ethical dilemma, or wanting to offer support or guidance, you can connect, engage and draw upon the collective expertise of the membership through the AAEP's online communities.

One component of this complimentary benefit of your membership is the Rounds, which are online forums centered on specific topics and an ideal way to exchange ideas and share knowledge with colleagues around the world. Members may subscribe to any of the following Rounds:

Business Education	Podiatry
Complementary & Alternative Veterinary Medicine	Public Auction
Dentistry	Purchase Exam
Equitarian	Racing
Ethics Talk	Reproduction/
Infectious Disease	Perinatology
New Practitioners	Solo Practitioner
Performance Horse	Wellness & Family Life

You may also subscribe to the General Discussion List, which is open to all topics of interest. To join any of the discussions, visit communities.aaep.org/home.



In addition to the Rounds, the AAEP Member Vet Talk community on Facebook is another forum through which you can solicit or offer case advice or simply share content relevant to equine veterinary medicine. More than 1,000 members participate in AAEP Member Vet Talk. To join this AAEP members-only community, simply search for the group on Facebook.

Residents and grad students: Apply for research funding by June 1

A year after awarding nearly \$100,000 in support of exceptional science being conducted by five up-and-coming researchers, The Foundation for the Horse is again accepting grant proposals from AAEP-member graduate students, fellows and residents for up to \$20,000 in funding for the study of key diseases and disorders affecting equine health.

Pressing research topics and areas of special interest include musculoskeletal, gastrointestinal and metabolic disease; laminitis; factors to improve racing safety; and development of new technologies (i.e., stall-side tests). However, research applications on any topic will be considered for funding, and all investigators are encouraged to apply.

Pilot studies or preliminary studies that are part of a major study or which will lead to a major project are of particular interest; small stand-alone projects will also be considered.

Grant proposals must be received by June 1. Additional information, including application instructions, requirements and selection criteria, is available at foundationforthehorse.org/graduate-student-fellow-resident-research-grants.



Awarded researchers in 2019 included Dr. Aileen Rowland for her project, "Understanding the role of MHCI compatibility in equine allogenic mesenchymal stem cells."

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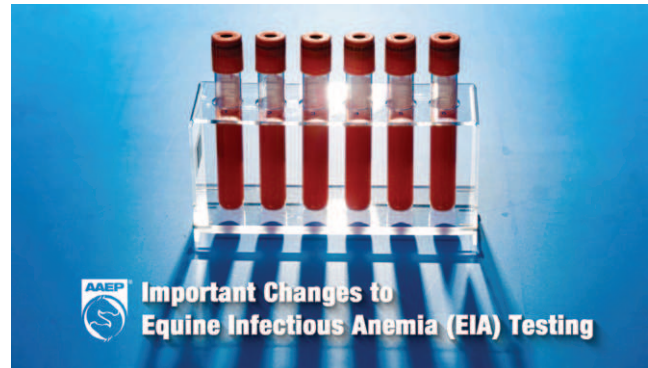


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Visit jobs.aaep.org

USDA APHIS implements new EIA testing requirements

The U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS) Veterinary Services has implemented new requirements for approved laboratories conducting Equine Infectious Anemia (EIA) Testing. Following are changes that affect the submitting veterinarian:

- Laboratories can only accept samples from federal accredited Category II Accredited Veterinarians. Laboratories are to confirm accreditation status prior to testing the sample. To check your accreditation status, visit aphis.usda.gov/aphis/ourfocus/animal-health/nvap/ct_areavet and click “Check My Accreditation Status.” The system will report your Category, Renewal & State(s) Authorized.
- By April 15, 2020, veterinarians must use the current federal approved forms or approved systems (i.e. VS Form 10-11 dated Feb 2018 or VSPS e10-11 form). Contact your local animal health official to obtain current forms.
- All fields in the form are required to be filled in or indicated as N/A. Laboratories are to reject incomplete forms and not test the sample.
- At the discretion of the laboratory, amended forms can be processed as long as they are received within 30 days of blood draw date, all previous distributed



copies are returned to the laboratory and change of ownership is not one of the items being amended.

- Labs are required to refer all non-negative test samples to the National Veterinary Service Laboratory for confirmatory testing. The ELISA test is sensitive and some false positive results are expected. The required testing at NVSL may delay results up to 5 days, so clients should be advised to plan accordingly.

Visit www.aphis.usda.gov/animalhealth-eia for more information; in the dropdown, choose “EIA Documents and References.”

AAEP Educational Partner Profile: Merck Animal Health

With a commitment to the Science of Healthier Animals®, Merck Animal Health works for you—and for horses. Backed by more than 70 years of innovation, the equine vaccine portfolio is known for its quality and safety, featuring the Prestige® line of vaccines with updated influenza strains. Veterinarians and horse owners trust the Merck Animal Health pharmaceutical line, headlined by Panacur® (fenbendazole), Banamine® (flunixin meglumine), Regu-Mate® (altrenogest) and Protazil® (1.56% diclazuril) antiprotozoal pellets.



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- More than 35,000 doses of life-saving vaccines donated to horses in rescue through the UHVRC, a 12-year partnership with AAEP
- Vet Story Night, which has raised more than \$55,000 since 2017 for The Foundation for the Horse at the AAEP Annual Convention

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Highlights of recent clinically relevant papers

Standing MRI for planning surgical fracture repair

In this retrospective case series, Martin Genton and colleagues in France reported the feasibility of standing MRI (sMRI) and the value of sMRI in surgical planning for repair of limb fractures in the horse.

Medical records of 31 horses with preoperative sMRI were reviewed for fracture type, application of a polyester cast, sMRI sequences performed, technical variables, and image quality. Fracture geometry and concomitant lesions were compared between sMRI and radiography. The relative value of sMRI with regard to surgical planning was classified as minor (sMRI did not provide additional findings), intermediate (additional lesions found or slight modification to surgical plan), or major (sMRI led to significant alterations in surgical plan).

Standing MRI provided good studies in all horses and was classified as having major relevance in 12/31 horses, intermediate relevance in 14/31 horses, and minor relevance in 5/31 horses. Application of a polyester cast seemed to improve comfort without appreciable loss of image quality.

The authors concluded that standing MRI can be considered as an adjunct to plan the repair of equine fractures, and that a polyester cast does not impair image quality.

Intraoral cheek tooth extraction

In this study Benjamin Dubois and colleagues in the UK described clinical and computed tomographic (CT) findings for horses and ponies undergoing intraoral cheek tooth extraction. Potential associations between these features and outcome of the procedure were also assessed.

Horses and ponies that had undergone CT and intraoral extraction of ≥ 1 cheek tooth with standing sedation were identified by searching medical records. Signalment and clinical variables were recorded, and CT scans were reviewed. Anatomic location and measurements of affected teeth; abnormalities of the periodontium, pulp, infundibula, roots, and tooth shape; fracture presence and type; presence of sinusitis; and affected sinus cavities were assessed. Intraoral extraction outcome was recorded as successful (complete removal of the tooth in one intraoral extraction procedure) or unsuccessful. Associations between clinical or CT findings and outcome were assessed using univariable and multivariable logistic regression analyses.

A total of 89 cheek teeth (80 maxillary and 9 mandibular) from 74 horses and 7 ponies were included in the analyses. Sixty of 89 (67%) cheek teeth were extracted successfully (56/80 [70%] maxillary and 4/9 [44%] mandibular cheek teeth). On multivariable regression analysis, only presence of a simple fracture (vs no fracture) was associated with outcome; odds of successful intraoral extraction were significantly lower when this feature was present.

Most extractions of cheek teeth in the study sample were successful, and results may be useful for practitioners in refining cheek tooth extraction plans for horses and ponies. Further studies are required to assess whether specific CT findings can be used to predict the outcome of intraoral extraction in equids.

Standing carpal sheath arthroscopy

In this experimental study Ludovic Miagkoff and Alvaro Bonilla from the University of Montreal, Canada, investigated the use of a needle arthroscope for diagnostic tenoscopy of the carpal sheath in standing horses.

Carpal sheath tenoscopy with a 1.2-mm-diameter needle arthroscope (65 and 100 mm long) was performed on six cadaveric limbs, followed by tenoscopy with a 4-mm arthroscope through a standard proximolateral approach. Unilateral standing carpal sheath tenoscopy was performed in six healthy sedated horses with a 65-mm-long needle arthroscope. A custom-made splint and base were used to maintain the limbs in flexion during the procedure. Degree of tenoscopic evaluation, safety, horse tolerance, and complications were recorded.

Visibility at the most distal aspect of the sheath was absent for the needle arthroscopes vs a standard arthroscope. The manoeuvrability with a 65-mm needle arthroscope was excellent and allowed exhaustive visualisation of the proximal region of the carpal sheath in cadaveric limbs and standing horses (6/6). However, visualisation of the intertendinous recess was partial in most horses (4/6) vs cadavers (complete in 6/6) because of remaining flexor tendon tension in standing horses. No major complications were encountered.

Standing carpal sheath tenoscopy allowed a safe and thorough evaluation of most structures in the proximal region of the sheath and offers an alternative diagnostic technique. Horses with unrewarding results after traditional imaging or that require an accurate diagnosis before treatment may benefit from this alternative procedure.

Chondromalacia of the medial femoral condyle

This retrospective cohort study by Alice Croxford and colleagues in the UK aimed to document the occurrence and significance of chondromalacia of the cranial medial femoral condyle (CMFC) in adult horses with stifle lameness.

Medical records and arthroscopic surgical videos were reviewed from horses with unilateral or bilateral lameness localised to the stifle that subsequently underwent arthroscopy of the cranial medial femorotibial joint at a single equine referral hospital between 2009 and 2014. The arthroscopy video recording for each was reviewed by three board-certified surgeons for the presence or absence of CMFC. Surgical intervention and post-operative rehabilitation varied based on the pathology and surgeon preferences. Regular exercise was not resumed for at least 6 months post-surgery. Follow-up information was obtained through telephone conversations with owners, with a satisfactory outcome being defined as a horse being in ridden work without requiring ongoing anti-inflammatory medication.

A total of 104 horses were included in the study; 79 (76%) had CMFC, of which 54 had CMFC in combination with other pathology and 25 had CMFC alone, and 25 (24%) had other pathology. At 12 months, 62 (59.6%) horses had a satisfactory outcome. The only variable that showed any significant effect on outcome was CMFC; with horses with CMFC being 9.9 times more likely to have an unsatisfactory outcome at the 12 month follow-up period compared to those without CMFC.

These results indicate that CMFC is associated with an increased likelihood of the horse not being in ridden work at long-term follow-up.

Using hoof wall temperature to predict laminitis

In this knowledge summary, Honoria Brown from the University of Cambridge Veterinary School, UK, considered the PICO question "In horses and ponies at risk of laminitis, does the use of hoof wall temperature and digital pulse pressure as diagnostic techniques for acute laminitis provide a method of detecting acute laminitis in the prodromal stage?"

Four experimental case-control studies were identified that document changes in hoof wall temperature and/or digital pulse pressure throughout induced pathological onset. An epidemiological study was also identified that investigated the current usage of such changes in the diagnosis of acute laminitis episodes in the UK. These studies were compared and appraised and the author concluded that a palpable bilateral increase in forelimb hoof temperature maintained for longer than half a day may indicate that the horse is 18–24 h from acute laminitis onset. Additionally, a period of increased digital pulse may also be expected up to 11 h prior to onset.

Further studies using larger and more representative cohorts are required to confirm the accuracy of the times at which such changes can be expected.

Residual lesions following equine dysautonomia

Equine dysautonomia (equine grass sickness) causes degeneration and loss of autonomic neurons. Approximately 50% of chronic cases recover, but it is unclear how they survive neuronal loss. In this study, Elspeth Milne and UK colleagues assessed lesions, autonomic neuron numbers, interstitial cells of Cajal (ICC), and neurodegeneration in recovered cases.

This prospective case-control study included 13 cases (group ED), euthanised 1–16 years from diagnosis, and six age-matched controls (group C). Post-mortem examination included neuron counts in peripheral and enteric ganglia and immunohistochemical assessment of neural networks (protein gene product [PGP] 9.5), ICC (c-kit), and neurodegeneration (beta-amyloid precursor protein and ubiquitin) in intestine.

Post-mortem findings in group ED were small intestinal dilation (4/12, 33%) and muscular hypertrophy (4/12, 33%), and gastric mucosal hypertrophy (3/11, 27%) and ulceration (4/11, 36%). Neuron density was lower in group ED (mean 39% lower for cranial cervical ganglion, median 44% lower in celiacomesenteric ganglion). In intestine, neuronal depletion was worst in ileum (median 100% lower in submucosal plexus, 91% lower in myenteric plexus). Group ED had less PGP 9.5 staining in ileal myenteric plexus (mean 66% lower) and circular muscle (median 75% lower). In ileum, there was less c-kit staining in myenteric plexus (median 57% lower) but not *muscularis externa*. Beta-amyloid precursor protein and ubiquitin results were not indicative of neurodegeneration.

Intact ICC in *muscularis externa* might help maintain motility after neuronal loss and the authors suggest that treatment supporting ICC function warrants investigation.

Laser salpingopharyngostomy

This study by Chantelle Jukic and colleagues in Australia and the USA evaluated the effect of laser salpingopharyngostomy on the guttural pouch environment of healthy horses.

Six adult Standardbred horses free from endoscopic evidence of guttural pouch abnormalities were included in the study. A stab incision was made ventral to the sternocephalicus tendon and a customised trocar inserted into the floor of the right medial guttural pouch compartment under standing sedation. Baseline (Day 0) temperature, humidity, oxygen (O₂) and carbon dioxide (CO₂) levels were recorded. A 2 × 2 cm salpingopharyngostomy was created into the dorsocaudal pharynx abaxially off midline into the floor of the right medial guttural pouch compartment. The guttural pouch environment was re-evaluated at 7 and 14 days post-operatively. All horses underwent upper respiratory tract and guttural pouch examination via endoscopy at 3 and 12 months after the completion of sampling.

The guttural pouch environment was altered by the laser salpingopharyngostomy, with considerable variation between horses and during the sampling period. The level of CO₂ post laser salpingopharyngostomy appeared to be linked directly to the horse's respiratory pattern, and the variation in CO₂ was significantly different at Days 7 and 14 post laser salpingopharyngostomy compared to baseline levels. Oxygen levels were also more varied during sampling compared to baseline. There was no change in humidity or temperature during the study.

Laser salpingopharyngostomy into the guttural pouch may be useful in clinical cases of guttural pouch disease where alteration of the environment may be beneficial.

S. WRIGHT

EVE Editorial Office

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Editorial

Clinical audit in equine practice, and the International Colic Surgery Audit

It has been 21 years since the adoption of clinical audit by our profession was first suggested in the literature (Mosedale 1998) and 19 years since an editorial in this journal introduced two thought-provoking articles on the subject (Rossdale and Mair 2000). A human consultant surgeon (Collier 2000) and equine orthopaedic surgeon (McIlwraith 2000) offered their perspectives of clinical audit, while also reflecting on several of the practical challenges we face in its application. The challenges identified are just as relevant today and the articles are highly recommended to the reader. Among other edifying points, we are reminded of our responsibilities to learn from our mistakes and encouraged to view audit not as a competitive or finger-pointing exercise, but rather as a means by which we should aspire towards excellence together. Dr McIlwraith concluded his article as follows: 'One needs to be careful not to be considered 'elitist', but it seems time to take up the gauntlet'. So, what progress has been made?

The intervening years have seen a steadily growing interest in veterinary clinical audit, reflected in the many review articles on the topic (Rayment 2002; Viner 2005, 2009; Mair 2009; Dunn 2012; Waine and Brennan 2015; Wylie 2015; Waine *et al.* 2018a,b). However, there remains a dearth of published veterinary examples and those that do exist commonly suffer poor design and reporting (Rose *et al.* 2016a).

The lack of published veterinary clinical audits is perhaps unsurprising. Clinical audits performed in practice are often seen as only relevant to that one centre. Colleagues conducting clinical audit may not perceive any wider interest in their experience or may be reluctant to publish their results. Even in the National Health Service, where clinical audit is a mandatory process (Anon 2000), the number of audits that are published as a percentage of all those performed is very small. However, in the authors' experience, reading a practical example of clinical audit can be far more informative than a review, especially in understanding the logistical aspects and possible pitfalls of the process. There are many good examples in the human medical literature (Harmer and Davies 1998; Polkinghorne *et al.* 2009; Patel *et al.* 2013; Vratisistas-Curto *et al.* 2017).

Variable definitions of clinical audit exist (Rose *et al.* 2016a) but one of the most commonly used describes it as 'a quality improvement process that seeks to improve patient care and outcomes through systematic review of care against explicit criteria and the implementation of change' (National Institute for Clinical Excellence 2002). It forms one part of clinical governance, a broader concept that encompasses a multi-faceted approach to accountability and quality improvement in healthcare (Scully and Donaldson 1998; Mair 2009). The key stages that differentiate 'clinical audit' from just auditing clinical data are the selection of explicit criteria, implementation of change, and repeating the audit cycle. These steps instigate an 'ongoing upward spiral' of improvement that is a central principle of clinical audit (Viner 2005).

While the terminology involved can seem complex, in essence clinical audit is a process to ensure what should be done is being done (Smith 1992). The well-defined stages of this process provide an excellent framework to achieve this and introduce the changes that drive quality improvement. However, over-prescriptive definitions and inconsistent terminology should not dissuade clinicians from embarking upon what should fundamentally be a simple process of improving the care we give our patients.

Although there is no statutory requirement for clinical audit in the veterinary profession, evidence of clinical governance is essential for practices in the UK enrolled in the Royal College of Veterinary Surgeons Practice Standards Scheme (RCVS 2018). Furthermore, audit is specifically mentioned in requirements of those wishing to attain Veterinary Hospital status (RCVS 2018). In addition, to fulfilling these requirements, multiple other benefits of clinical audit are well described (Morrell and Harvey 1999; Viner 2009; Dunn 2012; Waine and Brennan 2015). A prospective, multicentre study recently surveyed complications of equine castration with the express aim of facilitating clinical audit (Hodgson and Pinchbeck 2019). However, to the authors' knowledge, there are no published examples of the full clinical audit cycle in the equine literature. The closest example could be considered the Confidential Enquiry of Perioperative Equine Fatalities (CEPEF) (Johnston *et al.* 1995, 2002, 2004). Although we do not yet have proof of their quality improvement effects, the findings of CEPEF-1, -2, and -3 have been widely adopted at equine clinics around the world. CEPEF-4 is currently underway (Gent and Bettschart-Wolfensberger 2013) and could be viewed as the first re-audit stage. The distinctions between research and clinical audit are important (Viner 2009; Wylie 2015) and CEPEF may not fulfill the exact definition of clinical audit. However, it shines as an excellent example of the possibilities for well-designed, international collaborations.

The lack of published examples does not mean that clinical audit is lacking in equine practice. Indeed, the authors are aware of many clinics performing effective clinical audits that lead to quality improvement. However, we believe the publication of such examples, as has occurred in small animal practice (Dunn and Dunn 2012; Rose *et al.* 2016b), will inspire and educate colleagues wishing to undertake their own clinical audits. A full review of the process is beyond the scope of this article. However, the reader is encouraged to explore the vast number of reviews and clinical audit tools available (e.g. <https://knowledge.rcvs.org.uk/quality-improvement/tools-and-resources/clinical-audit/>). Importantly, clinical directors and practice managers are encouraged to dedicate specific time for employees to discuss and perform clinical audit. It can be both immensely fulfilling for colleagues and profitable to a practice. As with all things, informed preparation and starting simple are advised to maximise the benefits of the process.

Colic surgery has been identified as a discipline well-suited to clinical audit (Mair and White 2005). Despite significant improvements in treatment and outcomes for horses undergoing colic surgery, mortality, and complication

rates remain relatively high (Mair 2009; Salem *et al.* 2016). The associated financial costs are also high and keeping colic surgery affordable for the horse-owner is important. The rates of morbidity and mortality are influenced by the type of lesion and other patient factors, such as systemic status and degree of intestinal compromise. However, the contribution of surgical performance and our treatment choices are undoubtedly significant. These can and should be scrutinised to enable further improvements in quality of care for colic patients (Freeman 2018). The establishment of an international database of colic surgery has been proposed with the primary aim of achieving exactly this (Mair and White 2005).

The potential benefits of such a database are well documented (Mair and White 2005; Freeman 2018) and a survey of equine surgeons indicated a high level of interest and willingness to contribute data (Mair and White 2008). However, the same survey identified significant concerns and potential barriers. These included the time involved in data collection, maintenance of confidentiality, and how the database would be managed and interpreted (Mair and White 2008). Recent conversations between the authors and colleagues across the world reveal there is still scepticism regarding the usefulness and administration of such a database. Despite the considerable logistical challenges involved, it is our intention to launch the International Colic Surgery Audit (INCISE) in 2019. Data collection must be as easy as is feasibly possible when considering such a multifactorial set of processes and outcomes. These data must then be anonymised prior to analysis and presentation, to inspire confidence in those willing to contribute. Feedback to individual clinics must be useful, prompt, and facilitate rigorous clinical audit. Finally, interpretation of the total dataset should be done with caution, accounting for the complex multitude of factors affecting disease processes and outcomes (Mair 2009).

The potential applications of INCISE are vast but attempting to run before we have even stood up would be ignoring our own advice to start simple! Collecting an up-to-date, international dataset of colic surgery processes and outcomes will provide benchmarks for ongoing clinical audit. Changing trends within the specialty can be monitored and targets for quality improvement can be identified (Mair and White 2005). Importantly, clinical audit should be a continuous process of appraisal and improvement (Viner 2005). As such, an important aim of these first stages of INCISE is the establishment of a process and database that allow repeated assessment at regular intervals and, importantly, a community of veterinary surgeons willing to contribute to this project. The authors would like to invite the participation of all clinics undertaking colic surgery around the world. Further information is available at www.internationalcolicaudit.com, and we welcome any correspondence on the subject.

'The best time to plant a tree was twenty years ago. The second best time is now.' (Chinese Proverb)

M. D. CULLEN*  **D. C. ARCHER†** and **T. S. MAIR‡**

*School of Veterinary Science, Philip Leverhulme Equine Hospital, Neston, Cheshire; and ‡Bell Equine Veterinary Clinic, Mereworth, Maidstone, Kent, UK

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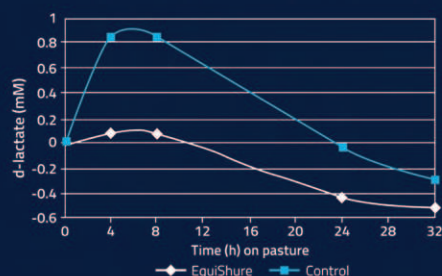
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Case Report

Concurrent repair of a displaced rib fracture and splenic capsular tearing using laparoscopic technique in a standing horse with acute haemoperitoneum

H. D. O'Neill*  and G. Ricardi

Donnington Grove Veterinary Surgery, Newbury, Berkshire, UK

*Corresponding author email: henryoneill@donningtongrove.com

Keywords: horse; spleen; rib; fracture; haemoperitoneum; laparoscopic, barbed suture

Summary

A 16-year-old Thoroughbred mare was presented for signs of dullness and suspected haemoperitoneum. The mare was kept at pasture with a cohort and was noted the previous day with a cut over the left stifle. Veterinary examination prior to admission had detected both tachycardia (76 beats/min) and pale mucous membranes. The mare was 23 days pregnant. Triage on admission confirmed the dullness, tachycardic (88 beats/min) and tachypnoeic (20 breaths/min) signs. Haematological analysis indicated a PCV of 37.2%, total protein of 44 g/L and plasma lactate of 16.1 mmol/L. Abdominal ultrasonography identified a large volume of free fluid with a swirling echogenic appearance, consistent with blood (**Fig 1**). Digital examination of the left thorax confirmed a plaque of swelling with a palpable step in the contour of the underlying left 17th rib, at a level approximate with the ventral aspect of the *tuber coxae*. Ultrasonographic examination of the area confirmed suspicions of a rib fracture. Examination of the spleen revealed no evidence of capsular trauma or haematoma formation. Standing laparoscopic examination of the left abdominal structures confirmed a focal area of protruding parietal peritoneum, in the area directly under the rib fracture. The fractured rib ends had not penetrated through the peritoneum. Focal puncture of the mid-parietal splenic capsule was noted with ongoing haemorrhage originating from the parenchyma (**Fig 2**). A decision was taken to perform intracorporeal suturing of the torn splenic capsule. This was performed without complication using

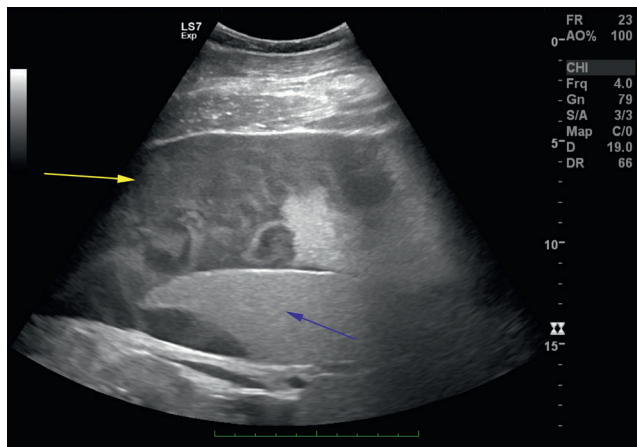


Fig 1: Ultrasonographic image from the left side of the abdomen with the spleen (blue arrow) and haemoperitoneum (yellow arrow) highlighted.

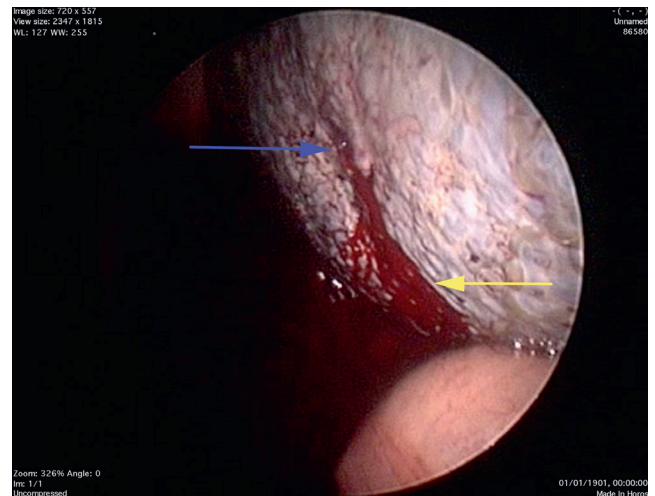


Fig 2: Laparoscopic view of the parietal surface of the spleen with the site of capsular penetration highlighted (blue arrow) and the resulting persistent haemorrhage (yellow arrow).

unidirectional, barbed, 3.5 metric copolymer of glycolic acid and trimethylene carbonate in a continuous Cushing pattern and a 50-cm long laparoscopic needle holder. No further haemorrhage was noted from the penetration upon completion. In the following 72 h the PCV steadily declined to a nadir of 18.3%. Plasma lactate measurements were taken q. 4 h during the first 24 h post-operatively, with values progressively decreasing to <1 mmol/L. Ultrasonography revealed an initial stabilisation of free abdominal fluid with progressive separation in echogenicity over 48 h, followed by a gradual reduction in fluid quantity thereafter. The mare was discharged 6 days following surgery. Follow-up veterinarian assessment 30 days following discharge revealed no incisional complications and continued viability of the pregnancy. Small paddock turnout was permitted for a further 10 weeks before allowing full paddock turnout thereafter.

Key points

- Sterilised polyamide ties can be used to secure simple rib fractures in the adult horse.
- Laparoscopic intracorporeal suturing of capsular tears involving the dorsal half of the spleen is a viable option in the standing patient if warranted.
- Plasma lactate levels are a sensitive indicator of acute hypovolaemia despite apparently normal PCV values.



Case Report

Alternative surgical treatment for synovial ganglion cyst of the digital tendon sheath in one horse

G. Lipreri^{†*}  and P. G. Kelly[‡][†]Leahurst Equine Hospital, University of Liverpool, Neston; and [‡]The Dick Vet Equine Hospital, University of Edinburgh, Midlothian, UK

*Corresponding author email: G.Lipreri@liverpool.ac.uk

Keywords: horse; lameness; tendon sheath; synovial cyst; tenoscopy

Summary

A 6-year-old Highland pony gelding was presented with severe left fore (LF) limb lameness of acute onset. The lameness occurred concomitantly with mild digital flexor tendon sheath (DFTS) effusion and focal painful swelling on the lateral aspect of the LF fetlock region. Clinical examination and diagnostic analgesia localised the lameness to the fetlock region and on ultrasound, a cyst-like structure filled with anechoic fluid was detected just proximal to the lateral sesamoid bone, at the proximo-lateral aspect of the DFTS and adjacent to the lateral neurovascular bundle. The edge of the cyst-like structure was well demarcated and closely associated with the lateral wall of the DFTS. A defect in the medial aspect of the cyst wall was suggestive of an open communication between the two structures (**Fig 1**). Communication between the cyst-like structure and the DFTS was then confirmed with contrast tenography. Tenoscopic examination of the LF DFTS was performed and the communication between the fluid filled structure and the synovial cavity was detected (**Fig 2**). The defect in the DFTS wall was enlarged tenoscopically and the cyst-like structure lining was debrided. The rationale behind opening the communication was to convert the unidirectional flow of synovial fluid into a bidirectional flow. The horse recovered well post-operatively and the LF limb lameness improved significantly immediately after surgery. At the 6-week follow-

up there was mild thickening of the area but the cyst-like structure was no longer visible ultrasonographically. Nine weeks after surgery the horse was considered sound and fit to resume ridden exercise. This alternative minimally invasive surgical treatment had an excellent outcome and allowed the simultaneous assessment of the structures in the DFTS and the debridement of the cyst without the need for a second surgical approach for en bloc resection of the cyst.

Key points

- Cyst-like lesions associated with the DFTS can be traumatic in origin and thorough ultrasonographic and tenoscopic examination is recommended.
- The correlation between the cyst-like lesion and lameness may be explained by existence of a one-way valve effect that results in progressive increase in intra-lesional pressure.
- The single-stage tenoscopic procedure here described allows the simultaneous assessment of the structures in the DFTS and the debridement of the cyst without the need for a second surgical approach.

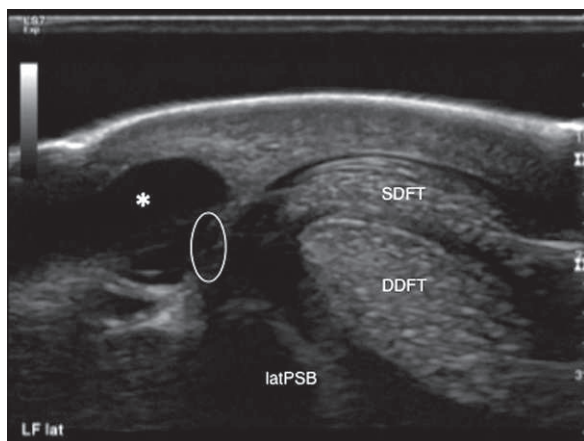


Fig 1: Transverse ultrasonographic image of the palmaro-lateral aspect of the LF fetlock showing the cyst-like structure filled with anechoic fluid (see asterisk). The communication between the medial edge of the cyst-like structure and the lateral wall of the DFTS can be appreciated (see circled area).

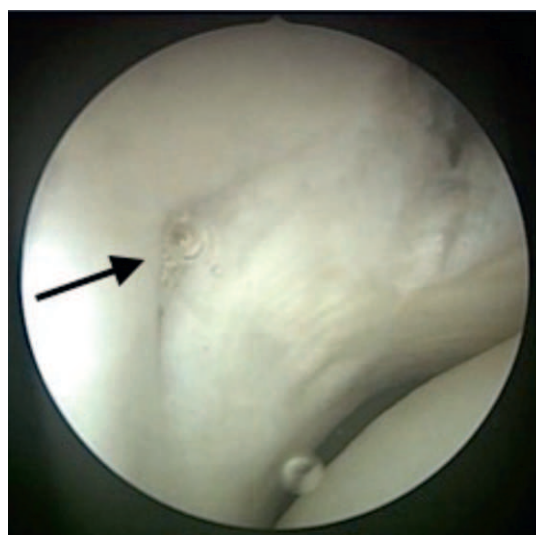


Fig 2: Tenoscopic image of the small tear in the wall of the DFTS, just proximal to the PAL. It is possible to note few gas air bubbles (see black arrow) emanating from the defect into the DFTS when external pressure is applied on the cyst-like lesion.





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Case Report

Standing repair of an articular dorsal medial oblique fracture of the proximal third metacarpal bone in a racing Standardbred

N. E. Lean*  and B. J. Ahern

School of Veterinary Science, Equine Specialist Hospital, University of Queensland, Gatton, Australia

*Corresponding author email: n.lean@uq.edu.au

Keywords: horse; fracture; third metacarpal bone; Standardbred; racehorse

Summary

A 4-year-old Standardbred pacing mare presented with a right dorsomedial proximal third metacarpal bone (McIII) fracture which occurred mid race 8 days prior to presentation.

At presentation the mare was severely lame at the walk. Firm swelling over the dorsal proximal aspect of the cannon bone produced a marked pain response to palpation. Radiographs revealed a 10.7 cm in proximal to distal length, complete displaced fracture of the proximal dorsomedial aspect of McIII.

Preoperatively the mare received antimicrobials and analgesia. A median and ulnar peri-neural block and a ring block proximal to the carpometacarpal joint were performed. The mare was sedated in stocks and the limb

aseptically prepared for surgery. The limb was aligned with the body and the foot positioned in a normal weight-bearing position. Three 5.5 mm cortical bone screws were inserted in lag fashion via stab incision in triangular orientation. Intra-operative radiographs confirmed screw placement and fracture compression (**Fig 1**). The most distal screw was long, however radiographs confirmed the splint bone was not engaged. The screw was left in place with the plan to remove it after bone healing if it was an issue. A full limb Robert Jones bandage was applied.

At 72 h post-operatively the mare was sound at the walk. Radiographic examinations performed at 4, 8 and 10 weeks showed progressive healing. At 6 months the mare resumed racing and has remained sound.

Articular fractures of dorsomedial proximal McIII are rare. This report describes the successful standing surgical repair of this fracture configuration in a Standardbred racing mare using minimally invasive lag screw fixation.

Standing fracture repair can be a good choice due to the reduced cost, time and expense associated with the procedure. Furthermore, the weight-bearing position of the limb allows easier screw placement and the risks associated with general anaesthesia and recovery are avoided. Adequate sedation and peri-neural analgesia are essential to minimise movement of the patient.

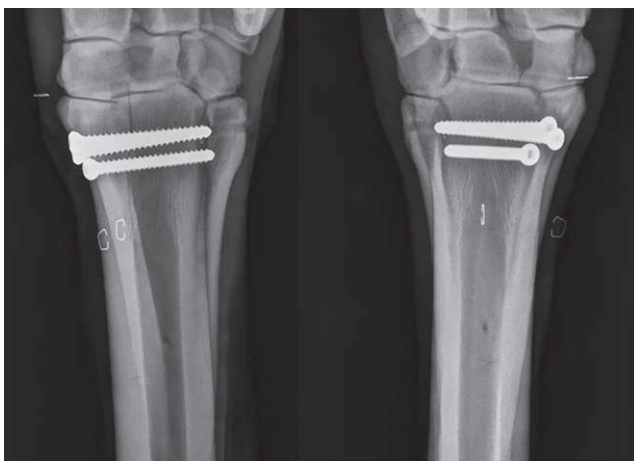


Fig 1: Dorsolateral palmaro-medial oblique (left) and dorso-palmar (right) radiographs showing final screw placement.

Key points

- Minimally displaced, articular, dorsoproximal medial McIII fractures can be repaired using lag screw fixation such that athletic function can be restored.
- Standing minimally invasive fixation reduce cost, time, expense and risks associated with the procedure.



Case Report

Successful outcome of a Standardbred filly after conservative treatment for a Salter–Harris type III fracture of the distal femoral condyle

N. Valk*  and J. Schumacher 

Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Tennessee, Knoxville, Tennessee, USA

*Corresponding author email: nvalk1@utk.edu

Keywords: horse; Salter–Harris fracture; femur; physis; condyle

Summary

A 10-day-old Standardbred filly sustained a complex Salter–Harris type III fracture of the right, lateral, distal femoral condyle. The lateral condyle was fractured in transverse, sagittal and frontal planes. The filly was treated by restricting it and its dam to a small, level paddock until lameness was no longer apparent. The filly, when weaned at 7 months of age, was turned out to pasture with three other weanlings. The filly entered race training as a 2-year-old, qualified to race as a trotter, was placed second in its first start and won its third race. Conservative treatment should be considered as an option for a young horse with a minimally displaced, Salter–Harris type III fracture of the distal lateral femoral condyle.

Introduction

Fractures of the femur of foals are not uncommon. One study reported that 25% of all long bone fractures of foals involved the femoral diaphysis (Dwyer and Powell 1989). A retrospective study investigating the outcome of 38 horses <1 year old that had incurred a femoral fracture found that 31.6% of fractures involved the distal femoral physis (Hance *et al.* 1992). Another retrospective study of horses <2 years old that had incurred a physeal fracture found that 10% of the fractures involved the distal femoral physis, and 15.7% involved the proximal femoral physis (Embertson *et al.* 1986a). Two studies found the incidence of Salter–Harris type III fractures of the femur to be lower than Salter–Harris type II or type IV fractures of the femur (Embertson *et al.* 1986a; Hance *et al.* 1992).

Options for treating horses that have incurred a Salter–Harris type III fracture of the distal aspect of the femur have included confinement to a box alone or internal fixation and confinement to a box (Embertson *et al.* 1986b; Hance *et al.* 1992; Byron *et al.* 2002). The outcome of a 5-month-old foal with Salter–Harris type III fracture of the distal aspect of the femur treated by confinement to a box alone was considered good, although the foal developed a slight tarsal valgus of the contralateral limb (Hance *et al.* 1992). In a retrospective study, seven horses (mean age, 9.5 months; range, 5–18 months) that suffered a fracture of the distal femoral physis were found to have a poor prognosis for survival or soundness, regardless of whether the horse was managed by confining it to a box or the fracture was repaired by using internal fixation. In that study, five of seven foals were subjected to euthanasia for unspecified reasons,

and the two surviving foals were reported to be lame on the affected limb after the fracture had healed. The method by which the survivors were treated (i.e. surgical treatment or confinement) was not reported (Embertson *et al.* 1986b). Authors of a case report described the successful use of a condylar screw plate to repair a Salter–Harris type III fracture of the distal aspect of the femur of a 2-year-old horse intended for breeding (Byron *et al.* 2002). We report the outcome of conservative treatment of a Standardbred filly for a Salter–Harris type III fracture of the distal aspect of a femur.

Case history

A 10-day-old Standardbred filly was evaluated because of acute onset of lameness of the right pelvic limb. The filly was at pasture with its dam when the lameness was discovered. During examination, the attending veterinarian observed that the filly was mildly to moderately lame on the right pelvic limb at a walk and assigned grade 4 (American Association of Equine Practitioners 1991) to the lameness. The joints of the right stifle were moderately distended. The attending veterinarian observed no oedema, heat or crepitus surrounding the stifle, and palpation of the stifle did not cause the filly to show signs of pain. The filly could stand on the right pelvic limb when the contralateral limb was raised, but the filly seemed to mildly resent flexion of the right stifle. Based on findings of physical examination, the attending veterinarian believed the swelling of the stifle to be caused by soft tissue trauma, and he instructed the owner to confine the filly for several days. The filly was re-evaluated 5 days later by the attending veterinarian, because lameness failed to improve. Results of physical examination were unchanged since the filly was initially evaluated. Synovial fluid collected by centesis from the medial compartment of the right femorotibial joint appeared to have low viscosity, was clear and had an orange discoloration. Total protein concentration of the fluid was 3.3 mg/dL (0.03 g/L), and the fluid contained 2000 nucleated cells/ μ L, mostly nondegenerate neutrophils, and 80,000 RBC/ μ L (0.08×10^{12} /L). Nucleated cells were mostly neutrophils, but some were macrophages. The sample was interpreted as reflecting mild neutrophilic inflammation of the joint. The filly was referred to a teaching hospital for radiographic evaluation.

Diagnosis

When presented to our hospital, we observed that the filly was bright and walked with only mild lameness on the right

pelvic limb. The femoropatellar and femorotibial joints were moderately distended. A complex Salter–Harris type III fracture of the distal aspect of the femur (**Figs 1–3**) was observed during examination of lateral, caudolateral-craniomedial oblique and caudocranial radiographic views of the right stifle, obtained with the filly sedated. The filly and its dam were returned to the farm after the attending veterinarian was consulted by telephone.

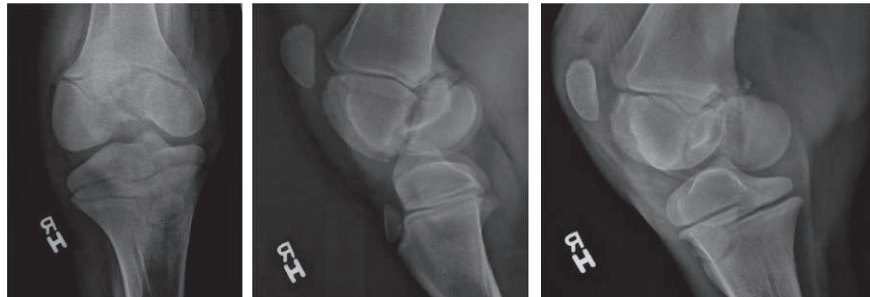
Treatment

The radiographic images were electronically transmitted to several equine orthopaedic surgeons with whom the authors were familiar, seeking advice about how to best treat the filly. Recommendations received included the recommendation to euthanise the filly on humane grounds due to a poor prognosis for survival and a recommendation to place several lag screws into the fracture fragments with the hope of rendering the filly sound enough for breeding. Due to the lack of a consensus on how to best treat the filly, the owner and attending veterinarian decided to treat the filly conservatively, based on the filly's ability to ambulate freely and the minimally displaced nature of the fracture fragments. The filly was confined, along with its dam, to a 7.3 × 3.7 m box. The filly received no analgesic medications, because the filly displayed only mild lameness. The farm manager

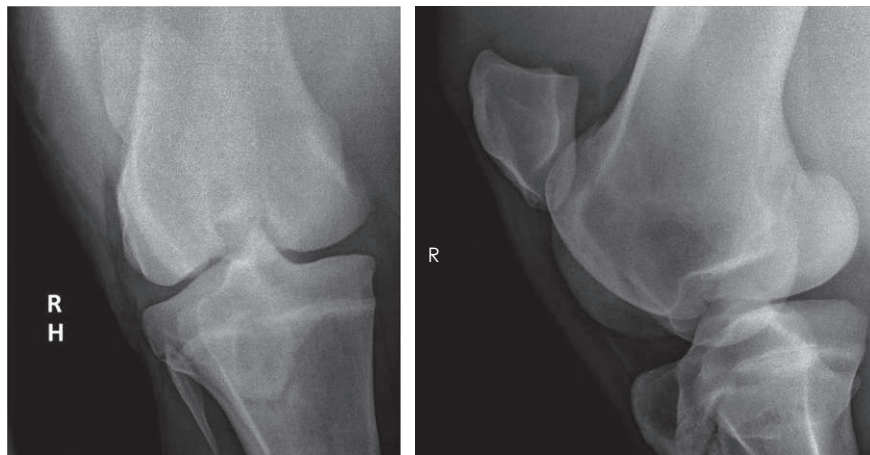
observed that the filly would canter from one end of the box to the other, pivoting on its hind quarters when turning. Due to concerns that this repetitious activity might result in torsional forces on the fracture fragments, the filly and its dam were moved from the box after 3 days to a level, 0.4-hectare paddock for the duration of the recovery. The farm manager believed that the filly would be less active when not confined to a box.

Outcome

The filly was sound at a walk 6 weeks after injury but would not bear weight on the right pelvic limb when trotting or cantering. By 3 months, the filly was observed to be mildly lame on the right pelvic limb, but lameness was evident only when the filly trotted (grade 3; American Association of Equine Practitioners 1991). By 7 months, the attending veterinarian could no longer detect lameness when the filly moved at any gait. At this time, the filly had been weaned and turned out to pasture with three age-matched weanlings. The filly's injured stifle was not examined radiographically until 13 months after the injury. At this time, complete healing of the fracture, unaccompanied by evidence of degenerative joint disease, was observed during radiographic examination of the right stifle (**Figs 4–5**). The filly entered race training at 2 years of age, and raced successfully.



Figs 1–3: Radiographs of the right stifle obtained 5 days after the filly was first observed to be lame on the right pelvic limb. These radiographs show a complex Salter–Harris type III fracture of the distal aspect of the femur.



Figs 4–5: Healing of the fracture was observed to be complete during examination of radiographs of the right stifle obtained 13 months after injury. No signs of degenerative disease of the joints of the stifle were observed.

Discussion

Lameness associated with effusion of one or both joints of the stifle in a young foal, such as the foal in this report, is more commonly associated with synovial sepsis of the stifle than with trauma. The most expedient means of determining whether effusion and lameness is caused by trauma or by sepsis is to grossly and cytologically examine fluid obtained from the joints of the stifle. The relatively low WBC count in the fluid obtained from the medial compartment of the femorotibial joint of this foal 5 days after the foal was observed to be lame indicated that trauma to the stifle was the more likely cause of effusion. Radiographic examination of the stifle confirmed that trauma to the stifle was the cause of lameness. Damage to the soft tissue structures of the stifle could have been assessed ultrasonographically or by using MRI to better determine the filly's prognosis for soundness.

The femur is a common location for fractures in foals (Dwyer and Powell 1989), and a physis is frequently involved (Embertson *et al.* 1986a; Hance *et al.* 1992; Levine and Aitken 2017). Diagnosis is based on clinical and radiographic examinations. Choice of treatment depends on many factors, including, but not limited to, the type of fracture, expectations for use of the horse, financial considerations, availability of veterinary expertise and quality of life desired for the patient. Foals with a physeal fracture involving an articular surface may develop degenerative joint disease, if the fracture is not adequately reduced and stabilised (Nixon 1996).

Treatment of foals for a fracture of the distal femoral physis typically consists of internal fixation of the fracture or an extended period of box rest. In a retrospective study, three foals with a minimally displaced fracture of the distal femoral physis had a good or excellent outcome after being confined to a box for 3–5 months and then to a small paddock for an unspecified time, whereas two foals with a widely displaced fracture of the distal femoral physis treated by internal fixation of the fracture had poor outcomes (Hance *et al.* 1992). The choice of treatment of the five foals in these two studies, however, was based on the severity of the fracture, and the fracture of the two foals that received surgical treatment was considered more severe. Another study found that the prognosis for foals with a fracture of the distal femoral physis was poor, regardless of whether the foal was treated surgically or by confinement, based on the observation that five of seven foals died or were subjected to euthanasia, and the two surviving foals remained lame. The method by which the survivors were treated was not specified (Embertson *et al.* 1986b). A minimally displaced, Salter–Harris type IV fracture of the distal femoral physis of a yearling Thoroughbred was repaired using lag screws, although long-term results were not included in the report (DeBowes *et al.* 1983). Successful outcome of a similarly treated colt for a similar fracture was reported, although the ability of the colt to perform athletically was not reported (Walmsley and Summerhays 1990). A more recent report documented the successful treatment of a 427-kg, 2-year-old colt for a displaced Salter–Harris type III fracture of the distal femoral physis using a condylar screw plate. The horse appeared to be sound at pasture, but soundness for athletic performance was not reported (Byron *et al.* 2002).

Nondisplaced and incomplete fractures that have an articular component are reported to be best repaired by

internal fixation to compress the subchondral bone and articular cartilage and re-establish congruency of the articular surface, thereby preventing secondary degenerative changes (Nixon 1996). Nevertheless, numerous studies have reported good success for soundness using conservative methods to treat horses for a fracture that involves an articular surface (Tetens *et al.* 1997; Bassage and Richardson 1998; Zekas *et al.* 1999; Murphey *et al.* 2000; Elce *et al.* 2001; Kearney *et al.* 2010). Seventeen of 24 racing Standardbreds treated conservatively for an incomplete midsagittal fracture of the proximal phalanx returned to racing and did not experience reduced racing times, whereas 19 of 25 treated surgically returned to racing but experienced reduced racing times. The investigators emphasised that decisions about treatment were based on the length of fracture, which was determined radiographically, and that they could not conclude that medical treatment led to a better outcome (Tetens *et al.* 1997). In one study, treating racing Arabians, Thoroughbreds and Standardbreds for incomplete, lateral or medial condylar fracture of the third metacarpal or metatarsal bone by confining the horse to a box and applying a bandage or cast to the affected limb, appeared to have less of a negative impact on racing performance than did treating similarly affected horses surgically (Bassage and Richardson 1998). In another study, 87% of Thoroughbreds and Standardbreds with a short, incomplete lateral or medial condylar fracture treated by confining the horse to a box and applying a bandage or cast to the affected limb returned to racing, whereas only 74% of horses with a similar fracture treated surgically returned to racing (Zekas *et al.* 1999). Although treatment groups (i.e. those treated conservatively and those treated surgically) of these two studies were not randomised, the good outcome of a large percentage of horses indicates that the outcome of horses with an incomplete condylar fracture is often good when the horse is treated conservatively. In one study, horses with a slab fracture of the central or third tarsal bone responded well to conservative treatment despite articular involvement, even when the fracture was comminuted (Murphey *et al.* 2000; Elce *et al.* 2001; Kearney *et al.* 2010). One study concluded conservative management [i.e. confinement to a box (time unspecified)] is indicated for horses with a type II or III fracture of the distal phalanx, and that the prognosis for return to soundness is good and is not improved by applying an immobilising shoe/cast to the foot or by internal fixation of the fractured bone (Rijkenhuizen *et al.* 2012).

Fracture of the distal physis of the femur may result in premature closure of the physis and consequently, an abnormally short femur (Richardson 2012). A recent report indicated that repair of distal physeal fractures of the femur inevitably results in early closure of the growth plate and a shortened limb (Levine and Aitken 2017). The authors of a retrospective study, however, contended that although fractured physes commonly close prematurely, shortening or abnormal angulation of the affected limb is not grossly apparent (Embertson *et al.* 1986a,b). Foals treated conservatively for a fracture of a long bone often develop an angular deformity of the contralateral limb (Richardson 2012). A study by Hance *et al.* (1992) reported that of three foals treated conservatively (i.e. confinement to a box for 3–5 months followed by confinement to a small paddock) for a distal femoral physeal fracture, one developed a slight tarsal

valgus in the contralateral limb but still could be ridden for pleasure. The filly in our report did not develop an angular deformity of the left pelvic limb during convalescence, most likely because lameness of the fractured limb was not severe. The good outcome of this filly was likely facilitated by the filly's youth and size. Fractured bones of foals heal more rapidly than do fractured bones of adult horses (Levine and Aitken 2017).

Treatment of the foal in this report was unique, because the foal was not confined to a box during convalescence. Recommendations for conservative treatment of horses for a fracture invariably include long-term confinement to a box (Hance *et al.* 1992; Tetens *et al.* 1997; Bassage and Richardson 1998; Zekas *et al.* 1999; Murphey *et al.* 2000; Elce *et al.* 2001; Kearney *et al.* 2010; Rijkenhuizen *et al.* 2012). In one study, foals with a stable, minimally displaced, distal physeal femoral fracture were treated successfully by confining them, first to a box for 3–5 months and then to a larger area (unspecified) for an unspecified time (Hance *et al.* 1992). Authors of a study reporting successful conservative treatment of adult horses for a tarsal slab fracture recommended confining the horse to a box for two months and then confining the horse to a small paddock for two more months before allowing the horse to receive controlled exercise (Elce *et al.* 2001). Authors of a similar study investigating the outcome of racing Standardbreds with a slab fracture of a tarsal bone recommended confining the affected horse to a box for prolonged time (Murphey *et al.* 2000). Although the duration of confinement to a box was not specified, the mean total time of convalescence after diagnosis was 8 months. The filly in this report was excessively active when confined to a box, necessitating that the filly and its dam be confined to a small (0.4 hectare), level paddock. The foal's behaviour and activity, while in the paddock, were more subdued than when the foal was in a box, likely contributing to the successful outcome.

Conservative management consisting of turnout into a small level paddock should be considered an option for the treatment of foals for a nondisplaced Salter–Harris type III fracture of the distal aspect of the femur. This treatment may not preclude an athletic career for the affected horse.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This case report adheres to the accepted standards of care at the University of Tennessee's Veterinary Medical Center. No experimental procedures were performed on this animal.

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Authorship

Each author contributed to preparation of the manuscript and was involved in diagnosis and treatment. N. Valk

contributed more towards preparation of the manuscript and recommendations for treatment.

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Clinical Commentary

Orthopaedic case management: A balancing act

T. B. Lescun 

Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Purdue University, West Lafayette, Indiana, USA

Corresponding author email: tllescun@purdue.edu

Summary

Balancing the activities of a foal with an orthopaedic injury can be challenging. Physal fractures also provide additional complexities to consider. This commentary examines both the juxtaposition of confinement and reduced activity, and the complex features of physal injuries.

The case report by Valk and Schumacher (2020) describes the diagnosis and conservative management of an intra-articular, distal physal femoral fracture in a 10-day-old foal. The fracture healed without radiographically detectable osteoarthritis and the Standardbred filly ultimately raced. The report highlights some challenges encountered when managing physal fractures in the foal and the balancing act that often needs to be struck. The successful outcome illustrates that juvenile fractures, particularly those of the physis, heal rapidly and can on occasion overcome a degree of imperfect fracture alignment in the process. The unique feature of this case report, however, was the way in which the challenge of controlling the activity level of the foal was approached. The authors describe the filly cantering the length of the stall and pivoting on the hindlimbs while 'confined'. The foal was ultimately managed in a small paddock (0.4 hectares; approximately 1 acre) rather than in a double sized box stall. A judgement was made with the farm manager that the foal may be less active in a paddock area. Upon follow-up, the foal was sound at the walk within 6 weeks (although still carrying the limb when moving at faster gaits), considered grade 3 lame at the trot at 3 months, and judged to be sound at 7 months following the initial injury. This commentary will explore two interesting aspects of the case; confinement versus reduced activity, and the complexity of physal fractures.

Confinement versus reduced activity

Enforcing confinement does not always result in reduced activity. While the majority of horses, including foals, adjust to being confined to a box stall, there are exceptions. A study measuring limb activity during box stall confinement in six horses found that one horse displayed stereotypic locomotor activity and shifted weight on its forelimbs four times more, and on its hindlimbs 10 times more, than the average of the rest of the study group (McDuffee *et al.* 2000). These exceptions are challenging to manage in the fracture patient and result in greater cycling of orthopaedic implants and potential complications when managing external coaptation. The reported prevalence of stereotypic behaviour varies widely but may be observed in up to 33% of horses (Roberts *et al.* 2017). Efforts to reduce stereotypic behaviour include

ad libitum access to forage, slow-feeding strategies such as small weave hay bags, reduced concentrate feeding and increasing social interactions for confined horses (Roberts *et al.* 2017). Providing either contact with other horses or the ability to observe other horses can reduce locomotor stereotypic behaviours. Mirrors or large posters of other horses have been used to reduce stall weaving and stall walking successfully. The ultimate remedy is increased turnout, grazing and exercise as most horses with locomotor stereotypies in the box stall do not display these behaviours when turned out to pasture. Of course, the orthopaedic patient may be at increased risk of repair failure or re-injury if turned out to pasture too early in the healing phase. However, gradually increasing levels of controlled activity must be a part of the rehabilitation programme for all orthopaedic patients.

Foals with orthopaedic injuries can present additional challenges for activity management. A study of the locomotor activities of warmblood foals on pasture during the first 4 months of life found that the percentage of time spent cantering and in other high impact activities was greatest in the first 4 weeks of life (Kurvers *et al.* 2006). However, the percentage of time observed cantering and trotting was only 1.4% of the total time observed on pasture in these foals, or approximately 20 min per day. This may be an overestimation of total time per day since the study observations were performed during daylight hours only. Regardless, the remainder of the time (98.6%) was spent grazing, walking, lying down or standing, all activities that are also performed by a foal confined to a box stall. The time spent cantering or trotting reduced to 0.5–0.6% of time in older foals, or approximately 7 min per day. Interestingly, the same study also found that foals kept in a box stall for part of each day were more active during their time on pasture, spending more time cantering, trotting, walking and grazing, when compared to foals that were on pasture 24 h a day, perhaps in some way compensating for their time in confinement. It was proposed that greater locomotor activities during the early weeks of life may be important for healthy musculoskeletal development in the foal (Kurvers *et al.* 2006). That said, just 1 min of cantering or high impact activity may be all that is needed for a foal to convert a minimally displaced fracture or a minor injury into a career or life-threatening one. Another challenge in managing the foal's activity as an orthopaedic patient is the mare. Some mares are going to make their foal move more on pasture than others, and some mares are going to be difficult to manage in a box stall for a prolonged period of time. In a box stall environment, both the reproductive health of the mare and the orthopaedic health of the foal are potentially compromised. Recommending pasture turnout for the initial

management of significant orthopaedic injuries cannot be considered under most circumstances, however it is illustrative to consider that the foal in the case report by Valk and Schumacher (2020) may have been less active in the small paddock based on the description of its stall behaviour and the information known about normal activity levels of foals on pasture.

The complexity of physal fractures

The initial description of physal (epiphyseal plate) injuries by Salter and Harris aimed to classify the observed fracture configurations according to their prognosis. This was based on the likelihood of growth disturbance and articular involvement of the injury (Salter and Harris 1963). Physal fracture configurations are dependent upon many factors, including the size and age of the animal, the magnitude and direction of force that causes the injury, the particular physis involved, its shape, any pre-existing local physal abnormalities and the associated soft tissues of the region. The uncommon configuration of the physal fracture reported by Valk and Schumacher (complex type 3 Salter-Harris fracture of the distal femur) is also uncommon in other species, including children (Berg *et al.* 1984; Arkader *et al.* 2007; Little and Milewski 2016; Pennock *et al.* 2017). This type of fracture in adolescent children is recognised to have a delay of diagnosis in almost 40% of cases, particularly when the fracture is minimally displaced (Pennock *et al.* 2017). That presentation bears similarity to the foal in the report by Valk and Schumacher, where initial evaluation by the attending veterinarian, and presumably the relative comfort of the foal, did not raise fracture sufficiently as a likely diagnosis to perform radiographs of the stifle. Despite the delay in diagnosis, the foal was able to perform athletically following fracture healing. This type of fracture also carries an excellent prognosis in children for future athletic endeavours (Pennock *et al.* 2017).

Physal fractures are known to heal and stabilise rapidly (Salter and Harris 1963; Chung and Xian 2014; Levine and Aitken 2017). The reasons for this are two-fold. First, most physal fractures occur through the relatively weak hypertrophic zone (with its high cell to matrix ratio), or the junction of the mineralised cartilage and the hypertrophic zone (Ogden *et al.* 1993). This region of the physis is already fully engaged in bone formation, with the creation of the primary spongiosa and their active remodelling into metaphyseal trabeculae. Re-establishing physal alignment and contact can allow this process to continue and healing to occur rapidly providing local blood supply and cellular viability are intact. The proliferative cells of the physis continue to divide following injury as they are typically away from the damaged region and the processes of matrix mineralisation and endochondral ossification resume within 7–10 days (Salter and Harris 1963; Chung and Xian 2014). Healing can occur in as little as 2–3 weeks. Second, the physis itself is typically loaded in compression, transferring joint forces from the epiphysis through to the thicker cortex of the diaphysis. Bending forces in the region of the physis are generally small and counteracted by soft tissue attachments. The thick perichondrium, periarticular soft tissues and muscle, ligament and tendinous attachments all play a role in stabilising the physis. As a result, soft tissue injury and subsequent healing, which invariably accompany physal fracture, also contribute to the rapid return of stability in this

region of the bone. The degree of soft tissue support surrounding the fracture in the report by Valk and Schumacher (2020) was likely one reason that the fracture remained minimally displaced and healed without long-term complications.

While it is known that physal fractures can heal rapidly, for any particular case it is unknown whether the injured physis will resume symmetrical longitudinal growth, grow asymmetrically and result in an angular deformity, or close prematurely due to significant damage or blood supply compromise. Follow-up radiographs of the foal in the report by Valk and Schumacher (2020) performed at 13 months of age showed that the distal femoral physis was closed and the proximal tibial growth plate was open but thin. Radiographic closure time for the distal femoral physis is reported as 19–27 months of age, while the proximal tibial physis closure occurs from 23 to 32 months of age (Strand *et al.* 2007). While that particular study was performed in Icelandic horses, overall closure times correlated well with reports from other breeds at other physes. The radiographs suggest that the fractured physis in this case closed prematurely and that the femur of the foal was likely to be shortened (Levine and Aitken 2017). This is consistent with studies in the dog and children (Shapiro 1982; Berg *et al.* 1984; Arkader *et al.* 2007). However, as noted in previous reports, this presumed shortening was not appreciated grossly (Embertson *et al.* 1986). Mechanisms for compensation of shortened long bones due to early physal closure include compensatory overgrowth of adjacent physes and an alteration of the joint angles within the limb. Interestingly, in both children and dogs, the evidence for compensatory overgrowth by the proximal tibial physis as a result of early physal closure of the distal femoral physis is weak. In fact, it has been suggested not to occur to any significant degree by some (Shapiro 1982; Berg *et al.* 1984). In contrast, in cases of femoral diaphyseal fracture, physal overgrowth of both the distal femoral physis and the proximal tibial physis, is a well-recognised phenomenon in children, which occurs even when anatomic bone alignment is achieved (Shapiro 1982; Stilli *et al.* 2008). This has also been reported in dogs (Schaefer *et al.* 1995). Altered joint angles have been shown to compensate for up to a 20% shortening of the femur in dogs without a significant effect on gait. The stifle angle was reduced on the shortened limb and increased on the unaffected limb, while the angle at the tarsus compensated minimally (Franczuski *et al.* 1987). While it is pure speculation that the horse would follow these same mechanisms for compensation, it is clear from this case report and clinical experiences that the young animal has a tremendous capacity to adjust to various injuries over time, or at least obscure the facts sufficiently from our visual recognition.

The specific set of circumstances in the case report by Valk and Schumacher (uncommon fracture configuration, excessive stall activity by the foal, presumably substantial soft tissue stabilisation of the fracture site) were able to result in a favourable outcome. While the authors concluded 'Conservative management consisting of turnout into a small level paddock should be considered an option', the option of box stall confinement, had the foal been amenable to this approach, would have also been appropriate. The take home message from this statement should not be that stall confinement is necessarily 'bad' or 'good', but rather

that under specific circumstances an alternative to the normally recommended course of action may be appropriate or necessary. It is often a balancing act to keep a foal confined and reduce its activity when necessary.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Case Report

Surgical correction of entrapment of the large colon and caecum through a mesoduodenal rent with standing laparoscopic repair in a mare

E. E. Cypher*, J. Blackford, R. T. Snowden, J. A. Sexton and J. Schumacher 

Department of Large Animal Clinical Sciences, University of Tennessee College of Veterinary Medicine, Knoxville, Tennessee, USA

*Corresponding author email: ecypher@utk.edu

Keywords: horse; surgery; equine; laparoscopy; colic; soft tissue

Summary

A 12-year-old Tennessee Walking Horse mare displaying signs of severe colic for 48 h was found during an exploratory celiotomy to have entrapment of a cranially displaced large colon and the caecum through a rent in the mesoduodenum. The entrapment was relieved, and 24 h later, the mesoduodenal rent was closed laparoscopically, with the mare standing. The owner reported 6 months later that the mare had displayed no signs of colic since being discharged from the hospital 11 days after surgery.

Introduction

Entrapment of intestine through a mesenteric rent is an uncommon cause of colic in the horse (Gayle *et al.* 2000; Freeman 2012), accounting for only 1.7–4% of lesions observed in horses undergoing exploratory celiotomy for signs of colic (Phillips and Walmsley 1993; Gayle *et al.* 2000; Sutter and Hardy 2004; Mair and Smith 2005; Kelmer *et al.* 2008). Tears specifically within the mesoduodenum are rarely reported (Gayle *et al.* 2000; Sutter and Hardy 2004). In the two published reports of colic secondary to a mesoduodenal rent, in each case, only the small intestine was found to be incarcerated (Gayle *et al.* 2000; Sutter and Hardy 2004). To our knowledge, the following report is the first to describe incarceration of the large colon and caecum of a horse in a mesoduodenal rent and its successful surgical correction and laparoscopic repair.

Case summary

History

A 12-year-old Tennessee Walking Horse mare was evaluated at the University of Tennessee's Veterinary Medical Center for a 48-h history of inappetence, during which time the mare had developed worsening signs of abdominal pain. Administration of analgesic drugs by the referring veterinarian failed to ameliorate these signs.

Clinical findings

The mare had a heart rate of 52 beats/min, a respiratory rate of 30 breaths/min and a rectal temperature of 37.6°C (99.6°F). The mare was estimated to be 5% dehydrated; her mucous membranes were tacky, and her capillary refill time mildly prolonged (3 s). Borborygmi were decreased or absent in all abdominal quadrants. The mare was in fair bodily condition (BCS 4/9) and weighed 333 kg. Six litres of foul-

smelling fluid was siphoned from the mare's stomach through a nasogastric tube. A markedly distended gas and ingesta-filled viscus was palpated within the pelvic inlet during palpation of the abdomen per rectum. A mildly distended, fluid-filled stomach was observed during complete ultrasonographic examination of the mare's abdomen. Serum biochemical analyses indicated that the mare had a metabolic alkalosis [pH 7.502 (reference range 7.36–7.49), HCO₃⁻ 37.3 mmol/L (rr 26–35 mmol/L), TCO₂ 38.7 mmol/L (rr 27–37 mmol/L) and base excess 12.4 mmol/L (rr 0–10 mmol/L)], mild hypochloraemia [93 mmol/L (rr 94–108 mmol/L)], mild hypocalcaemia [1.19 mmol/L (rr 1.40–1.77 mmol/L)] and a normal hematocrit (38% (rr 30–47%)). The mare was hospitalised, held off feed and placed on i.v. fluid therapy (5 L bolus then 70 mL/kg bwt/day lactated Ringer's Solution¹ i.v.). Eight hours after the mare was presented, her signs of abdominal pain became increasingly severe, necessitating surgical exploration of the abdomen through a ventral midline celiotomy.

Surgical treatment

Pre-operative care

The mare was administered i.m. tetanus toxoid², 2L hypertonic saline solution³ i.v., cefazolin⁴ (11 mg/kg bwt i.v. q. 8 h), gentamicin sulphate⁵ (6.6 mg/kg bwt i.v. q. 24 h), and flunixin meglumine³ (1.1 mg/kg bwt i.v. q. 12 h). The mare was sedated with xylazine HCl³ (1 mg/kg bwt i.v.) and general anaesthesia was induced with ketamine HCl³ (2.2 mg/kg bwt i.v.) and diazepam¹ (0.05 mg/kg bwt i.v.). Anaesthesia was maintained by administering a mixture of isoflurane and oxygen through an endotracheal tube and by administering ketamine HCl³ (50 µg/kg bwt/min i.v.) and 2% lidocaine³ (50 µg/kg/min bwt i.v.).

Exploration of the mare's abdominal cavity found the large colon to be displaced cranially and together with the caecum passing through a rent (16 cm in length) in the mesoduodenum. The large colon and caecum traversed through the mesoduodenal rent from right to left, entrapping the bowel between the duodenum and the greater curvature of the stomach. The mesocolonic veins and lymphatic vessels were moderately distended, but the colon and caecum were not oedematous and the colour of each was normal. The displaced colon and caecum were replaced with difficulty, but without emptying the colon, through the rent in the mesoduodenum and returned to their normal anatomical positions. Routine closure of the celiotomy was performed with

the linea alba closed using synthetic, absorbable 6 metric polyglactin 910⁶ suture in an inverted cruciate pattern, the subcutaneous tissues were closed using synthetic, absorbable 2.5 metric polydioxanone sulphate⁶ suture in a simple continuous pattern, and the skin closed using skin staples⁷. The mare recovered uneventfully from anaesthesia.

Right flank laparoscopy

Twenty-four hours following ventral midline celiotomy, and with the mare still off feed from her previous exploratory

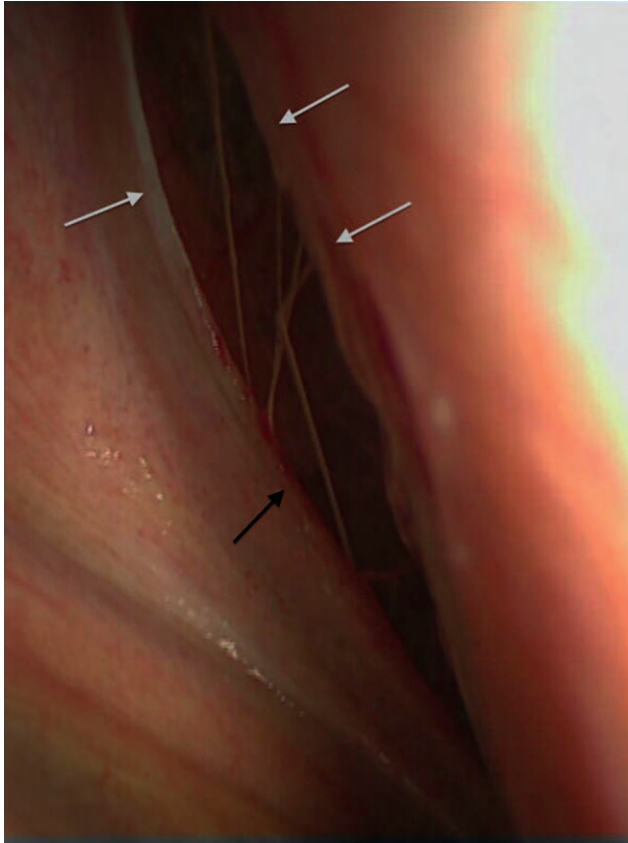


Fig 1: Laparoscopic appearance of the mesoduodenal rent from which the most of the large colon and a small portion of the caecum had been removed 24 h previously. Note the haemorrhage (black arrows) present along the margin of the defect (white arrows). Cranial is to the right of the image.

laparotomy, laparoscopic repair of the mesoduodenal rent was performed. To repair the rent, the mare was placed in stocks and sedated with butorphanol tartrate² (0.02 mg/kg bwt i.v.) and detomidine HCl² (0.02 mg/kg bwt i.v.). Sedation was maintained by administering detomidine in 1L isotonic saline solution (0.01 mg/kg bwt/h i.v.) by constant rate infusion. The right flank, extending from the 16th intercostal space to 10 cm caudal to the tuber coxae, was prepared for aseptic surgery. Each of three proposed incision sites for laparoscopic portals in right flank were desensitised with 20 mL of 2% mepivacaine HCl² injected subcutaneously and intramuscularly. Portals were created at the 17th intercostal space, slightly ventral to an imagined line drawn horizontally through the ventral border of the tuber coxae (cranial portal), a site at the dorsal aspect of the crus of the internal abdominal oblique muscle, midway between the ventral aspect of the tuber coxae and the last rib (middle portal) and a site 6 cm ventral to the middle portal (i.e. the ventral portal). To equilibrate intra-abdominal pressure with atmospheric pressure, an Argyle® 24-Fr chest⁸ tube was inserted into the abdominal cavity through a 1-cm incision in the left flank at the dorsal aspect of the crus of the internal abdominal oblique muscle, midway between the ventral aspect of the tuber coxae and the last rib (middle portal).

The rent in the mesoduodenum was located during examination of the right cranial aspect of the abdomen, through a 40-cm long, 10-cm diameter, 30-degree forward-viewing laparoscope inserted into the abdominal cavity through the cannula at the cranial portal (**Fig 1**). The margin of the mesoduodenal rent was sharp and hemorrhagic, and the rent was spanned by multiple thin strands of erythematous mesenteric tissue. The laparoscope was repositioned to the middle portal, and the abdomen insufflated with CO₂ to 12 mm Hg to enhance observation of the mesoduodenal defect. Babcock laparoscopic forceps inserted through the ventral portal were used to maintain tension on the duodenum. The rent was closed within a simple-continuous suture pattern with 3.5-metric, braided, synthetic, absorbable, polyglycolide colactide suture attached to the centre of a 9-mm long, 0.9-mm wide needle, sharp on both ends, using a 38-cm long Endo Stitch Automatic Endoscopic Suturing Device⁹ inserted through the cranial portal (**Fig 2**). The abdomen was decompressed, and two layer closure of the portals performed via placement of a single cruciate suture of 3.5-metric polydioxanone sulphate in the muscle layer and stainless steel staples for the skin.

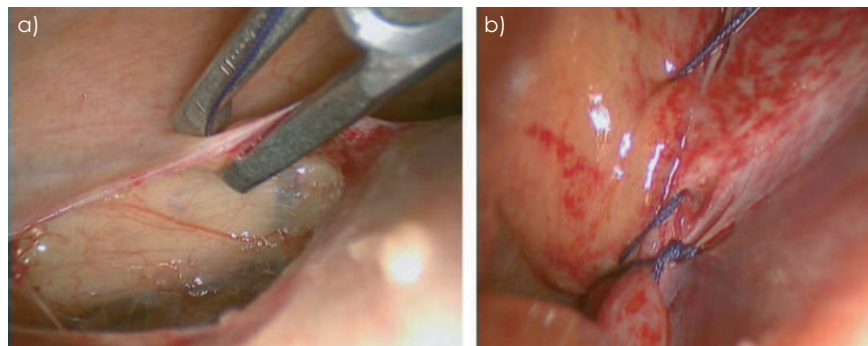


Fig 2: Laparoscopic repair of the mesoduodenal rent a) Initial bite b) Appearance of the most dorsal portion of the mesoduodenal rent after laparoscopic closure. Cranial is to the right of the image.

Post-operative care

The mare was administered fluids (LRS, 60 mL/kg bwt/day i.v.), lidocaine (0.05 mg/kg bwt/min i.v.), cefazolin⁴ (11 mg/kg bwt i.v. q. 8 h), and gentamicin sulphate⁵ (6.6 mg/kg bwt i.v. q. 24 h) for 3 days and firocoxib (0.2 mg/kg bwt loading dose i.v. q. 24 h, then 0.09 mg/kg bwt per os q. 24 h) for 5 days.

Outcome

The mare remained free from clinical signs of abdominal discomfort after the entrapped large colon and caecum were returned to their correct position and the rent laparoscopically repaired. The mare was discharged from the hospital 11 days after laparoscopic closure of the mesoduodenal rent. The owners, when contacted 6 months after the mare was discharged, reported that the mare had remained free of signs of abdominal pain or discomfort.

Discussion

Incarceration of intestine in a mesoduodenal rent as a cause of colic in the horse has been reported only rarely (Phillips and Walmsley 1993; Gayle *et al.* 2000; Sutter and Hardy 2004; Mair and Smith 2005). Of the reported cases of mesoduodenal rents, all involve the small intestines, most commonly the jejunum (Sutter and Hardy 2004; Withers and Mair 2008; Witte *et al.* 2013). Incarceration of the colon has been well documented as secondary to mesocolic rents (Booth *et al.* 2000, Torre 2000; Rackestraw and Hardy 2012; Torre *et al.* 2010, tears in the gastrosplenic ligament (Trostle and Merkel 1993), in abnormal mesenteric bands (Mogg *et al.* 1992) or in one recent report the apex of the caecum within the epiploic foramen (Grzeskowiak *et al.* 2017).

Defects in the mesentery may be congenital (e.g. diverticular bands) or acquired (e.g. trauma, iatrogenic) (Withers and Mair 2008; Freeman 2012). Mares are reportedly more often affected than are males, and are most commonly affected during a periparturient period (Withers and Mair 2008; Freeman 2012). Although the parity of the mare in this report was not known, the owners reported that the mare had not been bred during the decade they owned her. The mare had neither incurred trauma recently nor had undergone colic surgery while under the present owners' care. Though the cause of the mesoduodenal rent in this mare was not known, the rent may have occurred secondary to stretching of the mesoduodenum as a consequence of displacement of the large colon. Incarceration of the large colon through a rent in the mesoduodenum in this mare represents a yet unreported cause of colic in the horse. An additional entrapment of the caecum by an omental rent was likely incidental to other lesions, but nonetheless, may have contributed to signs of abdominal discomfort displayed by this mare.

Ventral midline celiotomy was required to correct the cranial displacement and incarceration of the large colon and caecum through the mesoduodenal rent, but this approach was inadequate to observe and close the mesoduodenal defect. The rent was closed laparoscopically, with the mare standing, to prevent intestine from again becoming incarcerated by the mesoduodenal rent.

Laparoscopy allows surgical access to structures, including the duodenum, inaccessible through a ventral

midline celiotomy (Galuppo *et al.* 1995; Hendrickson 2012; Graham and Freeman 2014). Laparoscopic closure of a mesoduodenal rent entrapping small intestine, performed with the horse standing, has been reported (Sutter and Hardy 2004). In the case reported here, and as reported by Sutter and Hardy, placement of the laparoscopic portal in the right flank allowed adequate observation and closure of the mesoduodenal rent in this mare. Absorbable suture material was used to close the rent of this mare, though a barbed suture, had it been available, may have simplified closure of the rent (Albanese *et al.* 2016; Gandini *et al.* 2017).

Incarceration of the large intestines or caecum through a mesoduodenal rent should be considered as a differential cause of colic in the adult horse. Based on the case reported here, successful outcome following surgical correction and standing laparoscopic repair of a mesoduodenal rent in the horse is possible.

Ethical animal research

There is no ethical review body for client treated cases that would need reporting here. This was a case treated in clinics as a patient at the University of Tennessee College of Veterinary Medicine. Express approval has been obtained by the owner from the author Robert T. Snowden.

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None.

Authorship

E. E. Cypher, J. Blackford, R. T. Snowden, J. A. Sexton and J. Schumacher all involved manuscript preparation and approval E. E. Cypher, J. Blackford, R. T. Snowden and J. Schumacher clinical surgery.

Manufacturers' addresses

¹Hospira Inc., Lake Forest, Illinois, USA.

²Zoetis Inc., Kalamazoo, Michigan, USA.

³MWI Boise, Idaho, USA.

⁴Hikma farmaceutica, Portugal.

⁵Sparhawk Laboratories, Inc., Lenexa, Kansas, USA.

⁶Ethicon INC., Somerville, New Jersey, USA.

⁷Covidien LLC, Mansfield, Massachusetts, USA.

⁸Sherwood Medical St. Louis, Missouri, USA.

⁹Auto Suture Company, Division of Covidien Surgical, Norwalk, Connecticut, USA.

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Clinical Commentary

Mesoduodenal rents: An uncommon cause of colic

J. Williams* 

Large Animal Medicine, University of Georgia, Athens, USA

*Corresponding author email: jarred@uga.edu

Keywords: horse; mesoduodenal

The authors of the accompanying case report (Cypher *et al.* 2020) describe a unique lesion as a cause of colic in a 12-year-old Tennessee Walking Horse mare. They reported an entrapment of the large colon and caecum within a rent in the mesoduodenum that was identified and corrected via a ventral midline celiotomy. Approximately 24 h after successful recovery from surgery and anaesthesia, the mare underwent a standing laparoscopy, in which the mesoduodenal rent was identified and successfully repaired. Follow-up with the mare's owner 6 months later indicated that the mare was doing well post-operatively, as defined by no signs of colic after being discharged from their hospital.

Incarcerations involving portions of the equine gastrointestinal tract within a space in the abdomen are not unique, whether that space is natural (i.e. the epiploic foramen, inguinal ring) or created after a tear has occurred in a tissue (i.e. the diaphragm, gastrosplenic ligament, mesentery) (Phillips and Walmsley 1993; Gayle *et al.* 2000; Sutter and Hardy 2004; Mair and Smith 2005; Freeman 2012). In most scenarios, the entrapped bowel is a section of the small intestine rather than the large colon (Phillips and Walmsley 1993; Mair and Smith 2005; Freeman 2012); likely a result of the size of bowel, the diameter of the opening and the relatively emptiness of the small intestine vs. the large colon. Thus, entrapment of the entire large colon and caecum through a rent in the mesoduodenum as reported by Cypher *et al.* (2020) is fascinating. The most similar reported lesion is incarceration of the large colon through the epiploic foramen of a 6-year-old Thoroughbred stallion (Steenhaut *et al.* 1993).

Since the mesoduodenum, unlike the mesojejunum, is very short, a tear large enough for the large colon to pass through must be oriented parallel with the duodenum. Amazingly, the health of the duodenum was not in question in the affected horse, suggesting that the vessels within the mesoduodenum were unaffected by the large rent, a truly fortunate scenario. Had the blood supply to the duodenum been affected to the point of tissue ischaemia and necrosis, the horse would have required the use of a unique and experimental technique for resection and anastomosis in that location.

Reports of bowel entrapped within mesoduodenal rents are scarce (Phillips and Walmsley 1993; Gayle *et al.* 2000; Sutter and Hardy 2004; Mair and Smith 2005). In a 2016 case series of 38 broodmares with duodenojejunal mesenteric rents, the overall short- and long-term survival rates were 76% and 74% respectively (Lawless *et al.* 2016). However, when adjusted for horses that survived to discharge, the long-term survival rate was 97%. The mesenteric rent was closed in 85% of the mares via the ventral midline celiotomy, oftentimes, partially blindly. They reported that failure to close the rent was associated with increased odds of colic after discharge

but had no effect on survival (Lawless *et al.* 2016). Of the mares with rents not closed during the initial surgery, two mares were examined for colic caused by re-entrapment of small intestine within the rent. In both cases, closure was performed during the repeat exploratory surgery. A third mare presented for colic, but ultimately did not have a ventral midline celiotomy. The rent was closed; however, via a standing laparoscopic flank approach and there was no further report of colic (Lawless *et al.* 2016). In that case series, the typical location of the rent was at the junction of the mesoduodenum and proximal mesojejunum, axial to the caecum where the mesentery courses to its root, oftentimes extending into the attachment with the dorsal body wall (Lawless *et al.* 2016). This location is different from the one reported by Cypher *et al.* (2020), in which the rent was within the mesoduodenum of the descending duodenum abaxial to the caecum.

While the right-to-left direction of the entrapment is unimportant, it does help one to rationalise the development of the lesion. Right dorsal displacements do not always have the same intra-abdominal configuration; oftentimes the pelvic flexure is within the right caudal quadrant of the abdomen, rather than the left (Rakestraw and Hardy 2012). The path of migration is surmised as a retroflexion of the pelvic flexure and accompanying left dorsal and ventral colon cranially, until they have migrated between the stomach and sternal/diaphragmatic flexures of the colon. If the pelvic flexure continues to displace along this path, it will then move between the right dorsal/ventral colon and caecum, and right body wall, until ultimately coming to rest in the right caudal quadrant. This path is most commonly encountered as there are few impediments to movement between the right gastrointestinal viscera and the right body wall. In the case described by Cypher *et al.* (2020), one can assume that rather than the pelvic flexure moving strictly caudally after displacing to the right side of the abdomen, it migrated dorsally through a rent in the mesoduodenum. This naturally makes one wonder whether the rent was a pre-existing lesion or if it was traumatically created? The description of the appearance of the rent in duodenum via laparoscopic evaluation as 'sharp and haemorrhagic' suggests that traumatic tearing with subsequent colon migration was likely (Cypher *et al.* 2020).

While the mare had a 56-h history of anorexia and/or colic prior to surgery (Cypher *et al.* 2020), it is impossible to know whether this prolonged period of time before surgical intervention increased the likelihood of the tear occurring or if it occurred early in the disease process. However, it is also important not to dismiss the time as a potential factor. As was the situation with this case, there is always a large degree of subjectivity when deciding on the management of a colicky horse. This dilemma is one that is a fundamental crossroad in

the decision-making of any attending veterinarian; when is the 'right' time to explore an abdomen vs. continued medical management? Anecdotally, when the economic downturn occurred, many veterinarians attending horses with colic were forced to expand medical management beyond their previous convention. As a result, they learned how long horses with nonstrangulating obstructions could be treated without surgery and still have the potential for a positive outcome. Of course, all actions come at a cost and the reward of medically managing a colicky horse is juxtaposed with the horror of a worsened outcome when medical management is unsuccessfully pursued in a patient with a surgical option. Comfort with lesion classification (strangulating vs. nonstrangulating obstruction) is paramount, but because one can never be certain of a preoperative diagnosis, the clinician must rely on the degree and longevity of pain, clinical impression and experience when/while deciding to progress to surgical management.

After the ventral midline celiotomy was completed, Cypher *et al.* (2020) chose to perform a standing laparoscopy in an effort to view, assess and repair the mesoduodenal rent. The purpose of repairing this lesion was to prevent recurrence. Because laparoscopic repair of a rent of this size previously would have been considered rare, the decision to repeat an abdominal surgery, albeit minimally invasively, 1 day later for prophylactic purposes, must have been carefully deliberated. The decision to proceed was ultimately correct, as the lesion was identified, accessible and repaired and there has been no recurrence of colic. The confidence to proceed with the second surgery must have come from a number of factors: mastery of the anatomy, confidence and experience of laparoscopy and the knowledge of previous literature describing similar circumstances.

Over the past few years, surgeons' comfort and experience of standing laparoscopic repair of rents and potential spaces have improved. For example, numerous reports describe closure of the epiploic foramen and internal inguinal ring (Wilderjans *et al.* 2012; Ragle *et al.* 2013; Rossignol *et al.* 2014; van Bergen *et al.* 2016; Munsterman *et al.* 2014). Closure of the mesenteric rents, in particular mesoduodenal rents are also in the literature (Sutter and Hardy 2004; Witte *et al.* 2013; Lawless *et al.* 2016). The importance of knowing this literature prior to attempting a repair similar to that described in the present case report should be emphasised.

In summary, the authors (Cypher *et al.* 2020) describe a very unique and unusual gastrointestinal lesion causing signs of colic. The surgical management and decision-making on the case led to a favourable outcome thus far, and demonstrate the value of experience, surgical skills and the knowledge of anatomy and literature when encountering a new problem intraoperatively. This is a scenario that equine veterinarians are likely to encounter on occasion.

Author's declaration of interests

No conflicts of interest have been declared.

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Original Article

Comparison of visual lameness scores to gait asymmetry in racing Thoroughbreds during trot in-hand

T. Pfau^{†‡*} , M. F. Sepulveda Caviedes^{†‡}, R. McCarthy[†], L. Cheetham[†], B. Forbes[§] and M. Rhodin[¶] 

[†]Department of Clinical Science and Services, The Royal Veterinary College; [‡]Structure and Motion Lab, The Royal Veterinary College, Hatfield, Hertfordshire, UK; [§]Singapore Turf Club, Singapore; and [¶]Department of Anatomy, Physiology and Biochemistry, Swedish University of Agricultural Sciences, Uppsala, Sweden

*Corresponding author email: tpfau@rvc.ac.uk

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Summary

Regular monitoring of movement asymmetry with inertial measurement units (IMUs) to aid in the diagnosis of the underlying cause of a lameness is feasible. Normal ranges for specific groups of horses may be required, with consideration of expert veterinary opinions for both asymmetry screening and lameness assessment. The aim of this study was to determine movement asymmetry values compared with expert lameness scores to enable screening for lameness in Thoroughbreds in race training. IMU gait assessment during in-hand trot-up was performed in 25 racehorses undergoing routine gait analysis or lameness examination at the Singapore Turf Club. Video recordings were graded numerically (0–5) for lameness by six experienced racehorse veterinarians. Inter-observer agreement and consistency were determined. Median lameness scores were used to calculate sensitivity and specificity for head, withers and pelvic movement asymmetry. Guideline values for aligning movement asymmetry values with expert opinions about forelimb and hindlimb lameness were determined from receiver operating characteristics (ROC). Inter-observer agreement was poor to fair, inter-observer consistency was good (intraclass correlation coefficient: 0.667 for forelimbs and 0.617 for hindlimbs). ROCs indicated higher discriminative power for hindlimb lameness using pelvic asymmetry (90% sensitivity, 93% specificity) compared with forelimb lameness using head asymmetry (69% sensitivity, 89% specificity) or withers asymmetry (44% sensitivity, 89% specificity). When compared to expert lameness scores from videos of a limited number of Thoroughbred racehorses, preliminary guideline values for movement asymmetry screening for forelimb lameness (>|14.5 mm|) and hindlimb lameness (>|7.5 mm|) are higher than previously reported clinical thresholds of >|7 mm| for head movement and >|4 mm| for pelvic movement asymmetry.

Introduction

Lameness is a major cause of lost days in training for Thoroughbred racehorses (Jeffcott *et al.* 1982; Rosedale *et al.* 1985; Bailey *et al.* 1997; Olivier *et al.* 1997; Dyson *et al.* 2008). Inertial measurement units (IMUs) have been reported accurate and precise for quantifying movement asymmetry (Pfau *et al.* 2005; Warner *et al.* 2010; Keegan *et al.* 2011). Movement asymmetry threshold values for clinical lameness examinations have been determined based on repeat

assessments, (Keegan *et al.* 2011) and through comparison with expert veterinary visual assessment after induction of lameness (McCracken *et al.* 2012) with the aim of quantifying the effect of diagnostic analgesia. After administration of local diagnostic analgesia, changes above these clinical thresholds can be reliably quantified based on receiver operating characteristics (Maliye *et al.* 2013) and used in support of clinical lameness decision-making. The mobile nature of IMUs enables the regular monitoring of gait (Ringmark *et al.* 2016) aiming at early detection of lameness or injury.

It is not clear, however, whether the previously reported clinical lameness thresholds (Keegan *et al.* 2011; McCracken *et al.* 2012) are suitable for use as 'lameness screening thresholds' for long-term monitoring of Thoroughbred racehorses in training. The distinction between previously reported clinical lameness thresholds and asymmetry screening thresholds is crucial since the former assesses for the occurrence of lameness in an environment of expected high prevalence, while the latter aims at identifying horses exceeding the expected normal variation of the investigated cohort, where prevalence of abnormality is unknown. A high proportion of horses deemed to be free from lameness by owners or trainers are identified as outside previously reported clinical lameness thresholds (Pfau *et al.* 2015, 2016b; Rhodin *et al.* 2015, 2017). The comparatively high percentage (up to 67%) of Polo horses found outside previously reported clinical thresholds (Pfau *et al.* 2016b) supports the need for breed and use specific lameness screening thresholds for horses. Also, racing Thoroughbreds frequently operate near their limits as evidenced by the relationship between the number of gait cycles at high speed and their increased fracture risk (Reed *et al.* 2012).

Therefore, screening thresholds should also be aligned with what veterinarians perceive to be gait patterns that represent lameness. Visual gait scoring appears limited to reliably detecting movement asymmetries >25% (higher than the clinical thresholds of 6 mm for head movement and 3 mm for pelvic movement [McCracken *et al.* 2012]) likely contributing to inconsistencies between observers (Keegan *et al.* 1998, 2010). A comparison between expert gait scoring and quantitative gait parameters is hence likely to identify higher values than the previously reported tight clinical thresholds, however, before prospective, longitudinal studies have been conducted relating changes in daily (weekly, monthly) gait asymmetry to risk of injury, it appears of interest to investigate asymmetry values that align with the opinion of

experienced veterinarians familiar with the specific type of horses of interest.

The aim of this study was to provide supporting evidence for aligning movement asymmetry values with expert veterinary gait scores for racing Thoroughbreds in training. It was hypothesised that inter-observer agreement and consistency are independent of the group of horse investigated and hence will be in line with previous studies in non-Thoroughbreds. It was also hypothesised that asymmetry values distinguishing between horses considered lame and non-lame, with sufficiently high specificity, will be higher than previously reported clinical lameness thresholds. Also investigated was whether the relationship between head and withers movement asymmetry aids differentiation between forelimb lameness and hindlimb lameness as has been previously indicated experimentally (Persson-Sjodin *et al.* 2016).

Materials and methods

This study is part of a longitudinal study funded by the Horserace Betting Levy Board and approved by the RVC Ethics and Welfare Committee (URN_2013_1238).

Horses

Twenty-five Thoroughbred racehorses in training at the Singapore Turf Club (STC) were recruited; six horses presented for lameness examinations and 19 horses selected randomly from horses undergoing routine gait analysis. The group mean age was 4.6 years (median 4.4, range 3.2–8.4), there were three mares and 22 geldings.

Gait analysis system

Horses were equipped with five IMUs (4x MTx,¹ 1x MTi-G¹) attached to head, withers, between the tubera sacrale (MTi-G¹) and to left and right tuber coxae.

Quantitative gait assessment

Horses were trotted in-hand on concrete for approximately 50 m aiming to collect data for >27 strides (Keegan *et al.* 2011), whilst being filmed with a Nikon1² (J2) digital camera (viewed from front and behind). Data were collected simultaneously from all IMUs at 100 Hz sample rate per individual data channel via Bluetooth® to a nearby laptop computer. MATLAB³ scripts processed the data. After sensor fusion based on tri-axial acceleration, tri-axial rate of turn and tri-axial magnetic field data was used to derive sensor orientation, accelerations were transformed into a right handed Cartesian horse/gravity based reference frame (z: vertical, up positive, x: positive forwards, y: perpendicular to x and z) and double integrated to displacement (Pfau *et al.* 2005; Warner *et al.* 2010) and segmented into strides (Starke *et al.* 2012). Gait asymmetry values were derived per stride (Fig 1) and median values across strides were calculated:

- HDmin, WDmin, PDmin: differences between displacement minima during contralateral stance phases from head (H), withers (W) and mid pelvis (P).
- HDmax, WDmax, PDmax: differences between displacement maxima after contralateral stance phases from head (H), withers (W) and mid pelvis (P).
- HDD: hip hike difference calculated as the difference between left tuber coxae upward movement during right hind (RH) stance and right tuber coxae upward movement during left hind (LH) stance.

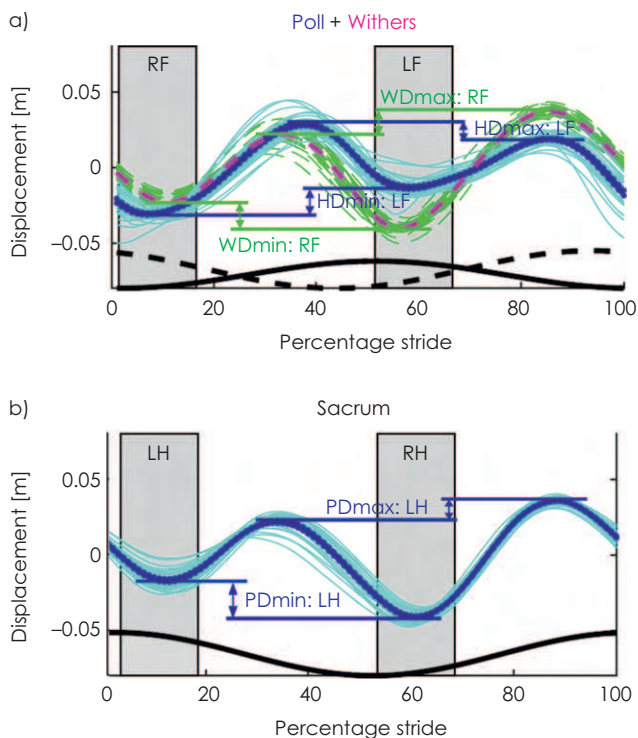


Fig 1: Mean vertical displacement of head (a, thick blue line), withers (a, thick green/magenta line) and tuber sacrale (b, thick blue line) movement in one of the study horses. This horse shows movement asymmetry with reduced vertical head movement during LF stance, reduced vertical withers movement during RF stance and reduced vertical tuber sacrale movement during LH stance. Directionality of movement asymmetry parameters (Table 3) is given next to the double arrows illustrating the differences between displacement minima or maxima. Displacement is given in m; black and black dashed lines illustrate amount and phase of asymmetry between strides halves (Audigié *et al.* 2002) and thin (green and cyan) lines are representing individual strides (in this example 31 strides) allowing to assess stride-to-stride variability.

Visual lameness scores

Six experienced veterinary surgeons at STC viewed the 25 videos with audio of the trotting horses (viewed from the front and from behind), allowing them to watch videos repeatedly at normal speed, pause or rewind as necessary. Veterinarians were blinded to horse identity and asked to score the gait using a numerical 0–5 scale (0–nonlame; 5–non-weight bearing lame), with a degree of lameness assigned to one or multiple limbs. Assessors were asked not to compare scores or discuss findings with each other and they had no access to the gait analysis data.

Data analysis

SPSS⁴ (v23.0.0.3) was used for statistical analysis.

Inter-observer agreement and consistency

Inter-observer agreement was assessed between 15 pairs of observers using Cohen's Kappa coefficient (κ). Category boundaries were as previously defined by Landis and Koch (1977): >0.8–almost perfect, >0.6–substantial, >0.4–moderate, >0.2–fair, >=0–slight, and <0–poor. Inter-observer consistency

was calculated using mean two-way random intraclass correlation coefficients (with option 'consistency') across all six observers (ICC(2,6)) with category boundaries as defined by Cicchetti (1994): <0.40–poor, 0.40 to 0.59–fair, 0.60 to 0.74–good, and 0.75 to 1.0–excellent).

Aligning forelimb and hindlimb lameness scores with gait asymmetry

Horses were categorised based on the median visual lameness score across observers: negative values for left sided lameness, positive values for right sided lameness:

- Nonlame: neither forelimb nor hindlimb lame
- Forelimb only: forelimb lame but not hindlimb lame
- Hindlimb only: hindlimb lame but not forelimb lame
- Ipsilateral: identified as forelimb and hindlimb lame on same side
- Contralateral: identified as forelimb and hindlimb lame on opposite sides

In order to combine left and right limb lame horses for calculating sensitivity and specificity, asymmetry parameters were inverted for horses visually identified as left forelimb or left hindlimb lame, rendering horses typically right forelimb and right hindlimb asymmetric, respectively, in terms of movement symmetry data, i.e. expecting positive values for HDmin and PDmax and negative values for HDmax, PDmin and HHD. Sensitivity and specificity for detecting forelimb lameness were calculated using horses of category 2 (forelimb only), 4 (ipsilateral forelimb and hindlimb) and 5 (contralateral forelimb and hindlimb) for the 'lame' category and horses of category 1 (nonlame) and category 3 (hindlimb only) for the 'sound' category. Sensitivity and specificity for detecting hindlimb lame horses were calculated using horses of category 3 (hindlimb only), 4 (ipsilateral forelimb and hindlimb) and 5 (contralateral forelimb and hindlimb) for the 'lame' category and horses of category 1 (nonlame) and 2 (forelimb only) for the 'sound' category. Receiver operating characteristics (ROC) curves were created for head and withers variables for forelimb lameness and for pelvic variables for hindlimb lameness based on side corrected movement asymmetry data. Area under the curve (AUC) and its confidence interval were calculated.

Discrimination between forelimb and hindlimb lameness based on head and withers movement asymmetry

The ability to use the relationship between HDmin and WDmin to differentiate between forelimb and hindlimb lame horses was investigated for all horses that were found to be concurrently outside 'normal ranges' for both pelvic and head movement asymmetry. For categorising existence and side of lameness, previously reported clinical thresholds values of $>|6\text{ mm}|$ for head movement asymmetry and $>|3\text{ mm}|$ for pelvic movement asymmetry (McCracken *et al.* 2012) were adapted to $>|7\text{ mm}|$ for HDmin and $>|4\text{ mm}|$ for PDmin based on correction equations presented in (Pfau *et al.* 2016a). Horses with HDmin and WDmin values showing same signs were categorised as forelimb lame, horses with HDmin and WDmin of opposite sign were categorised as hindlimb lame (Persson-Sjodin *et al.* 2016; Pfau *et al.* 2017). For qualitative comparison between visual assessment and quantitative asymmetry measurement, the side of lameness was defined

from HDmin for forelimb lameness and PDmin for hindlimb lameness (based on previously identified associations with peak force asymmetry (Keegan *et al.* 2012; Bell *et al.* 2016)).

Results

Visual lameness scores

Lameness scores of all horses are given in **Table 1** (forelimbs) and **Table 2** (hindlimbs) together with median scores across observers. Based on median scores, nine horses were considered nonlame in front, eight horses right forelimb (RF) lame and eight horses left forelimb (LF) lame. Median hindlimb scores found 15 nonlame horses and ten hindlimb lame horses (7 with RH lameness and 3 with LH lameness).

Quantified gait asymmetries

Asymmetry values varied across horses with means of absolute asymmetry values (row abs mean in **Table 3**) of 6 mm (0–17 mm, HDmax), 9 mm (0–32 mm, WDmax), 12 mm (1–57 mm, WDmin, 1–62 mm, PDmin), 13 mm (2–49 mm, PDmax), 19 mm (2–67 mm, HDmin) and 27 mm (1–137 mm, HHD).

Applying previously reported clinical lameness thresholds to HDmin and PDmin, 12 horses showed RF and 6 horses LF lameness, 10 horses RH and 6 horses LH lameness. HDmin and PDmin were concurrently outside previously reported clinical thresholds for eleven horses (nine showing ipsilateral head/pelvis asymmetry, two contralateral head/pelvis asymmetry).

TABLE 1: Forelimb lameness scores (0–5) of 25 racing Thoroughbreds obtained from videos (with sound, cranial/caudal views) of in-hand trotups on hard surface (concrete/cement) for six experienced racing veterinarians (at Singapore Turf Club)

ID	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	FLMEDIAN
1	0	0	1LF	2RF	1RF	0	0
2	1RF	1RF	0	3RF	2RF	3RF	2RF
3	1LF	0	1LF	2LF	1LF	2LF	1LF
4	2LF	2LF	1RF	3LF	2LF	2LF	2LF
5	1RF	0	0	2RF	2RF	0	1RF
6	0	0	0	1RF	0	1RF	0
7	0	1LF	0	3LF	2LF	1LF	1LF
8	1LF	0	0	0	1LF	2RF	0
9	0	1RF	0	2RF	0	1RF	1RF
10	1LF	0	1LF	1LF	1LF	2RF	1LF
11	2LF	2LF	0	3LF	2LF	2RF	2LF
12	0	0	0	1LF	1LF	2RF	0
13	2RF	2RF	0	3RF	3RF	3LF	2RF
14	1LF	1LF	0	1LF	1LF	1RF	1LF
15	0	2RF	1LF	3RF	3RF	2RF	2RF
16	3RF	2RF	3LF	3RF	3RF	2LF	3RF
17	0	0	0	1RF	0	0	0
18	0	0	0	1RF	1RF	0	0
19	2RF	2LF	0	3LF	3LF	2LF	2LF
20	0	0	2RF	1LF	0	0	0
21	0	0	0	1RF	0	2RF	0
22	0	0	0	2RF	1RF	0	0
23	0	1LF/1RF	0	1LF	1LF	1LF	1LF
24	2LF	0	1LF	3RF	1RF	2RF	1RF
25	1RF	2RF	3LF	3RF	3RF	3RF	3RF

ID: horse number, OBS1–OBS6: forelimb lameness scores attributed to each horse, FLMEDIAN: median forelimb lameness score (based on left sided lameness with negative sign, right sided lameness with positive sign).

TABLE 2: Hindlimb lameness scores (0–5) of 25 racing Thoroughbreds obtained from videos (with sound, cranial/caudal views) of in-hand trotups on hard surface (concrete/cement) for six experienced racing veterinarians (at Singapore Turf Club)

ID	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	HLMEDIAN	OVERALL	CAT
1	1RH	0	0	0	2RH	2RH	1RH	1RH	3
2	0	0	2RH	0	2RH	0	0	2RF	2
3	0	0	0	0	0	0	0	1LF	2
4	0	0	0	0	1RH	0	0	2LF	2
5	1LH	1LH	2LH	0	0	1RH	1LH	1RF1LH	5
6	2RH	1RH	0	0	3RH	1LH	1RH	1RH	3
7	2LH	0	0	0	1LH	3LH	1LH	1LF1LH	4
8	0	1RH	2RH	0	0	1RH	1RH	1RH	3
9	2RH	0	0	0	2LH	0	0	1RF	2
10	0	0	0	0	1RH	0	0	1LF	2
11	0	0	2RH	0	1LH	0	0	2LF	2
12	2LH	0	0	2LH	3LH	2RH	1LH	1LH	3
13	0	0	0	0	2RH	0	0	2RF	2
14	0	0	0	0	0	0	0	1LF	2
15	2RH	0	0	2RH	2RH	1LH	1RH	2RF1RH	4
16	0	0	0	0	1RH	1RH	0	3RF	2
17	1LH	0	0	0	0	0	0	Sound	1
18	1LH	0	0	0	0	3RH	0	Sound	1
19	0	0	0	0	2RH	0	0	2LF	2
20	2RH	1LH	0	0	1RH	2RH	1RH	1RH	3
21	1RH	0	0	0	1LH	0	0	Sound	1
22	2RH	0	0	0	2RH	2RH	1RH	1RH	3
23	1RH	0	0	0	1LH	0	0	1LF	2
24	3RH	2RH	0	3RH	4RH	3RH	3RH	1RF3RH	4
25	0	0	0	0	0	2RH	0	3RF	2

ID: horse number, OBS1–OBS6: hindlimb lameness scores attributed to each horse, HLMEDIAN: median hindlimb lameness score (based on left sided lameness with negative sign, right sided lameness with positive sign), OVERALL: combined lameness scores of forelimb (Table 1) and hindlimb lameness, CAT: category indicating type of lameness: 1: sound, 2: forelimb lame, 3: hindlimb lame, 4: ipsilateral concurrent forelimb and hindlimb lameness, 5: contralateral concurrent forelimb and hindlimb lameness.

Two horses were considered nonlame based on previously reported clinical lameness thresholds.

93.3% and a threshold of +10 mm for PDmax results in 50% sensitivity at 93.3% specificity.

Inter-observer agreement and consistency

Inter-observer agreement (kappa, **Supplementary Item 1**) indicates poor to fair agreement between pairs of observers. Consistency of assessments across all observers resulted in ICC values of 0.667 for forelimb lameness and 0.617 for hindlimb lameness, both indicating good consistency.

Aligning forelimb and hindlimb lameness scores with gait asymmetry

ROC curves are presented in **Figure 2** (A, forelimb lameness; B, hindlimb lameness). ROC curves for hindlimb lameness show higher AUC values of 0.890 (confidence interval [0.731;1.0]; PDmin), 0.743 ([0.537;0.950], PDmax) and 0.857 ([0.681;1.0], HDD) compared with 0.799 ([0.620;0.977], HDmin), 0.767 ([0.571;0.964], HDmax), 0.653 ([0.425;0.881], WDmin) and 0.521 ([0.293; 0.748], WDmax) for forelimb lameness.

For forelimb lameness, a threshold of +14.5 mm for HDmin results in 68.8% sensitivity and 88.9% specificity. A threshold of –5 mm for HDmax results in 43.8% sensitivity with 88.9% specificity. Withers values show lower discriminative performance than head movement values (+7 mm for WDmin: 37.5% sensitivity and 88.9% specificity; 0.5 mm for WDmax: 43.8% sensitivity and 88.9% specificity).

For hindlimb lameness, a threshold of –7.5 mm for PDmin results in 90% sensitivity and 93.3% specificity, a threshold of –15 mm for HDD results in 80% sensitivity with a specificity of

Discrimination between forelimb and hindlimb lameness based on head and withers movement asymmetry

Eleven horses were quantified with concurrent forelimb and hindlimb lameness based on the adapted previously reported clinical HDmin and PDmin thresholds (McCracken *et al.* 2012; Pfau *et al.* 2016a) (**Table 3**, column ORIG THRESS +HW). Three of these horses had been visually assessed as concurrently forelimb and hindlimb lame. In the remaining eight horses, the head-withers asymmetry relationship was used to select the primary lameness. In six of these horses, the chosen primary lameness agreed with visual gait scoring. In one horse movement asymmetry identified a primary hindlimb lameness and visual scoring a forelimb lameness. In the remaining horse, movement asymmetry identified a primary RH lameness with concurrent RF lameness and visual gait scoring identified a LF lameness.

Prompted by the observation that horses with induced forelimb or hindlimb lameness show differences in the relationship between head and withers movement asymmetry (Persson-Sjodin *et al.* 2016) and that racing Thoroughbreds show these patterns (Pfau *et al.* 2017), we further (qualitatively) investigated the head-withers movement asymmetry relationship.

In six of eight horses identified by quantitative gait analysis as concurrently forelimb and hindlimb lame and deemed unilaterally lame by visual gait scoring (**Table 3**, CLIN THRS +

TABLE 3: Visual lameness scores (median across six observers, 0–5 scale, cranial/caudal views with audio, in-hand trot, hard surface) and head (HDmin), withers (WDmin) and pelvic (PDmin) movement asymmetry measures quantifying asymmetry of weight bearing between contralateral limbs

Horse	HDmin	HDmax	WDmin	WDmax	PDmin	PDmax	HHD	Visual Score	ORIG THRES + HW	ROC THRES + HW
1	19RF	(3LF)	4LF	8RF	11RH	(4LH)	2RH	1RH	RFRH	RFRH
2	24RF	(1RF)	1LF	4RF	(2RH)	11LH	15LH	2RF	RF	RF
3	10LF	10RF	1LF	10RF	(1RH)	12RH	13RH	1LF	LF	LF
4	38LF	(1RF)	18RF	6LF	22LH	8RH	31RH	2LF	LFLH	LFLH
5	22RF	9RF	18RF	32RF	8LH	36LH	46LH	1RF1LH	RFLH	RFLH
6	8RF	(4LF)	10LF	1RF	20RH	(2RH)	30RH	1RH	RFRH	RH
7	17LF	10RF	18RF	16LF	24LH	12RH	43RH	1LF1LH	LFLH	LFLH
8	(4RF)	15LF	3RF	1LF	(4LH)	15LH	23LH	1RH	Nonlame	Nonlame
9	21RF	(1RF)	9RF	1RF	(1LH)	(4RH)	2RH	1RF	RF	RF
10	8RF	(0)	2RF	1LF	(1LH)	6LH	6LH	1LF	RF	Nonlame
11	45LF	(3LF)	2LF	5LF	6LH	6LH	4RH	2LF	LFLH	LF
12	(7RF)	(2RF)	20RF	1LF	23LH	12RH	44RH	1LH	LH	LH
13	24RF	(3LF)	4RF	3LF	7RH	15LH	17LH	2RF	RFRH	RF
14	12RF	(2LF)	11LF	4LF	17RH	7RH	10LH	1LF	RFRH	RH
15	32RF	(8RF)	11LF	4RF	22RH	(4RH)	17RH	2RF1RH	RFRH	RFRH
16	28RF	11RF	17RF	4LF	5RH	6RH	13RH	3RF	RFRH	RF
17	(6RF)	(4RF)	3LF	0	(4RH)	(4LH)	1LH	Nonlame	Nonlame	Nonlame
18	(5RF)	(1LF)	17RF	8RF	11LH	14LH	29LH	Nonlame	LH	LH
19	52LF	(6RF)	17LF	9RF	6RH	15LH	15LH	2LF	LFRH	LF
20	(6RF)	(2RF)	21LF	2LF	35RH	26RH	75RH	1RH	RH	RH
21	12RF	16LF	5RF	5LF	(3LH)	(3LH)	12LH	Nonlame	RF	Nonlame
22	(2LF)	(6RF)	17LF	2RF	16RH	(4RH)	26RH	1RH	RH	RH
23	8LF	17RF	2RF	3RF	(1LH)	6RH	10RH	1LF	LF	Nonlame
24	(5RF)	(2RF)	57LF	32LF	62RH	49RH	137RH	1RF3RH	RH	RH
25	67RF	(0)	15RF	32RF	(4RH)	28LH	34LH	3RF	RF	RF
Mean abs	19 mm	6 mm	12 mm	9 mm	12 mm	13 mm	27 mm			

Asymmetry measures are given in mm with the addition of LF, RF, LH, RH indicative of the direction of lameness (with head and withers movement relative to forelimb stance phases and pelvic movement relative to hind limb stance phases) according to the 'typical' lameness curve presented in (Buchner *et al.* 1996) with reduced vertical movement during lame (forelimb or hindlimb) stance. Values in brackets are below the clinical lameness thresholds. Visual score: median lameness score across six experienced racehorse veterinarians. Limb in bold is primary lameness based on law of sides.

ORIG THRES +HW: categorisation using clinical lameness thresholds and using head-withers relationship to identify the primary lameness in horses with concurrent forelimb and hindlimb lameness. Limb in bold is primary limb identified from head-withers relationship. ROC THRES + HW: categorisation using revised thresholds from this study and using head-withers relationship to identify the primary lameness in horses with concurrent forelimb and hindlimb lameness. Limb in bold is primary limb identified from head-withers relationship. Values in red: disagreement in side of lameness between visual score and quantitative gait analysis. Values in blue: changes between original and revised thresholds.

HW), the head-withers relationship identified the affected limb correctly. In the other two horses, quantitative gait scoring identified the hindlimb as the primary lameness, while visual scoring indicated the forelimb. It is impossible to judge from this study, which is correct. This would require a veterinary lameness examination. In three horses, where both quantitative and visual assessment identified concurrent forelimb and hindlimb lameness, picking the primary lameness from visual assessment based on the 'law of sides' (Maliye and Marshall 2016) and from gait asymmetry using the head-withers relationship, resulted in complete agreement.

Finally, by applying screening thresholds for HDmin and PDmin determined from the ROC curves, the categorisation of eight horses changed compared with using the previously reported clinical thresholds (compare columns CLIN THRS +HW to ROC THRES +HW, **Table 3**). Five horses, originally categorised as concurrently forelimb and hindlimb lame, were then categorised as unilaterally lame (4 forelimb, one hindlimb). Three horses, originally considered forelimb lame, were then categorised as nonlame (one of the horses considered nonlame by visual scoring, two considered forelimb lame).

In our small sample of horses, applying the ROC thresholds of >|14.5 mm| (HDmin) and >|7.5 mm| (PDmin) resulted in a similar outcome to the clinical thresholds of >|7 mm| and >|4 mm| combined with the head-withers relationship for identification of the primary lameness. The latter requires assessment of head, withers and tuber sacrale movement, while the ROC thresholds are applicable to commonly measured head and tuber sacrale movement.

Discussion

Head, withers and pelvic movement asymmetries were quantified in 25 racehorses in training. Lameness scores of six experienced racehorse veterinarians were also applied to these horses.

Pairwise inter-observer agreement on a numerical 0–5 lameness scale indicated poor to fair agreement between observers, considerably lower than reported for agreement on presence of lameness or on the categorical 0–5 AAEP scale during live assessment (Keegan *et al.* 2010). Our videos showed horses from front and behind during in-hand trot. During a clinical lameness examination additional viewing

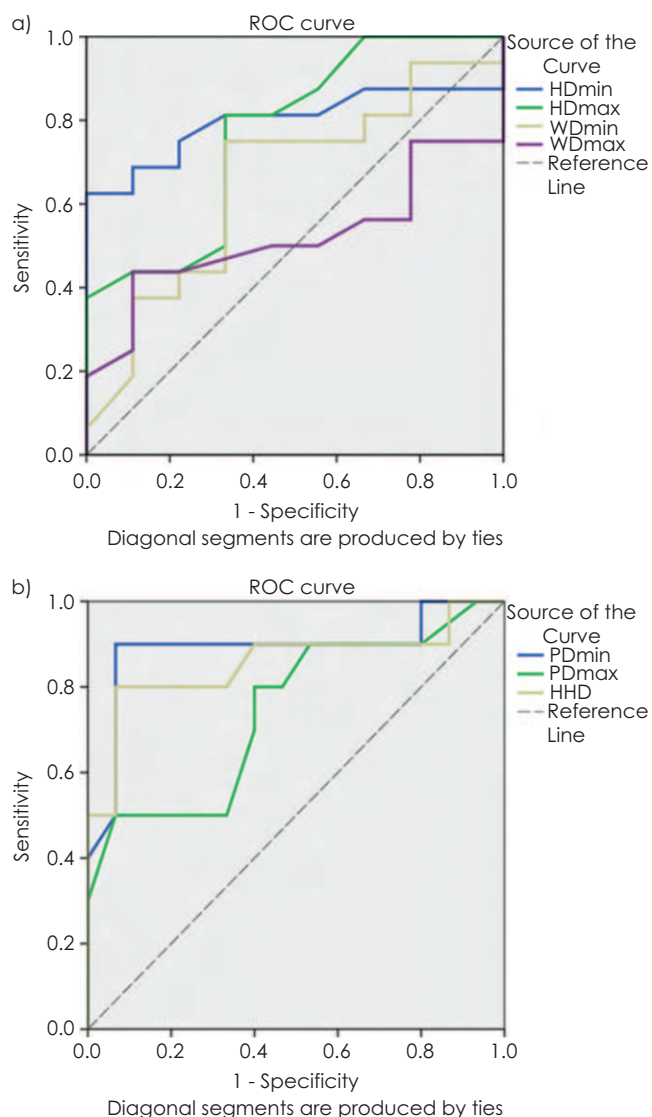


Fig 2: ROC curves for a) detection of forelimb lameness based on head and withers movement asymmetry and for b) detection of hindlimb lameness based on pelvic movement asymmetry. ROC curves for pelvic movement asymmetry indicate higher values for area under curve (AUC) compared with head and withers movement asymmetry. Movement asymmetry measures related to the difference in maximum downward position between contralateral stance (HDmin and PDmin) show the highest AUC values.

angles are chosen and the examination includes additional exercises (Dyson 2014) aimed at helping identification of the (most) affected limb.

Kappa values can be low when investigating findings with a low prevalence (Viera and Garrett 2005). Only three horses were considered nonlame and lameness scores were not evenly spread across categories. In an attempt to choose a subsample of horses representative for our envisaged application, we concentrated on horses in active race training ($n = 19$) supplemented by clinical cases ($n = 6$).

ICC values indicated good consistency across observers. While not immediately comparable, since force and IMU

measurements are on a continuous scale, ICC values of force plate and IMU asymmetry measures are ranging from 0.72 to 0.95 (Keegan *et al.* 2011, 2012). Compared with horses with neurological deficits (ICC value of 0.74 on a 0–4 scale for the neurological grade) (Olsen *et al.* 2014), we report similar values. We chose a variant of ICC focusing on assessing rank orders between observers ('consistency') (Hallgren 2012), rather than absolute agreement in lameness scores, limiting the influence of mean differences between observers, e.g. when one observer consistently scores higher (or lower) than another observer. Following published recommendations (Hallgren 2010), ICC values across observers ('average') were calculated as indicated as appropriate for studies using hypothesis testing based on average observer ratings, in our case the use of median lameness scores for calculating sensitivity and specificity for ROC curves.

We hypothesised that screening thresholds for Thoroughbred racehorses would be wider than previously reported clinical thresholds. General thresholds for when a movement asymmetry is definitely caused by pain and not simply related to other influences (e.g. conformation or day-to-day variation) are unknown. Whether screening thresholds differ between breeds or disciplines requires further study. However, racehorses can be assumed to be operating near their limits and consequently it appears important to establish, at what level racehorse veterinarians, experienced in evaluating lameness in Thoroughbred racehorses, consider gait as abnormal. It should be highlighted that in the scenario here (screening of gait asymmetry in large numbers of horses) it would be logistically challenging under the constraints of a busy racing yard to ensure that the level of measured asymmetry is 'stable' (i.e. does not change) between subsequent assessments, as is best practice during clinical lameness examinations. Hence, in this study only one data collection trial (typically consisting of between 2 and 4 straight-line runs) was investigated per horse. The amount of movement asymmetry may have changed in some horses, if further assessments would have been conducted. However, the study design, comparing visual assessments to gait measurements for the same runs, limits the potential influence of a change in movement asymmetry over a series of runs.

In general, pelvic movement asymmetry resulted in higher discriminative power (increased AUC values, **Figure 2**) for detecting hindlimb lameness (i.e. a median score of 1 or above) compared with head or withers movement asymmetry for forelimb lameness. Head movement is often more variable than trunk movement. Highpass filtering is applied to IMU data during the integration process (Pfau *et al.* 2005), limiting but not completely removing variation (see **Fig 1** for example of stride-to-stride variability after filtering). Also, compensatory head movements are present in horses with hindlimb lameness (Uhlir *et al.* 1997; Rhodin *et al.* 2013; Maliye and Marshall 2016; Persson-Sjodin *et al.* 2016) and horses considered nonlame in the forelimbs may show considerable head movement asymmetry related to a hindlimb lameness (Rhodin *et al.* 2013). Our estimated screening values reflect the real-life situation in which concurrent forelimb and hindlimb lameness may be present.

Requiring at least 80% specificity, thresholds of 14.5 mm for HDmin and -7.5 mm for PDmin were determined. Asymmetry parameters quantifying upward movement of the head or body showed considerably lower sensitivity values of 44% for a threshold of -5 mm for HDmax, (37% for 7 mm for

WDmax; 50% for 10 mm for PDmax). A threshold of -15 mm for HHD, a parameter assessing the combined effect of pelvic upward movement amplitude and pelvic rotation, indicated a sensitivity in between the one found for PDmax and PDmin. The comparatively low sensitivity values and consequently low AUC value for PDmax may indicate that either this type of asymmetry is more difficult to see or simply not the specific movement that is being evaluated by these experienced racing veterinarians. Higher sensitivity values (for any of the gait asymmetry parameters) can be achieved at the 'cost' of lower specificity values when using thresholds closer to zero. This will be of advantage (lead to a higher positive predictive value) in populations with higher prevalence of lameness, e.g. in horses presented to veterinarians for a clinical lameness examination based on the trainer's or owner's belief that something is wrong with the horse.

All presented threshold values derived from ROC curves are calculated for detecting RF (HDmin >0 , HDmax <0) or RH (PDmin and HHD <0 , PDmax >0) lameness and as a consequence threshold values need inverting for detection of LF or LH lameness. It should also be emphasised, that sensitivity and specificity values need to be cross validated on an independent data set (horses undergoing visual and quantitative gait analysis but different from the horses used for calculating ROC curves themselves). The presented values are first estimates aiming at investigating at what level of asymmetry experienced racehorse veterinarians identify a lameness based on comparison to median values with a non-negligible amount of interobserver variability. Interestingly, while the threshold of 14.5 mm for HDmin is close to the 25% identified previously as required for reliable detection of movement asymmetry (Parkes *et al.* 2009) (based on an assumed movement amplitude of 60 mm) the 7.5 mm for PDmin is clearly below this 25% threshold.

Conclusion

We found poor pairwise agreement but good consistency across visual lameness scores of six experienced racing veterinarians scoring videos of in-hand trot-ups of Thoroughbreds used for racing. The median values of visual lameness scores were used to calculate ROC curves for head, withers and pelvic movement asymmetry from IMU gait analysis in a small sample of horses. ROC based thresholds of $>|14.5$ mm| for HDmin and of $>|7.5$ mm| for PDmin were found identifying horses consistent with visually identified lameness during straight-line trot with $>88\%$ specificity and 69% (HDmin) and 90% (PDmin) sensitivity. Using the relationship between head and withers movement asymmetry for identifying the primary lameness is a promising approach based on a small number of horses with concurrent forelimb and hindlimb lameness.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This study was approved by the Royal Veterinary College Ethics and Welfare Committee (URN_2013_1238).

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Authorship

T. Pfau, M. Sepulveda and B. Forbes designed the study. M. Sepulveda, B. Forbes, R. McCarthy and L. Cheetham executed the study. All authors contributed to data analysis, interpretation, preparation of the manuscript and gave final approval of the manuscript.

Manufacturers' addresses

¹Xsens, Enschede, The Netherlands.

²Nikon, Minato, Tokyo, Japan.

³The Mathworks, Natick, Massachusetts, USA.

⁴IBM, Armonk, New York, USA.

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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: Pairwise kappa agreement between observers for forelimb and hindlimb lameness scored from cranial/caudal videos (with audio) of 25 racing Thoroughbreds during in-hand trotups on hard surface graded on a 0 to 5 lameness scale by six racehorse veterinarians.

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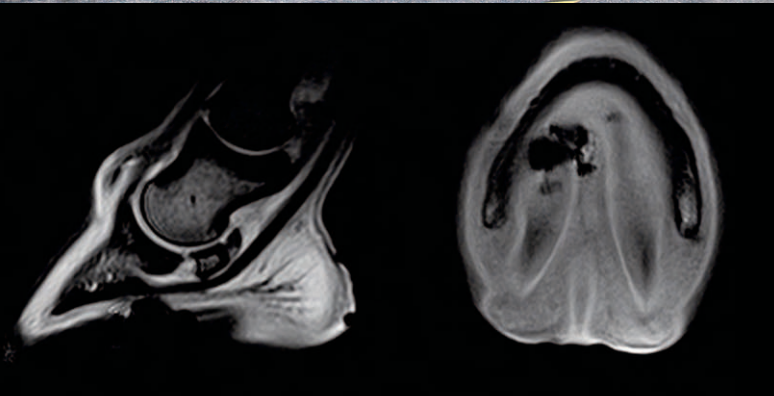
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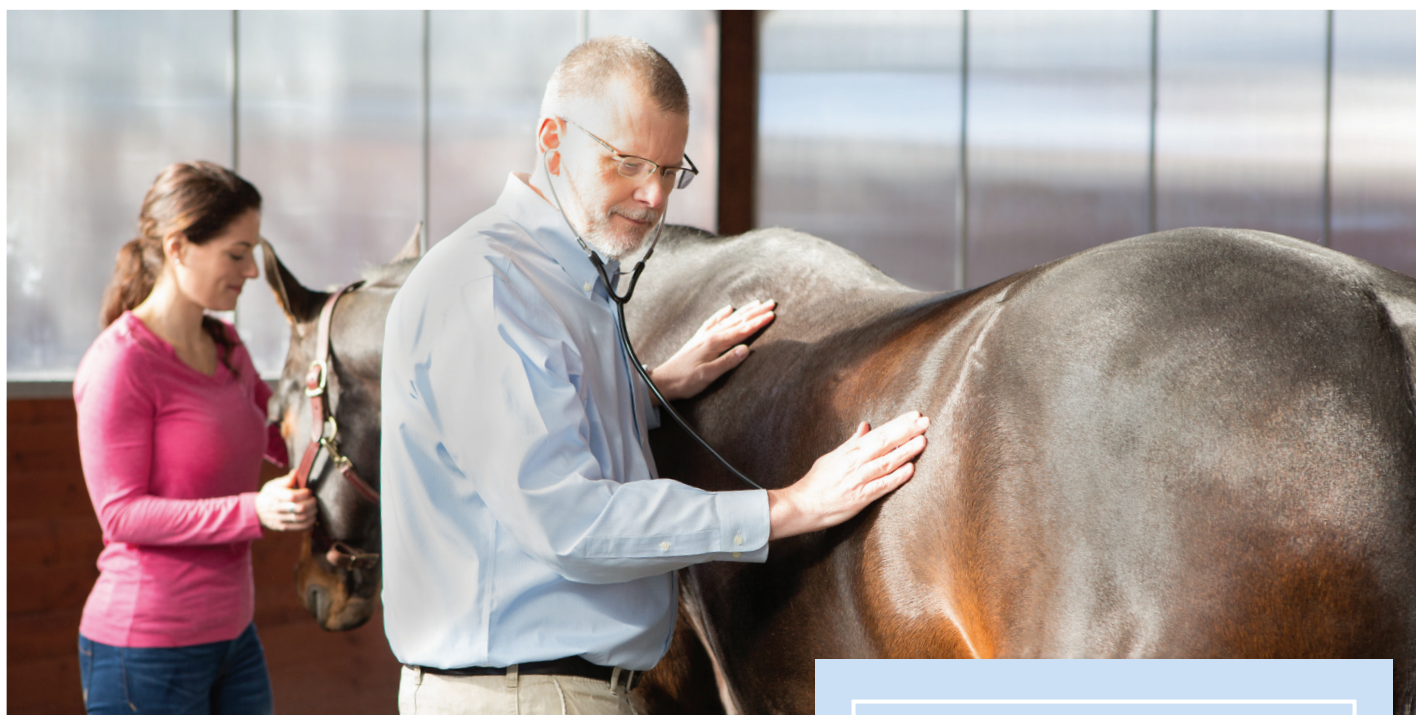


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Original Article

Comparison of lameness scores after a low 4-point nerve block to lameness scores after additional desensitisation of the dorsal metatarsal nerves in horses with experimentally induced pain in the metatarsophalangeal joint

M. Coleridge^{†*} , J. Schumacher[‡]  and F. DeGraves[§]

[†]Fethard Equine Hospital, Tipperary, Ireland; [‡]Department of Clinical Sciences, Auburn University, Auburn, Alabama; and [§]Department of Agriculture, Western Kentucky University, Bowling Green, Kentucky, USA

*Corresponding author email: modcoleridge@gmail.com

Keywords: horse; 4-point nerve block; metatarsophalangeal joint; dorsal metatarsal nerves

Summary

This study evaluated whether anaesthesia of the dorsal metatarsal nerves in addition to a low 4-point nerve block provides significantly more analgesia to the metatarsophalangeal joint than to a low 4-point nerve block alone. A wireless, inertial, sensor-based, motion analysis system was used to evaluate gaits of six horses before induction of lameness, after administration of interleukin-1 β into a metatarsophalangeal joint, after anaesthesia of the medial and lateral plantar nerves and the medial and lateral plantar metatarsal nerves, and after additional anaesthesia of the lateral and medial dorsal metatarsal nerves. The magnitude of hindlimb lameness was analysed considering both the push-off component (diffmaxpelvis) and the impact component (diffminpelvis) of the lame limb for all trials. There was no significant difference in the sum of diffmaxpelvis and diffminpelvis (SDMPs) when comparing the horse's gait after the low 4-point nerve block to the gait after additional anaesthesia of the dorsal metatarsal nerves, indicating that there is likely no benefit of medial and lateral dorsal metatarsal nerve anaesthesia when using regional anaesthesia to localise pain to the metatarsophalangeal joint during a lameness examination.

Introduction

Perineural anaesthesia or nerve blocks used to localise pain during a lameness examination are usually performed sequentially beginning distally on the limb and progressing proximally until significant amelioration of lameness is observed. Typically, the foot is desensitised first by anaesthetising the palmar/plantar digital nerves. If anaesthesia of the digital nerves does not ameliorate lameness, an abaxial (basisesamoid) nerve block is often performed to rule out the entire digit (the limb distal to the fetlock) as a source of pain causing lameness. If digital pain is determined not to be a source of lameness, the metacarpophalangeal/metatarsophalangeal region is desensitised. For a forelimb, the medial and lateral palmar and palmar metacarpal nerves are anaesthetised (a low 4-point nerve block). For a hindlimb, the medial and lateral plantar and plantar metatarsal nerves are anaesthetised. However, to completely desensitise the metatarsophalangeal region, the medial and lateral dorsal metatarsal (DMT) nerves must also be anaesthetised (low 6-point nerve block). The

medial and lateral DMT nerves, which are branches of the deep peroneal (fibular) nerve innervate the dorsal portion of the fetlock region (Sisson and Grossman 1953; Dyce *et al.* 1996) (Fig 1) and the digit. Anaesthesia of the DMT nerves, in addition to anaesthesia of the medial and lateral plantar and plantar metatarsal nerves, is advised by some clinicians in order to completely desensitise the metatarsophalangeal region of the hindlimb for diagnostic analgesia (Wyn-Jones 1988; Schmotzer and Timm 1990; Gaynor and Hubbell 1991; MacDonald *et al.* 2006; Baxter and Stashak 2011). However, others believe that performing only the low 4-point nerve block is sufficient to desensitise the metatarsophalangeal region for diagnostic analgesia (Carter and Hogan 1996; Bassage II and Ross 2011; Pilsworth and Dyson 2015).

To our knowledge, the ability to completely desensitise the metatarsophalangeal joint with a low 4-point nerve block, with or without anaesthesia of the DMT nerves, has not been critically evaluated. We hypothesised that anaesthesia of the DMT nerves would not significantly improve lameness caused by pain within the metatarsophalangeal joint when that joint has been desensitised with a low 4-point nerve block. This hypothesis was evaluated by comparing the gait of horses with pain in the metatarsophalangeal joint before and after performing a low 4-point nerve block, to their gait after the DMT nerves were anaesthetised to supplement the low 4-point nerve block.

Materials and methods

Six light-breed horses from our teaching herd were used in this study, which was approved by our Institutional Animal Care and Use Committee. These horses had a mean age of 13 years (8–16 years), and a mean weight of 547 kg (408–635 kg). The horses had no effusion in either the digital flexor tendon sheaths or in the metatarsophalangeal joints of the pelvic limbs. Examination of gait at baseline and all other time points involved evaluation of 40 trotting strides, on asphalt in a straight line, using a wireless, inertial, sensor-based, motion analysis system (Lameness Locator[®]). For horses with a pelvic limb lameness, the pelvic limb which showed the lowest sum of hip drop and hip hike (the least lame pelvic limb) was chosen for the study.

The horses were then sedated with detomidine HCl (0.01 mg/kg bwt i.v.), and the dorsolateral aspect of the metatarsophalangeal joint of the study limb was prepared for

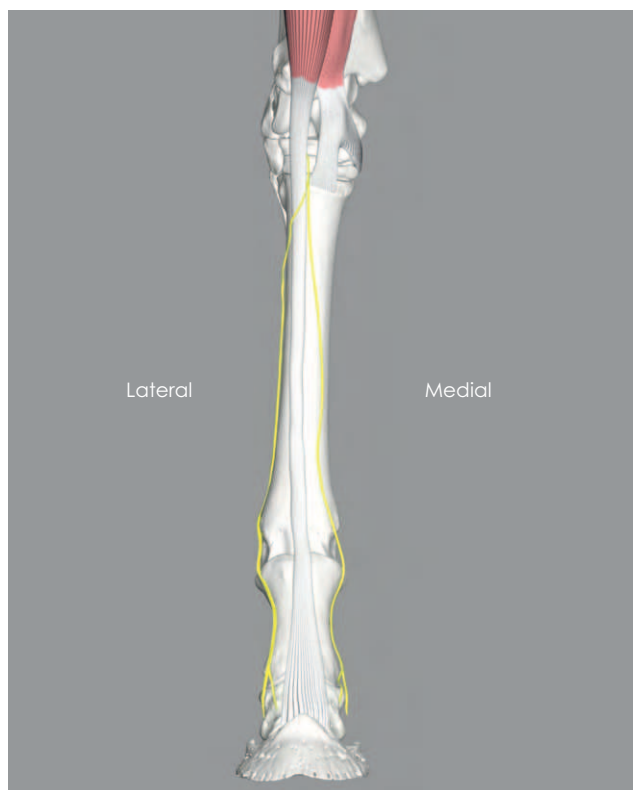


Fig 1: A representation of the medial and lateral dorsal metatarsal nerves in the right hind distal limb. The lateral DMt nerve courses close to the fourth metatarsal bone, deviating dorsally at the level of the fetlock, while the medial DMt nerve lies more dorsally on the third metatarsal bone.

aseptic synoviocentesis. Using a lip twitch for restraint, a 25-mm, 20 gauge hypodermic needle was inserted into the metatarsophalangeal joint using a dorsal approach (Moyer *et al.* 2007). Successful arthrocentesis was confirmed by visualising synovial fluid in the hub of the needle. Following confirmation, 100 nanograms (1 mL) of interleukin-1 β in sterile phosphate-buffered saline was injected into the joint.

Eight hours following administration of interleukin-1 β into the metatarsophalangeal joint, the horses were subjectively observed to exhibit lameness in the treated limb ranging from 4/10 to 7/10 where 0 corresponded to no sign of lameness and 10 corresponded to nonweightbearing. The Lameness Locator¹ was then used for all trials to determine the magnitude of hindlimb lameness by recording pelvic rise and fall for each weightbearing diagonal. For all trials, the Lameness Locator calculated the magnitude of hindlimb lameness as diffmaxpelvis for the push-off component and diffminpelvis for the impact component.

The lame limb was prepared for aseptic administration of a low 4-point nerve block. Nerves were anaesthetised with the horse bearing weight on the limb. The low 4-point nerve block was performed by anaesthetising the medial and lateral plantar metatarsal nerves by depositing 1 mL of mepivacaine HCL³ through a 16-mm (5/8-inch), 25 gauge needle, beneath the button of the second and fourth metatarsal bones. The subcutis of the plantar aspect of the metatarsal region was palpated to determine if communication (*ramus communicans*) between medial and

lateral plantar nerves existed. The plantar nerves were anaesthetised in the mid-metatarsal region by depositing 2 mL of mepivacaine HCL over each nerve, subcutaneously adjacent to the dorsal border of the deep digital flexor tendon using a 16-mm (5/8-inch), 25 gauge needle. For one horse, a communicating branch between medial and lateral plantar nerves could be palpated; this branch was near the distal end of the metatarsal region, and for this horse plantar nerve blocks were also performed in the mid-metatarsal region, proximal to this communication. The first author performed all nerve blocks.

Cutaneous sensation at the heel bulbs and dorsal pastern was tested by applying pressure with the tip of a ball-point pen 5 min after performing the low 4-point nerve block. Lack of reaction to this stimulus on the treated limb and positive reaction to similar stimulation on the untreated limb were interpreted as an indication the nerve block was successful. One horse continued to react to cutaneous stimulation of the heel bulbs 5 min after application of the low 4-point nerve block. For this horse, the entire low 4-point nerve block was repeated as described, and successful application of this repeat procedure was confirmed by applying point pressure to the heel bulbs as previously described. The gait was re-evaluated, using the Lameness Locator¹ at 5 and 10 min after administering the low 4-point nerve block. Immediately after recording the 10 min evaluation of gait on the Lameness Locator¹, the DMt nerves were anaesthetised by performing a semi-ring nerve block on the dorsal aspect of the third metatarsal bone. The semi-ring block was applied at the level of the most distal aspect of the second and fourth metatarsal bones to convert the low 4-point nerve block to a low 6-point nerve block. Mepivacaine was administered by inserting a 25 gauge, 16-mm needle through skin previously desensitised by the lateral plantar metatarsal nerve block. The needle was directed dorsally to its hub, and 2 mL of local anaesthetic solution was injected subcutaneously as the needle was withdrawn. The procedure was repeated on the medial aspect of the limb by inserting the needle through skin previously desensitised by the medial plantar metatarsal nerve block and directing the needle dorsally and subcutaneously and then reinserting the needle at the edge of the subcutaneous swelling created by the injection of mepivacaine and directing the needle dorsally for repeated injection. By using this technique, local anaesthetic solution was distributed across the entire dorsal aspect of the limb to ensure anaesthesia of the medial and lateral DMt nerves. Using the Lameness Locator¹, the gait of each horse was evaluated at 5 and again at 10 min after anaesthetising the DMt nerves. The Lameness Locator calculated the magnitude of hindlimb lameness as diffmaxpelvis and diffminpelvis for all lameness trials. Diffmaxpelvis and diffminpelvis data were modelled using repeated measures analysis after evaluating residual plots for normality of data (PROC MIXED, SAS 9.1). Correlated data were accounted for using the following linear model (Littell *et al.* 1998, 2000, 2006):

$Y = X\beta + Z\mu + e$; where Y was the vector of observations, X was the treatment design matrix (no treatment, treatment with interleukin-1 β , low 4-point or low 6-point nerve block; lameness evaluations at 5 and 10 min), β was the vector of fixed treatment effects, Z was the random effects design matrix (horse), μ was the vector of random nerve block effects and the e was the vector of experimental error. To account for the nonindependence of observations within

horses, five correlation structures were tested (compound symmetric, first-order autoregressive, Toeplitz, unstructured and variance components) (Littell *et al.* 1998, 2000, 2006). Models were compared using Akaike's information criterion (Littell *et al.* 1998, 2000, 2006). Horse was included in models as a random effect (Littell *et al.* 1998, 2000, 2006). The Kenward–Roger correction was used for all models (Littell *et al.* 1998, 2000, 2006). The P values of multiple comparisons were adjusted using the Tukey–Kramer method (Littell *et al.* 2006). Values of $P \leq 0.05$ were considered significantly different.

Results

Diffmaxpelvis and diffminpelvis data (Table 1) modelled using compound symmetry and Toeplitz covariance structures, provided the best fit based on the Akaike's information criteria, respectively. Horses were significantly lamer after administration of interleukin-1 β into the metatarsophalangeal joint (diffmaxpelvis, $P = <0.0001$; diffminpelvis, $P = 0.0004$). Five and ten minutes evaluations were not significantly different (4-point nerve block diffmaxpelvis, $P = 0.9939$; diffminpelvis, $P = 0.9957$; 6-point nerve block diffmaxpelvis, $P = 0.4358$; diffminpelvis, $P = 0.9949$). When comparing the horses' gait before intra-articular administration of interleukin-1 β into the metatarsophalangeal joint to their gait after both the low 4-point ($P = 0.9580$) and additional DMt nerve blocks ($P = 0.9305$), no significant differences were appreciated. There were significant differences after interleukin-1 β treatment and the low 4-point nerve block (diffmaxpelvis, $P < 0.0001$; diffminpelvis, $P = 0.0033$) and between treatment with interleukin-1 β and the additional DMt nerve blocks for diffmaxpelvis, $P = >0.0001$; but not for diffminpelvis, $P = 0.0963$. There were no significant differences between the 4-point nerve block alone and additional anaesthesia of the DMt nerves (diffmaxpelvis, $P = 0.5392$; diffminpelvis, $P = 0.9574$).

Discussion

Administration of interleukin-1 β into the metatarsophalangeal joint caused a significant lameness when compared with the subject's baseline lameness in the same limb. Administration of a low 4-point nerve block caused significant reduction in objectively determined lameness scores; however, anaesthesia of the DMt nerves in addition to the low 4-point nerve block failed to provide further improvement in lameness scores. In a study that examined the effect of

interleukin-1 β when administered intra-articularly to horses, there was no significant difference in subjectively determined lameness scores when horses were examined for lameness at 4 and 8 h post injection indicating that intra-articular administration of the cytokine produces a consistent lameness for an extended period of time (Ross *et al.* 2012). It is likely that the lameness we observed was consistent and thus any change or lack of change in gait was directly related to the anaesthetic techniques we performed. The response to intra-articular administration of interleukin-1 β was significant in all horses compared with their baseline gait evaluation; however, the magnitude of the response varied among the study subjects. As a result, using the same horse and limb as its own control negated any individual variation in response.

Evaluating the effectiveness of perineural anaesthesia in the equine limb is recognised to be difficult and is a limitation of this study. In the clinical setting, efficacy of a nerve block is frequently assessed by applying pressure to an area of skin to which the target nerve provides cutaneous sensory innervation (Carter and Hogan 1996). Not all diagnostic analgesic techniques used for lameness evaluation, however, can be tested by applying noxious stimulation to skin within the expected dermatome. The region of skin desensitised by some regional nerve blocks may vary somewhat among horses (Dyson 1984). It is also possible to achieve anaesthesia of the skin without achieving anaesthesia of the deeper structures (MacDonald *et al.* 2006). To evaluate the efficacy of a nerve block, it may be necessary to observe the horse's response to cutaneous stimulation with respect to similar stimulation of the contralateral limb (Bassage II and Ross 2011; Ross *et al.* 2012). Our methodology took these factors into account. Loss of skin sensation at the heel bulbs and dorsal pastern combined with elicitation of a reaction to similar stimulation in the contralateral limb indicated a successful low 4-point nerve block. Objective re-evaluation of the subject's gait revealing significant amelioration of lameness was further indication of success of the nerve block (Schumacher *et al.* 2013a).

Inadvertent administration of local anaesthetic solution into the digital flexor tendon sheath may occur when administering a palmar or plantar nerve block and local anaesthetic solution may be inadvertently deposited in the proximal palmar/plantar pouch of the metacarpo/metatarsophalangeal joint when administering palmar metacarpal/plantar metatarsal nerve blocks (Nagy *et al.*

TABLE 1: The magnitude of hindlimb lameness, displayed as diffmaxpelvis for the push-off component of pelvic movement and diffminpelvis for the impact component, of pelvic movement are shown before and 8 h after administration of interleukin-1 β , 5 and 10 min after anaesthesia of the plantar and plantar metatarsal nerves (low 4-point nerve block), and then 5 and 10 min after the additional anaesthesia of the dorsal metatarsal nerves (completion of the low 6-point nerve block)

x	Diffmaxpelvis						Diffminpelvis					
	Pre-IL	8 h post IL	5 min post 4-point	10 min post 4-point	5 min post 6-point	10 min post	Pre-IL	8 h post IL	5 min post 4-point	10 min post 4-point	5 min post 6-point	10 min post
1	-5.82	34.3	-2.79	-6.36	-6.39	-5.11	3.91	85.1	21.0	18.1	15.9	14.7
2	-0.943	-57.8	-7.47	-5.90	-6.71	-5.53	1.46	-24.5	0.346	2.03	3.97	2.93
3	-1.91	55.2	0.902	-1.69	-0.512	-2.18	1.88	57.1	12.5	8.98	3.49	7.61
4	-3.75	32.1	-0.422	0.837	1.06	1.67	-5.34	23.5	4.21	0.966	-0.979	-1.65
5	-1.01	6.14	-1.26	-0.125	0.429	-3.82	0.816	1.31	1.54	-1.00	-4.16	-4.44
6	-1.11	-47.6	-2.58	-0.938	-1.45	5.87	4.03	-24.8	-6.93	-3.66	-4.20	-5.65

2010; Seabaugh *et al.* 2011). We avoided risk of this complication by performing the plantar nerve blocks in the mid-metatarsal region, well above the proximal extent of the digital flexor tendon sheath. Blocking the nerves in this region runs the risk of blocking the medial plantar nerve below and the lateral plantar nerve above the ramus communicans thus resulting in incomplete desensitisation of a painful lesion distal to this communication which might cause lameness (Schumacher *et al.* 2013b). It is our experience that the ramus communicans often does not exist or is rudimentary in the hindlimb. When it can be palpated it is usually low in the plantar metatarsal region. We palpated for this communication on all horses but found it in only one horse. For that horse, the communicating branch was well distal to the mid-metatarsal region where the plantar nerves on all horses were blocked. The plantar metatarsal nerves were blocked by directing the needle beneath the buttons of the second and fourth metatarsal bones as opposed to depositing local anaesthetic solution subcutaneously at the end of the splint bones. This technique was used to minimise the risk of depositing local anaesthetic solution into the plantar pouch of the metatarsophalangeal joint a complication of the procedure reported by Seabaugh *et al.* (2011); however, no radiographic contrast studies or alternative techniques to validate this assumption were performed. We examined the influence of the anaesthesia of the DMt nerves on a synovitis model of lameness, and add a caveat that it is possible that the DMts could innervate subchondral bone which may be a source of pain in joints with osteoarthritis (Niv *et al.* 2003).

The DMt nerves are purely sensory nerves that are the terminal branches of the deep peroneal nerve (Sisson and Grossman 1953). The deep peroneal nerve branches into the medial and lateral DMt nerves over the dorsum of the hock, beneath the long digital extensor tendon. The medial DMt nerve courses over the medial aspect of the metatarsus coursing towards the distal end of the second metatarsal bone. The lateral DMt nerve courses distally in the metatarsal region close to the fourth metatarsal bone and deviates dorsally in the region of the metatarsophalangeal joint. Sisson and Grossman (1953) claimed that the medial DMt nerve supplies cutaneous sensation to the dorsal aspect of the metatarsus, whereas the lateral DMt nerve innervates skin on the lateral aspect of the metatarsus and fetlock. Dyce *et al.* (1996), however, claimed that both nerves supply branches that innervate the metatarsophalangeal and proximal interphalangeal joints in addition to skin. Although results of this study indicate that innervation of the metatarsophalangeal joint by the dorsal metatarsal nerves appears to be minimal, we concede that it is possible that diffusion over a 10-min period could have anaesthetised the dorsal metatarsal nerves (especially the lateral nerve which lies close to the 4th metatarsal bone). However, we found no significant difference between the lameness scores determined at 5 min and at 10 min after performing the low 4-point nerve block. If rapid diffusion of local anaesthetic solution was significant enough to anaesthetise the dorsal metatarsal nerves after performing the plantar metatarsal nerve blocks, then the conclusion of this study remains the same, that a low 4-point nerve block is sufficient to achieve regional anaesthesia of the metatarsophalangeal joint during a lameness examination.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This study was approved by the Auburn University IACUC committee.

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None.

Authorship

M. Coleridge involved in study design and performed study with J. Schumacher. F. DeGraves was involved in study design and statistical analysis of the data collected. All authors prepared and reviewed the submitted manuscript.

Manufacturers' addresses

¹Equinosis, St. Louis, Missouri, USA.

²R& D Systems Inc., Minneapolis, Minnesota, USA.

³Zoetis Inc. Kalamazoo, Michigan, USA.

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Review Article

Lameness originating from the proximal metacarpus/tarsus: A review of local analgesic techniques and clinical diagnostic findings

L. Pezzanite , E. Contino and C. Kawcak*

Gail Holmes Equine Orthopaedic Research Center, Department of Clinical Sciences, College of Veterinary Medicine, Colorado State University, Fort Collins, Colorado, USA

*Corresponding author email: ckawcak@colostate.edu

Keywords: horse; lameness; proximal suspensory ligament; magnetic resonance imaging

Summary

Accurate diagnosis of conditions of the equine proximal metacarpus and metatarsus presents a clinical challenge. Diagnostic analgesia of this region is nonspecific, which may lead to incorrect interpretation of blocking patterns, potentiating incorrect diagnoses and treatment. Results of local analgesia should be examined carefully during clinical lameness evaluations due to the possibility of diffusion of local anaesthetic solution and inadvertent intrasynovial injection. Supplementary diagnostic analgesia of surrounding anatomic regions and advanced diagnostic imaging, particularly magnetic resonance imaging, are recommended for most accurate diagnosis of lameness. Failure in response to therapy in cases where supplementary diagnostic analgesia and advanced diagnostic imaging have not been performed should prompt the clinician to broaden the approach to better characterise the site of pain.

Part I: Review of diagnostic analgesia of the proximal metatarsus and metacarpus

Introduction

Accurate diagnosis of conditions of the proximal metacarpus and metatarsus presents a clinical challenge in evaluation of equine lameness. Proximal suspensory desmopathy (PSD) is a common cause of lameness and poor performance in athletic horses in both fore- and hindlimbs (Cowles 2000), and therefore distinguishing this condition from other sources of lameness in the subcarpal or subtarsal (or surrounding) region is important in determining appropriate treatment. Localisation of the source of pain in lameness examination has traditionally relied upon diagnostic analgesic techniques, including perineural or regional analgesia, intrasynovial analgesia (intra-articular, or injection into a tendon sheath or bursa) and infiltration of local analgesic around the proximal suspensory ligament (Dyson and Romero 1993). However, specificity of subcarpal or subtarsal analgesia to localise lameness is not necessarily precise due to inadvertent injection of adjacent synovial structures, diffusion of local anaesthetic solution and possibly aberrant innervation (Bassage and Ross 2003). Pain from anatomic structures outside of the subcarpal or subtarsal area may be alleviated by local analgesia of the proximal metacarpal and metatarsal regions. Concurrent analgesia of the lateral plantar nerve is likely to occur when local analgesic is injected surrounding the deep branch of the lateral plantar nerve (DBLPN), which could lead to conditions of the distal

lateral limb responding to subtarsal analgesia (Hinnigan *et al.* 2014). Conversely, proximal diffusion of local anaesthetic solution following 'low 4-point' nerve block is not thought to be responsible for decreasing lameness caused by pain in the proximal metacarpal region (Nagy *et al.* 2010). Significant proximal diffusion of local analgesic did occur with time following low 4-point nerve block in 40 limbs as detected by presence of contrast medium on radiographs, but never progressed proximal to the mid-metacarpal region (Nagy *et al.* 2010). These results suggest that 'low 4-point' or 'low 6-point' nerve block should be performed prior to local analgesia of the proximal metacarpus or metatarsus to improve the specificity of results with diagnostic analgesia (Hinnigan *et al.* 2014).

Abnormalities observed on radiographic and ultrasonographic examination of the proximal metacarpus and metatarsus may be subtle and difficult to interpret in terms of clinical relevance in the proximal metacarpus and metatarsus, further complicating lameness diagnosis of this region. Using histology as the gold standard, Dyson and Pinilla (2015) concluded that ultrasonography was reasonably reliable for detection of PSD pathology but had limited ability to detect gross adhesions. Therefore, following improvement in lameness after local analgesia of the proximal metacarpus and metatarsus, supplementary diagnostic analgesia of surrounding anatomic regions and/or advanced diagnostic imaging may be useful in diagnosis of lameness isolated to the subcarpal and subtarsal regions. Selection and interpretation of imaging modalities in lameness diagnosis of this region following appropriate diagnostic analgesia have been described in detail previously (Meehan and Labens 2016) and will not be repeated here. Acknowledging the clinical challenge in lameness diagnosis of this region and taking into account the significant body of previous literature on this topic, the aims of this article are therefore (1) to review pertinent anatomy of and clarify described techniques for local analgesia of the equine proximal metacarpus and metatarsus, and (2) to present retrospective clinical data with case examples of horses that have improved in lameness following local analgesia of the proximal metacarpus and metatarsus.

Diagnostic analgesia of the proximal metatarsus and tarsus

In the pelvic limb, the tibial nerve branches into the medial and lateral plantar nerves just proximal to the calcaneus to

supply innervation to the proximal plantar metatarsal structures. The lateral plantar nerve gives off a deep branch (DBLPN) at approximately 2–4 cm proximal to the base of the fourth metatarsal bone, which provides innervation to the proximal aspect of the suspensory ligament (PSL) (Ghoshal 1975; Shively 1984). The DBLPN gives rise to the medial and lateral plantar metatarsal nerves. The lateral plantar metatarsal nerve supplies sensation to the third metatarsal bone including the lateral distal condyle, the fourth metatarsal bone, the lateral branch of the suspensory ligament and the plantar aspect of the metatarsophalangeal joint. The medial plantar metatarsal nerve supplies sensation to the third metatarsal bone, second metatarsal bone, medial branch of the suspensory ligament and plantar aspect of the metatarsophalangeal joint. Although the plantar nerves generally resemble the palmar nerves of the forelimb, two differences are of clinical significance: first, the communicating branch between the medial and lateral plantar metatarsal nerves is small or absent in the hindlimb, and secondly, the plantar metatarsal nerves play a larger role in the sensory innervation of the hoof than do the corresponding forelimb trunks (Dyce *et al.* 2010). Innervation to the metatarsus is illustrated in **Fig 1**. Approaches for diagnostic analgesia of the PSL (**Table 1**) include: the high plantar 4-point nerve block, direct infiltration of the origin of the suspensory ligament, subtarsal nerve block (Dyson 1991a, b) and two techniques to selectively produce analgesia of the deep branch of the lateral plantar nerve (Gayle and Redding 2007; Hughes *et al.* 2007). Adjacent structures, which may be influenced by these blocks, include the tarsal sheath, distal intertarsal and tarsometatarsal joints, intertendinous calcaneal bursa, and bones of the tarsus.

Multiple studies in cadaver specimens (Sack and Orsini 1981; Kraus *et al.* 1987) as well as in live horses (Dyson and Romero 1993; Contino *et al.* 2015) demonstrate the inadvertent involvement of adjacent structures following perineural analgesia of the subtarsal region. Dyson and Romero (1993) demonstrated that following intra-articular injection of the tarsometatarsal joint with 10 mL of contrast in both hindlimbs of 10 horses, contrast agent extended to the distal intertarsal joint in 7 of 20 limbs, surrounded the tendons of the tibialis cranialis and fibularis tertius in 18 of 20 limbs and extended to the tarsal sheath in 7 of 20 limbs. Kraus-Hansen *et al.* (1992) demonstrated that even smaller volumes of contrast (as low as 1 mL) injected intra-articularly to distend the tarsometatarsal joint were sufficient to result in diffusion to the tarsal sheath and distal intertarsal joint. This study illustrated that the smaller volumes of local anaesthetic solution typically used clinically may also complicate localisation of lameness diagnosis due to diffusion. Dyson and Romero (1993) further explored contrast diffusion following subtarsal regional analgesia, which was performed in one of two ways. In Technique I, a total of 6 mL of contrast was injected axial to the second and fourth metatarsal bones, around the lateral and medial plantar metatarsal nerves with sufficient volume for diffusion around the PSL. Using Technique I, a 20 gauge 1.5 inch needle was placed plantar to the fourth metatarsal bone approximately 1.5 cm distal to the tarsometatarsal joint, redirected axial to the fourth metatarsal bone and inserted until it encountered resistance. At that site, 3 mL of contrast material was injected. The needle was partially withdrawn, redirected dorsomedially towards the axial aspect of the second metatarsal bone, and a further

3 mL was deposited. In Technique II, a total of 6 mL was injected perineurally around both the lateral and medial plantar and plantar metatarsal nerves (1.5 mL superficially between the superficial and deep digital flexor tendons and 1.5 mL axial to the second and fourth metatarsal bones). Using Technique II, the medial and lateral neurovascular bundles were palpated between the superficial and deep digital flexor tendons. Using two 25 gauge 5/8 inch needles, 1.5 mL contrast material was injected beneath the fascia at these sites. Then, two 20 gauge 1.5 inch needles were inserted axial to each of the second and fourth metatarsal bones, approximately 1.5 cm distal to the tarsometatarsal joint until adjacent to the suspensory ligament and plantar aspect of the third metatarsal bone, and 1.5 mL contrast material was injected at each site. Technique I was considered easier and safer to perform by the authors. Following injection of the subtarsal region, contrast agent extended to the tarsometatarsal joint in 1 of 20 limbs (using Technique II) and to the tarsal sheath in 8 of 20 limbs (three limbs using Technique I and five limbs using Technique II). The authors concluded that while subtarsal injection using either technique should result in perineural analgesia of the plantar metatarsal nerves, it may also alleviate pain from the tarsal sheath and deep digital flexor tendon. The described techniques of subtarsal analgesia, as well as direct infiltration of the origin of the suspensory ligament, may lack specificity and result in diffusion of local analgesia to adjacent structures in comparison to the high plantar ('high 6-point') nerve block or techniques to selectively block the DBLPN (**Table 1**).

Hughes *et al.* (2007) proposed a technique of perineural infiltration of the DBLPN in an attempt to increase the specificity of diagnostic analgesia of the PSL and decrease the risk of inadvertent injection of the tarsal sheath or tarsometatarsal joint. Using this technique, the superficial digital flexor tendon was deflected medially, a 1 inch 23 gauge needle was inserted perpendicular to the skin surface 15 mm distal to the head of fourth metatarsal bone on the plantarolateral surface of the metatarsus. The needle was advanced between the fourth metatarsus and the lateral border of the superficial digital flexor tendon to the hub and 0.2 mL dye was injected. The results of this *in vitro* study indicated that this technique may carry reduced risk of diffusion to surrounding structures, with inadvertent puncture of the tarsal sheath in only one of 19 limbs (5%) when using small injection volumes (0.2 mL). Gayle and Redding (2007) compared the subtarsal nerve block (Dyson 1991a,b) and a variation in the technique of perineural infiltration of the DBLPN (similar to Technique I described by Dyson and Romero 1993) where 6 mL of dye solution was injected distal and plantar to the head of the fourth metatarsal bone with the needle directed proximodorsally and axial to the bone in a cadaveric study. The frequency of inadvertent infiltration of the distal tarsal joints and tarsal sheath with each technique was determined. Using the subtarsal block (Method A), inadvertent infiltration of the tarsometatarsal joint was seen in one of nine limbs (12.5%) and tarsal sheath in 50% of the limbs. Using Method B to inject local anaesthetic solution around the deep branch of the lateral plantar nerve, there was no evidence of infiltration of the tarsometatarsal joint, but there was evidence of inadvertent infiltration of the tarsal sheath in one of nine limbs (12.5%). This study concluded that the single-injection technique appeared to be more specific

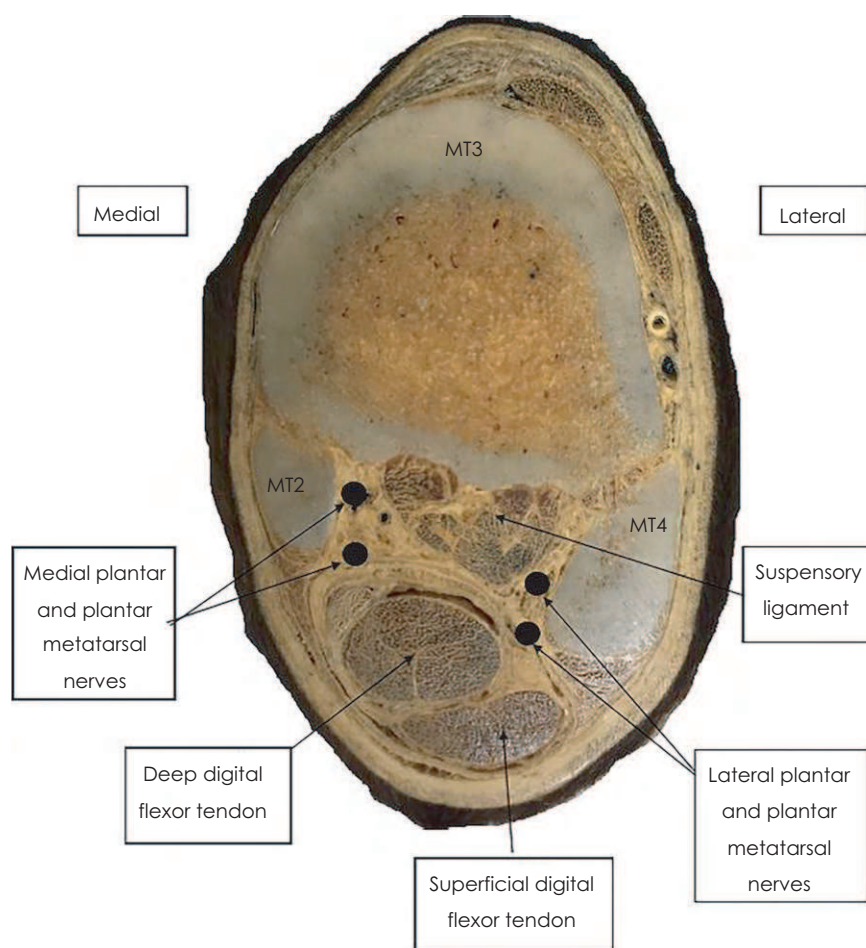


Fig 1: Axial section proximal metatarsus right hindlimb: MT2 = second metatarsal bone, MT3 = third metatarsal bone, MT4 = fourth metatarsal bone.

for the DBLPN and was associated with less diffusion to surrounding tissues in comparison with the subtarsal block. Lameness that improves significantly following local analgesia of the DBLPN but does not respond to a low 6-point nerve block of the plantar, plantar metatarsal and dorsal metatarsal nerves at the level of the distal end of the second and fourth metatarsal bones, has therefore been thought to originate from the proximal plantar metatarsal region, more specifically from the PSL (Dyson and Genovese 2003). Furthermore, a positive response to perineural infiltration of the DBLPN has been suggested to provide a more accurate assessment of whether lameness will improve following surgical neurectomy in horses with hindlimb proximal suspensory desmopathy (Toth *et al.* 2009).

Contino *et al.* (2015) further evaluated *in vivo* the single-needle injection technique that was described by Hughes *et al.* (2007) *in vitro* for perineural infiltration of the DBLPN. Using injection volumes similar to that used clinically (3 mL), the Contino *et al.* *in vivo* study revealed that analgesia of the DBLPN can result in inadvertent involvement of the tarsal sheath and/or tarsometatarsal joint. Contrast medium was visualised in the tarsal sheath in three of eight limbs injected. Mepivacaine concentrations sufficient to produce analgesia (>300 mg/L) were present in the tarsometatarsal joint in two of eight limbs at 10 mins post-injection. Contrast medium

diffused further in a distal direction than in a proximal direction. Hinnigan *et al.* (2014) further investigated the specificity of perineural infiltration of the DBLPN by determining the mechanical nociceptive threshold using a handheld force meter at 6 points on the lateral aspect of the limb, and subsequently dye distribution following injection. In this study, there were no inadvertent injections into the tarsometatarsal joint or tarsal sheath; however, there was staining present on the lateral wall of the tarsal sheath in 3 of 10 limbs, suggesting that the tarsal sheath, deep digital flexor tendon and possibly other structures may be desensitised inadvertently. The results of this study supported that concurrent analgesia of the lateral plantar nerve is also likely to occur when analgesia of the DBLPN is performed using the single-injection technique with volumes typically used clinically (2–4 mL). Findings of the study revealed that diffusion of dye around the lateral plantar nerve occurred in 9 of 10 limbs, and 4 of 20 horses lost sensation of the distal limb at the level of the lateral heel bulb (Hinnigan *et al.* 2014). Therefore, in a proportion of horses, desensitisation of structures at the level of the distal metatarsus and lateral aspect of the digit including the hoof may occur following perineural infiltration of the DBLPN and supports the poor specificity of this block. For this reason, local analgesia of the DBLPN will be more specific for the PSL following 'low 6-point'

TABLE 1: Summary of techniques of diagnostic analgesia of the equine metacarpus and metatarsus

Nomenclature	Targeted nerves	Injection site	Volume 2% local analgesic
Forelimb:			
Lateral palmar nerve block along medial aspect accessory carpal bone (Castro <i>et al.</i> 2005; Moyer <i>et al.</i> 2011)	Lateral palmar nerve	Insert 5/8 inch 25-gauge needle in medial to lateral direction into distal third of longitudinal groove in fascia over medial aspect of the accessory carpal bone	0.5 to 2 mL
Lateral palmar nerve block proximal to deep branch (Wheat and Jones 1981; Ford <i>et al.</i> 1988; Moyer <i>et al.</i> 2011)	Lateral palmar nerve	Insert 1 inch 22-gauge needle palmarolateral to dorsomedial direction at the distal aspect of the accessory carpal bone on the palmar border of the accessoriometacarpal ligament midway between ligament insertion of distal accessory carpal bone and proximal aspect of MCIV	5 mL
High palmar (high '4-point') (Wheat and Jones 1981; Ford <i>et al.</i> 1988; Stashak 2002; Bassage and Ross 2003; Moyer <i>et al.</i> 2011)	Medial and lateral palmar nerves; Medial and lateral palmar metacarpal nerves	- Insert 5/8 inch 25-gauge needle through heavy fascia and inject 2 to 3 mL at two sites where medial and lateral palmar nerves lie adjacent to dorsal surface deep digital flexor tendon distal to level of the carpometacarpal joint. - Insert 5/8 inch 25-gauge needle between axial surface of both MCII and MCIV and palmar surface of MCIII and inject 2 to 3 mL around each medial and lateral palmar metacarpal nerves.	2 to 3 mL/ site = total 8 to 12 mL
Direct infiltration proximal suspensory ligament (Ford <i>et al.</i> 1988; Stashak 2002; Bassage and Ross 2003)	Medial and lateral palmar nerves; Medial and lateral palmar metacarpal nerves	Insert 1 inch 20- to 22-gauge needle between the suspensory ligament and distal accessory ligament of the deep digital flexor tendon at the level of the junction of the head and shaft of MCIV	20 mL
Hindlimb:			
Deep branch of the lateral plantar nerve block (Hughes <i>et al.</i> 2007; Moyer <i>et al.</i> 2011)	DBLPN	- Deflect superficial digital flexor tendon medially. - Insert 1 inch 20- to 23-gauge needle perpendicular to the skin surface 15 mm distal to the head of fourth metatarsal bone on the plantarolateral surface of the metatarsus. - Advance needle between MTIV and the lateral border of superficial digital flexor tendon and inject.	0.2 to 5 mL
Deep branch of the lateral plantar nerve block (Gayle and Redding 2007)	DBLPN	Insert 1 inch 20- to 23-gauge needle distal and plantar to the head of the fourth metatarsal bone with the needle directed proximodorsally and axial to the bone	6 mL
High plantar (high six point) (Moyer <i>et al.</i> 2011)	Medial and lateral plantar nerves, medial and lateral plantar metatarsal nerves; dorsal metatarsal nerves	- Insert 1.5 inch 20- to 22-gauge needle 1 cm distal to the tarsometatarsal joint and axial to MTII or MTIV until its point contacts MTIII and inject 2 to 3 mL to anaesthetise medial and lateral plantar metatarsal nerves. - Insert 5/8 inch 25-gauge needle through heavy fascia to each plantar nerve adjacent to dorsal surface of deep digital flexor tendon and inject 2 to 3 mL to anaesthetise medial and lateral plantar nerves. - Insert 5/8 inch 25-gauge needle subcutaneously at the dorsomedial and dorsolateral aspects of the metatarsus at this level to anaesthetise the dorsal metatarsal nerves.	2 to 3 mL/ site = 12 to 18 mL total
Subtarsal (Dyson and Romero 1993)	Medial and lateral plantar nerves	Technique 1	6 mL
		- Insert 1.5 inch 20- to 22-gauge needle subcutaneously plantar to the fourth metatarsal bone 1.5 cm distal to TMT joint - Redirect needle axial to fourth metatarsal bone and insert until resistance is encountered then inject 3 mL - Withdraw needle partially, redirect dorsomedially towards the axial aspect of metatarsal bone and inject 3 mL	
		Technique 2	6 mL
		- Palpate medial and lateral neurovascular bundles between the superficial and deep digital flexor tendons - Insert 25-gauge 5/8 inch needle and inject 1.5 mL beneath superficial fascia at these sites	

TABLE 1: Continued

Nomenclature	Targeted nerves	Injection site	Volume 2% local analgesic
		- Flex metatarsophalangeal joint and insert 1.5 inch 20- to 22-gauge needle axial to each of the second and fourth metatarsal bones, 1.5 cm distal to TMT joint - Each needle is inserted until adjacent to suspensory ligament and plantar aspect of third metatarsal bone and 1.5 mL injected at each site	
Direct infiltration proximal suspensory ligament (Ford <i>et al.</i> 1988; Stashak 2002; Bassage and Ross 2003)	Medial and lateral plantar nerves; Medial and lateral plantar metatarsal nerves	Insert 1 inch 20- to 22-gauge needle between the suspensory ligament and distal accessory ligament of the deep digital flexor tendon at the level of the junction of the head and shaft of MTIV.	20 mL

or 'low 4-point' analgesia to rule out distal limb lameness (Dyson and Romero 1993; Hinnigan *et al.* 2014).

Claunch *et al.* (2014) compared the two previously described techniques for selective analgesia of the DBLPN (Gayle and Redding 2007; Hughes *et al.* 2007) in standing horses. This study documented diffusion radiographically with two different injection volumes (2 mL or 8 mL) of mepivacaine hydrochloride–iohexol (50:50 mixture) using the two previously described techniques to desensitise the DBLPN. This study noted a high degree of variability in contrast solution diffusion among injections, with high-volume injections diffusing significantly further proximally and distally than low-volume injections. Results of this study suggested that use of higher volumes (greater than or equal to 8 mL) of local anaesthetic solution may be excessive and are likely to lead to false-positive results and misinterpretation of results of lameness examination. Contrast agent was documented within the tarsal sheath in 5 of 32 (16%) injections and within the tarsometatarsal joint in 2 of 32 (6%) injections. No significant difference was found for risk of inadvertent penetration of synovial structures between the two techniques or between the two volumes of local anaesthetic solution used. An unexpected but interesting finding of this study was the disproportionate distribution of intrasynovial involvement between limbs (six of seven occurring in right limb and one of seven occurring in the left limb). The discrepancy between limbs was proposed to be a result of the right-handed author performing all injections with a cross-handed approach when injecting the right limb, resulting in inability to achieve maximum displacement of the flexor tendons and slight divergence of the needle, compared with injection of the left limb. The findings of this study supported the use of a low volume of local analgesic solution for the DBLPN, regardless of technique used and further supported the use of aseptic technique due to the risk of inadvertent penetration of the tarsometatarsal joint or tarsal sheath.

In summary, approaches for diagnostic analgesia of the proximoplantar metatarsus include the high plantar 4-point nerve block, direct infiltration into the origin of the suspensory ligament, subtarsal nerve block and two techniques to selectively produce analgesia of the deep branch of the lateral plantar nerve (Table 1). Subtarsal nerve block resulted in diffusion of local anaesthetic solution to the tarsal sheath in 40% of cases and to the tarsometatarsal joint in 5% of cases (Dyson 1991a,b). Perineural infiltration of the DBLPN resulted in

variable diffusion to the tarsal sheath in 5%, 15%, 30% or 37.5% of cases (Hughes *et al.* 2007; Claunch *et al.* 2014; Hinnigan *et al.* 2014; Contino *et al.* 2015) and diffusion to the tarsometatarsal joint in 25% or 6% of cases (Claunch *et al.* 2014; Contino *et al.* 2015; respectively). No difference in frequency of diffusion to adjacent synovial structures was appreciated between techniques to desensitise the DBLPN (Claunch *et al.* 2014). The single-injection technique for perineural infiltration of the DBLPN was more specific when directly compared with the subtarsal nerve block with less diffusion to surrounding synovial structures (Gayle and Redding 2007). The desire to avoid adjacent synovial structures, reduce additional needle insertions and ease of use may all factor into the clinician's decision to use one perineural anaesthetic block over another. However, taking into account the previously cited literature in terms of safety and selectivity, the authors propose the use of techniques to produce analgesia of the deep branch of the lateral plantar nerve (Gayle and Redding 2007; Hughes *et al.* 2007) as the preferred technique.

Diagnostic analgesia of the proximal metacarpus and carpus

In the thoracic limb, the lateral palmar nerve originates proximal to the carpus and is formed by the lateral palmar branch of the median nerve and palmar branch of the ulnar nerve. The lateral palmar nerve has a deep branch distal to the accessory carpal bone, which innervates the origin of the suspensory ligament and divides into the lateral and medial palmar metacarpal nerves at the level of the proximal end of the fourth metacarpal bone (Moyer *et al.* 2011). Muylle *et al.* (1998) demonstrated that to desensitise the PSL and the palmaroproximal aspect of the metacarpus, the lateral palmar nerve should be identified distal to the area where fibres from the ulnar and median nerves converge on the distal aspect of the radius. Innervation of the carpus and proximal metacarpus is illustrated in **Figs 2 and 3**.

Desensitisation of the palmaroproximal metacarpus has been described using four reported techniques: direct infiltration of the origin of the suspensory ligament (Stashak 2002; Bassage and Ross 2003), analgesia of the palmar and palmar metacarpal nerves at the level of the proximal metacarpus (Wheat and Jones 1981; Stashak 2002; Bassage and Ross 2003), analgesia of the lateral palmar nerve proximal to its deep branch (Wheat and Jones 1981) and

analgesia around the lateral palmar nerve along the medial aspect of the accessory carpal bone (Castro *et al.* 2005), which are illustrated in **Fig 4**. Analgesia of the lateral palmar nerve may be combined with analgesia of the medial palmar nerve at the level of the proximal aspect of the metacarpus for more extensive desensitisation of the skin and deeper structures of the metacarpus, including proximal suspensory ligament, deep digital flexor tendon, superficial digital flexor tendon and accessory ligament of the deep digital flexor tendon (Wheat and Jones 1981). Ford *et al.* (1989) compared three techniques for desensitising the palmaroproximal metacarpal region: either infiltration at the origin of the suspensory ligament (Method A), palmar and palmar metacarpal nerve blocks at the proximal end of the

metacarpus (Method B), or palmar and palmar metacarpal nerve blocks at the level of the accessory carpal bone (Method C). In Method A, 20 mL of dye was injected from lateral to medial between the suspensory ligament and accessory ligament of the deep digital flexor tendon at the level of the junction of the head and shaft of the fourth metacarpal bone. In Method B, 2.5 mL of dye was infiltrated around each of the medial and lateral palmar metacarpal nerves on the axial surface of the second and fourth metacarpal bones, and 2.5 mL of dye was infiltrated around the medial and lateral palmar nerves by inserting the needle under the heavy fascia between the superficial digital flexor tendon and the suspensory ligament. In Method C, also known as the 'Wheat block,' a needle was inserted

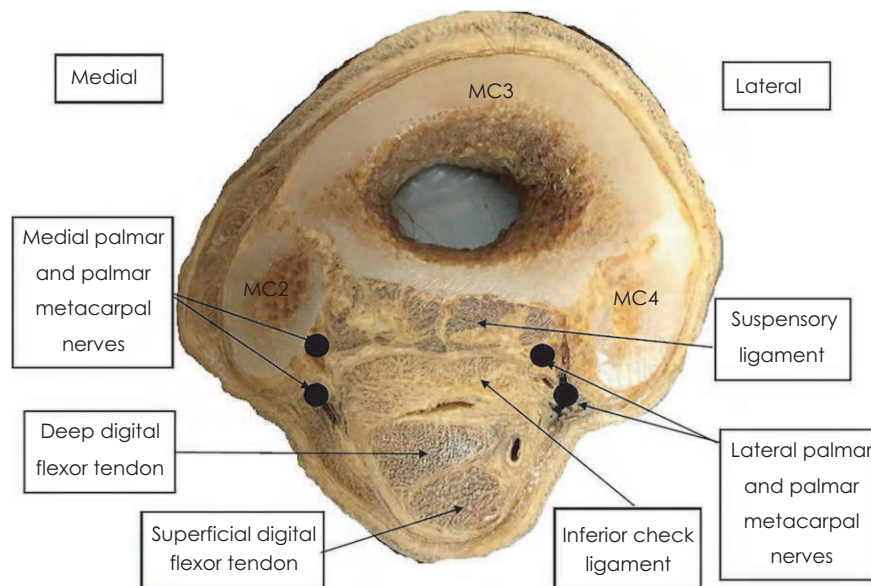


Fig 2: Axial section metacarpus right forelimb: MC2 = second metacarpal bone, MC3 = third metacarpal bone, MC4 = fourth metacarpal bone.

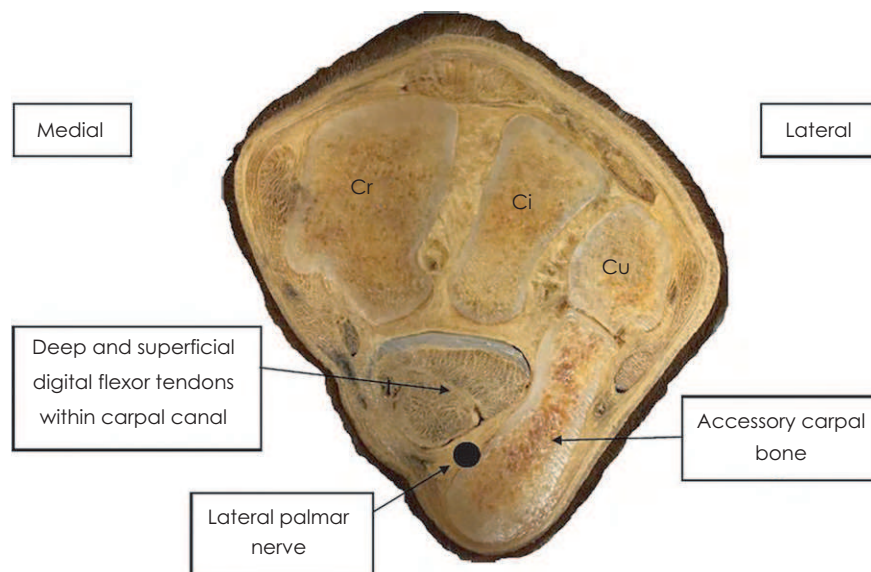


Fig 3: Axial section carpus right forelimb: Cr = radial carpal bone, Ci = intermediate carpal bone, Cu = ulnar carpal bone.

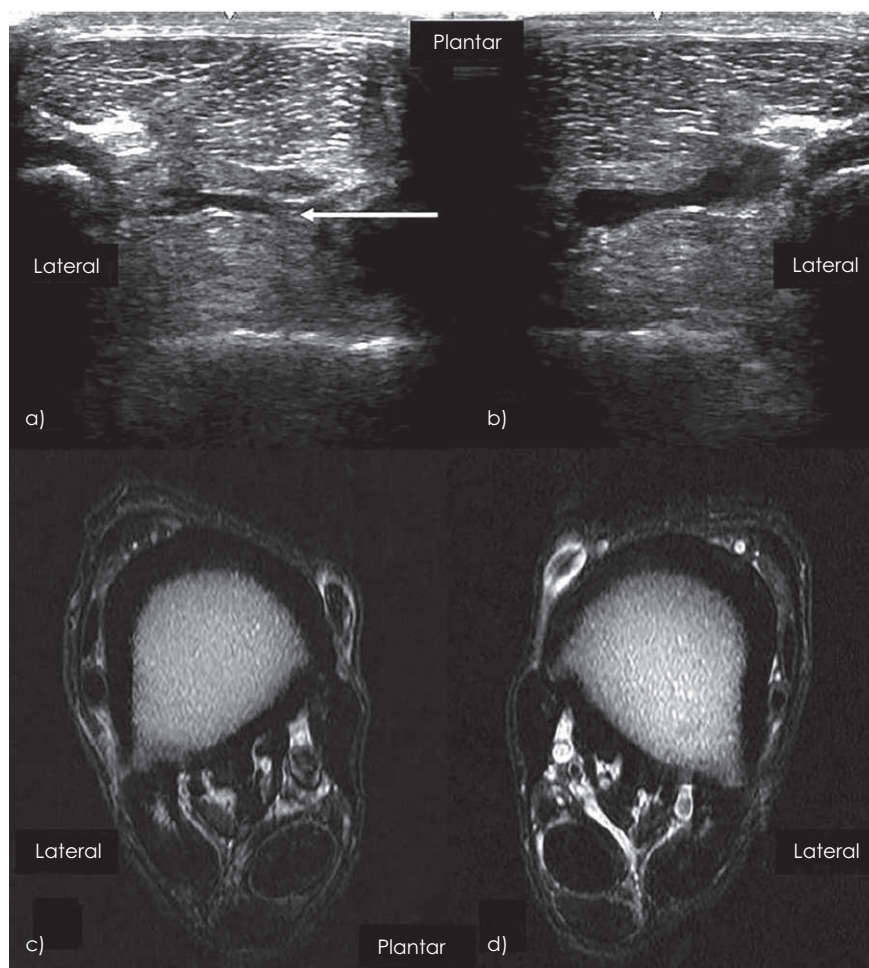


Fig 4: Ultrasound a) and b) and magnetic resonance c) and d) images of a 16-year-old Warmblood mare presented for left hindlimb lameness of 4 months duration. The affected limb a) and c) was compared with the nonaffected limb b) and d); all images were captured at 2.5 cm distal to the tarsometatarsal joint. Note the diffuse enlargement on ultrasound of the suspensory ligament at this level resulting in reduced space between the suspensory ligament and inferior check ligament on the affected left hindlimb with compression of the plantar vasculature between the plantar fascia and suspensory ligament (white arrow). Transverse proton density magnetic resonance images demonstrated similar findings with moderate diffuse enlargement of the proximal ligament origin with minimal alteration of the fat, muscle and ligamentous fibre definition of the left hindlimb. The suspensory ligament measured 2.2 cm² at 4 cm distal to the tarsometatarsal joint (vs. 1.90 cm² right hind).

palmarolateral to dorsomedial direction at the distal aspect of the accessory carpal bone and 5 mL dye was injected while withdrawing the needle slowly to achieve perineural infiltration of the lateral palmar nerve. Ford *et al.* (1989) reported the frequency of inadvertent injection into the distal carpal joints was 37%, 17% and 0% for methods A, B and C, respectively, and concluded that the carpometacarpal joint was unlikely to be penetrated when local anaesthetic solution was injected around the lateral palmar nerve distal to the accessory carpal bone at the level of the middle carpal joint. However, while there was no infiltration of the distal carpal joints in any specimen when using Method C, the carpal synovial sheath was penetrated in 68% of cases when using this technique described by Wheat and Jones (1981). In a cadaver study of 30 equine forelimbs, a fourth approach was described to deposit local analgesic around the lateral palmar nerve along the medial aspect of the accessory carpal bone (Castro *et al.* 2005). This technique

was found to be accurate for perineural infiltration of the lateral palmar nerve proximal to the origin of its deep branch, as dye was observed to be within 2 mm of the nerve in all cases and dye was not found in the carpal synovial sheath of any specimen (Castro *et al.* 2005). However, this study utilised smaller volumes of dye solution (0.5 mL) than that typically injected when performing diagnostic analgesia in a clinical case, and a larger volume may be anticipated to spread further and possibly enter synovial cavities. Because the solution can be placed accurately around the lateral palmar nerve using this technique, the authors recommended using only a small quantity of local anaesthetic solution (1.5 to 2.0 mL) to minimise potential for diffusion and undesirable desensitisation of adjacent structures (Castro *et al.* 2005).

Analgesia of the carpal joints presents similar challenges to the joints of the tarsus in interpretation of improvement of lameness following blocking of the proximal metacarpus due to diffusion of local analgesic to the surrounding tissues. The

middle carpal and carpometacarpal joints always communicate with each other, which becomes an important aspect of anatomy when evaluating regional anaesthesia of the proximal palmar metacarpal region (Ford *et al.* 1988; Ruggles 2012). The palmar outpouchings of the carpometacarpal joint capsule extend distally into the fibres of the proximal portion of the suspensory ligament (Kiely and McMullen 1987; Ford *et al.* 1988; Moyer and Carter 1996). Therefore, it has been suggested that following injection of local analgesic into the middle carpal joint, solution that diffuses to the carpometacarpal joint may subsequently result in analgesia of the origin of the suspensory ligament (Ford *et al.* 1988; Moyer *et al.* 2011). Likewise, inadvertent puncture to the carpometacarpal joint and subsequent analgesia of this joint and the middle carpal joint may occur when performing regional analgesia of the proximal metacarpal region (Ford *et al.* 1988; Moyer *et al.* 2011).

In summary, desensitisation of the palmaroproximal metacarpus may be achieved through direct infiltration of the origin of the suspensory ligament (Stashak 2002; Bassage and Ross 2003), analgesia of the palmar and palmar metacarpal nerves at the level of the proximal metacarpus (Wheat and Jones 1981; Stashak 2002; Bassage and Ross 2003), analgesia of the lateral palmar nerve proximal to its deep branch (Wheat and Jones 1981) or at the level of the distal aspect of the accessory carpal bone (Castro *et al.* 2005); these techniques are summarised in **Table 1**. Comparison of the first three techniques revealed that perineural analgesia of the lateral palmar nerve (Wheat and Jones 1981) may be less likely to result in inadvertent placement or diffusion of local anaesthetic solution into the carpometacarpal joint but resulted in injection of or diffusion into the carpal sheath in 68% of cases (Ford *et al.* 1989). The fourth technique described by Castro *et al.* (2005) using smaller volumes did not result in diffusion to the carpal sheath in any case indicating that this technique may result in greater specificity in blocking and reduced diffusion to adjacent synovial structures. Taking into account the previously cited literature, the authors propose the use of the lateral palmar nerve block along medial aspect of accessory carpal bone (Castro *et al.* 2005) as the preferred method for desensitisation of the palmaroproximal metacarpus.

Selection of diagnostic imaging modalities to assess clinical conditions of the proximal metatarsal and metacarpal regions

In the diagnosis of PSD of the forelimb or hindlimb, there may not be apparent localising clinical signs to distinguish pain arising from the PSL from other locations. Perineural infiltration of the DBLPN is not specific for diagnosis of PSD or for diagnosis of proximal plantar metatarsal pain, and alternate sources of proximal palmar metacarpal or plantar metatarsal pain have been described in addition to PSD (Brokken *et al.* 2007; Labens *et al.* 2010). These include neuropathy of the DBLPN, osseous injury at the origin of the suspensory ligament, avulsion at the origin of the suspensory ligament (Bramlage *et al.* 1980; Booth 2003; Launois *et al.* 2003), palmar or plantar cortical stress fractures (Ross *et al.* 1988), desmitis of the accessory ligament of the deep digital flexor tendon (aka inferior check ligament) (Dyson 1991a,b; McDiarmid 1994; Brokken *et al.* 2007), fractures of the proximal aspect of the splint bones (Peterson *et al.* 1987), and superficial and deep digital flexor tendonitis (Genovese

and Rantanen 1998; Reef *et al.* 1998) or conditions related to synovial structures in that region such as carpal or tarsal sheath, carpometacarpal or tarsometatarsal joints (Toth *et al.* 2009; Labens *et al.* 2010).

Multiple imaging modalities have been described for evaluation of the proximal metacarpus and metatarsus following diagnostic analgesia (radiography, ultrasonography, magnetic resonance imaging and nuclear scintigraphy), each with its benefits and challenges (Meehan and Labens 2016). Radiography and ultrasonography may often be recommended first due to their widespread availability and relative affordability as diagnostic techniques. However, differentiation between radiographic and ultrasonographic findings of lame vs. clinically sound individuals presents a clinical challenge (Dyson 1991a,b; Labens *et al.* 2010; Dyson and Pinilla 2015). Furthermore, while evaluation of the proximal metacarpal or metatarsal region using radiography or nuclear scintigraphy may be useful in detection of bony changes, such as avulsion fractures, splint bone exostoses or cortical stress fractures (Brokken *et al.* 2007), MRI provides an advantage in distinguishing injuries arising from soft tissue as well as those with concurrent bony involvement (Labens *et al.* 2010). Ultrasound can provide additional information in terms of fibre disruption and diameter thickening of tendons and ligaments. However, detection of some abnormalities, specifically desmitis of the PSL or accessory ligament of the deep digital flexor tendon, has not been possible in a percentage of horses with either ultrasound or nuclear scintigraphy (Dyson 2003; Brokken *et al.* 2007).

Advanced imaging such as MRI or nuclear scintigraphy can provide further diagnostic information. Magnetic resonance imaging provides information on abnormalities of the bone and changes in size and signal within the PSL and deep digital flexor tendon, which may not be possible to evaluate by palpation or other imaging modalities (Brokken *et al.* 2007). Increased signal intensity occurs in areas of ligamentous damage, representing increased cellularity or vascularity (Murray *et al.* 2006; Brokken *et al.* 2007). Magnetic resonance imaging and nuclear scintigraphy have been employed less frequently in the past for diagnosis of lameness in the proximal metacarpus and metatarsus for multiple proposed reasons, including financial constraints and/or lack of availability due to distance to tertiary referral centre. Labens *et al.* (2010) utilised MRI as the gold standard to demonstrate the lack of specificity of diagnostic analgesia of the proximal metatarsus in a retrospective study of lameness due to proximal plantar metatarsal pain, commonly attributed to PSD. This study examined 39 horses (46 hindlimbs) with lameness that improved by at least 60% following analgesia of the DBLPN and revealed that only 21 of 46 (46%) hindlimbs were diagnosed with desmopathy of the PSL on MRI, considered the clinical gold standard. Labens *et al.* (2010) further compared clinical, magnetic resonance and ultrasonographic imaging findings in horses with proximal plantar metatarsal pain, revealing that ultrasonography had a sensitivity of 0.77 and 0.66 and specificity of 0.33 and 0.31 for diagnosing PSD and accurately localising lesions, respectively, when compared with MRI. Brokken *et al.* (2007) further reported a retrospective study of 45 horses evaluated with MRI with lameness previously localised to the proximal metacarpal or metatarsal region. This study revealed that 23 of 45 (51%) horses (13 hindlimb, 10 forelimb) had PSD, 16 of 45 (36%) had

desmitis of the accessory ligament of the deep digital flexor tendon, 2 of 45 (4%) had concurrent desmitis of both PSL and accessory ligament of the deep digital flexor tendon, and 4 of 45 (9%) had abnormalities unrelated to either ligament (Brokken *et al.* 2007). Brokken *et al.* (2007) concluded that changes within the ligament can be observed in MR images when they cannot be detected ultrasonographically as ultrasound findings were unremarkable or misinterpreted in 8 of 45 (18%) horses, therefore, diagnosis made with MRI proved to be more sensitive in detecting abnormalities. Magnetic resonance imaging was therefore preferred over ultrasonography for characterisation of abnormalities of the PSL in these two retrospective studies (Brokken *et al.* 2007; Labens *et al.* 2010). These studies further support that perineural infiltration of the DBLPN is not specific for diagnosis of PSD or for diagnosis of proximal plantar metatarsal pain, as conditions outside the proximal plantar metatarsal region were also diagnosed on MRI. Magnetic resonance imaging was demonstrated as a valuable diagnostic modality to accurately localise lameness to select appropriate treatment.

Selection of appropriate imaging modality and interpretation of imaging findings following diagnostic local analgesia of the proximal metatarsus and metacarpus has been described in detail previously by Meehan and Labens (2016). While injuries of this region are common among sport horses, the anatomy of the region leads to difficulties in localisation of lameness and diagnostic imaging may be complicated by overlying structures (Meehan and Labens 2016). A consistent approach to clinical examination, diagnostic analgesia and multimodal imaging was advocated to help overcome these difficulties (Meehan and Labens 2016). Due to the difficulty in interpretation of results of subcarpal and subtarsal analgesia, magnetic resonance imaging is advocated by the authors as the preferred imaging modality for detection of disease and localisation of lesions in the subcarpal or subtarsal region and may allow for earlier detection of injury in comparison to other imaging modalities available (Brokken *et al.* 2007; Labens *et al.* 2010). Supplementary analgesia is strongly recommended to improve clinical confidence in localisation of lameness. Intra-articular analgesia of the middle carpal or tarsometatarsal joint is recommended in cases with proximal metacarpal or metatarsal pain, with evaluation of lameness recommended to be performed at 5 mins following injection when extra-articular diffusion is minimal. A thorough approach utilising both diagnostic imaging and supplementary blocking is advocated to marry the results of imaging and diagnostic analgesia for the most complete clinical diagnosis.

In conclusion, diagnosis of clinical conditions of the equine proximal metacarpus and metatarsus presents a clinical challenge. Results of local analgesia should be examined carefully during lameness evaluations due to the possibility of diffusion of local anaesthetic solution and inadvertent intrasynovial injection. Supplementary diagnostic analgesia of surrounding anatomic regions and advanced diagnostic imaging, particularly magnetic resonance imaging, are recommended for most accurate diagnosis of lameness. Failure in response to therapy in cases where supplementary diagnostic analgesia and advanced diagnostic imaging have not been performed should prompt the clinician to broaden the approach to better characterise the site of pain.

Part II: Retrospective review of clinical case population at Colorado State University Veterinary Teaching Hospital

Introduction

The clinical case population at the Colorado State University Teaching Hospital was examined retrospectively with the primary objective of evaluating the frequency with which perineural analgesia of the subcarpal or subtarsal regions was utilised in the diagnosis of lameness in the proximal metacarpal and metatarsal regions in that clinical population. The secondary objective of this study was to describe the frequency of utilisation of imaging techniques (magnetic resonance imaging, nuclear scintigraphy, computed tomography and ultrasonography) in the characterisation of lameness following local analgesia of the lateral palmar or plantar nerve. Case examples will be provided to demonstrate variability with blocking.

Materials and methods

A computerised search of medical records was performed to identify horses undergoing lameness evaluation including local analgesia of the proximal metacarpal or metatarsal regions, between 1 January 2010 and 31 December 2015 at the Colorado State University (CSU) Veterinary Teaching Hospital. Medical records were reviewed retrospectively and data collected from medical records included age, breed, clinician, degree of lameness on AAEP grading scale of 0 to 5 (Baxter 2011), forelimb or hindlimb affected, whether other blocks were performed (e.g. intra-articular), advanced diagnostic imaging pursued (nuclear scintigraphy, magnetic resonance imaging, computed tomography and ultrasonography) and treatment pursued following diagnosis.

In the cases included in this retrospective study, local analgesia of the proximal metacarpus was performed either by lateral palmar nerve block at the level where the nerve courses along the medial aspect of the accessory carpal bone (Castro *et al.* 2005), by high 4-point nerve block or by infusion of local analgesic into the PSL. Local analgesia of the proximal metatarsus was performed by either DBLPN nerve block as described by Hughes *et al.* (2007), by high 4-point nerve block or by infiltration of the PSL. Response was further classified as a positive response if >60% improvement of lameness was observed, and negative response if <60% improvement of lameness was observed following diagnostic analgesia. Two clinical cases (one forelimb, one hindlimb) that improved following local analgesia of the proximal metacarpus and metatarsus, respectively, were also described. All cases described had a low 4- or low 6-point nerve block performed with <60% improvement in lameness prior to local analgesia of the proximal metacarpus or metatarsus, respectively. Supplementary diagnostic analgesia of adjacent synovial structures was performed in a percentage of cases depending upon clinical presentation.

Results

Within the study period, 1860 lameness evaluations were performed at CSU by the Equine Surgery, Ambulatory and Sports Medicine Services. Of these, 168 of 1860 (9%) horses received regional analgesia of the proximal metacarpus or proximal metatarsus. Of these 168 horses, 119 horses (71%) were identified as improving >60% following regional analgesia of the proximal metacarpus or proximal metatarsus. An additional 49 of 168 horses (29%) were

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identified as receiving regional analgesia of the proximal metacarpus or metatarsus and improving <60% and will not be considered further.

There were 71 of 168 (42%) horses identified as receiving local analgesia of the proximal metacarpus. Of these, 48 of 71 (68%) improved >60% following local analgesia of the proximal metacarpus. Magnetic resonance imaging was performed in 8 of 48 (17%) cases, nuclear scintigraphy was performed in 10 of 48 (21%) cases and ultrasonography was performed in 43 of 48 (90%) of cases. Intra-articular analgesia of the middle carpal joint was performed in 2 of 48 (4%) cases that improved >60% following subcarpal analgesia and in 1 of 24 (4%) cases that improved <60% following subcarpal analgesia.

There were 100 of 168 (59%) horses identified as receiving local analgesic of the proximal metatarsus (three horses in this data set received local analgesia of both forelimb and hindlimb and are included in both subcarpal and subtarsal groups). Of these, 71 of 100 (71%) improved >60% following proximal metatarsus local anaesthetic. Magnetic resonance imaging was performed in 10 (14%) cases, nuclear scintigraphy was performed in five (7%) cases and ultrasonography was performed in 63 (89%) of the 71 cases. Intra-articular analgesia of the distal intertarsal and tarsometatarsal joints was performed in 3 of 71 cases (4%) that improved >60% following subtarsal local analgesia, and in 18 of 29 (62%) of cases that improved <60% following subtarsal local analgesia.

Diagnoses

With MR imaging interpreted as the clinical gold standard in 18 cases (eight forelimb, 10 hindlimb), diagnosis of desmopathy of the PSL was made in 10 (56%) cases (five of which had concurrent adaptive remodelling of the third metacarpus or metatarsus), an osseous injury including fracture in four (22%) cases, deep digital flexor tendonitis in one (6%) case and a condition related to the distal limb in three (16%) cases. Osseous injuries included diffuse cartilage loss of the medial condyle of the third metacarpus with associated focal subchondral bone defect, minimally displaced incomplete sagittal fracture of the talus with communication with the tarsocrural joint, sclerosis of the radial and third carpal bones, and sclerosis of the distal third of the medial third metacarpal bone. All cases described had a low 4- or low 6-point nerve block performed with <60% improvement in lameness prior to local analgesia of the proximal metacarpus or metatarsus respectively.

Of the 16 horses (nine forelimb, five hindlimb) that received a nuclear scintigraphy scan, increased radiopharmaceutical uptake was seen in the proximal aspect of the metatarsus/metacarpus in 2 of 16 (12.5%) cases, in the tarsus/carpus in 8 of 16 (50%) cases, in both the tarsus and metatarsal region in 2 of 16 (12.5%) horses, in both the carpus and metacarpal region in 2 of 16 (12.5%) cases and in various other regions of the distal limb in 2 of 16 (12.5%) cases.

Case examples

Case 1

A 16-year-old Warmblood mare presented to the CSU Equine Surgery Service for evaluation of left hindlimb lameness of approximately 4 months duration. Perineural and intra-articular anaesthesia performed by the referring veterinarian

previously isolated the lameness to the PSL and stifle. Ultrasound of the left hind metatarsus, stifle and coxofemoral joint was performed prior to referral to CSU. Ultrasound revealed moderate left hind PSD, mild-to-moderate effusion and synovitis of the left medial femoral tibial joint and mild tearing of the left middle patellar ligament. The coxofemoral joint was within normal limits.

The mare was rested for 4 weeks following ultrasound examination, with gradually increasing handwalking. The left hind PSL was injected with platelet-rich plasma and received extracorporeal shockwave and laser therapy. The left medial femoral tibial joint was injected with three intra-articular injections of autologous conditioned serum. When her left hindlimb lameness persisted, the PSL was infused with local analgesic for a second time and did not improve following local analgesia as it had previously. The mare was referred to CSU at that time for further evaluation and treatment.

On presentation, musculoskeletal palpation revealed mild left hind digital flexor tendon sheath effusion. No additional synovial structure effusion or sensitivity to palpation was appreciated. Lameness evaluation revealed a grade 3+ of 5 left hindlimb and grade 1 of 5 left forelimb lameness (AAEP Lameness Scale; Baxter 2011). Flexions of the left hindlimb were mildly positive to digit, moderately positive to stifle and moderately positive to full limb flexions. Perineural analgesic blocking was performed to further isolate the left hindlimb lameness. An abaxial sesamoid nerve block did not improve the lameness, nor did a low 4-point nerve block. A high 4-point nerve block improved the lameness by 65 to 70%. Intra-articular analgesic blocks of the left hind distal intertarsal and tarsometatarsal joints further improved the lameness to >80%.

Radiographs of the left tarsus were performed, which revealed smooth periarticular osteophytes of the dorsolateral periarticular tarsometatarsal joint and mild sclerosis and remodelling of the dorsal central and third tarsal bones. The mare was dismissed to her owners for MRI scheduled 2 weeks later. A high-field MRI (1.0T) under general anaesthesia was performed on the mare's left hind proximal metatarsus, which revealed moderate diffuse desmopathy and plantar fasciitis of the left hind proximal suspensory origin with no significant fibre disruption. Adhesion formation of the accessory ligament of the deep digital flexor tendon, plantar fascia and plantar margin of the suspensory ligament was suspected (**Fig 4**). Based on the results of MRI, left hindlimb fasciotomy and DBLPN neurectomy was performed. At the time of publication, the mare was rehabilitating from surgery and progressing appropriately for that stage post-operatively. The results of MRI in this case were critical in determining appropriate treatment.

Case 2

A 7-year-old Warmblood gelding presented to the CSU Equine Sports Medicine Service for evaluation of left forelimb lameness of 3 days duration. The gelding competes in high-level dressage work. On presentation, musculoskeletal palpation revealed mild sensitivity to palpation over the left and right forelimb proximal suspensory ligaments. Exostosis of the second metacarpal bone was palpable but no sensitivity to palpation was appreciated. Lameness evaluation revealed grade 2+ of 5 left forelimb lameness, which worsened to a grade 3 of 5 on the right circle on arena footing (AAEP Lameness Scale, Baxter 2011). Flexion of the

left front digit was negative and left carpal flexion was mildly positive. Diagnostic analgesia of the left forelimb was performed to further localise the source of lameness. An abaxial sesamoid nerve block of the left forelimb did not improve the lameness, nor did a low 4-point nerve block. A lateral palmar nerve block performed along the medial aspect of the accessory carpal bone (Castro *et al.* 2005) improved the left forelimb lameness by >80% and resulted in the lameness switching to a predominantly right forelimb grade 1 of 5 lameness (AAEP Lameness Scale, Baxter 2011).

Ultrasound examination of the left front metacarpal region was performed, which revealed mild loss of fibre pattern of the PSL in zone 2A and no other abnormalities. Radiographs of the left front metacarpal region revealed exostosis of the second metacarpal bone. The horse was treated with regional limb perfusion of bisphosphonate (Tildren¹) and extracorporeal shockwave (Versatron²) of the PSL region. Specifically, the regional limb perfusion was performed by placing an Esmarch tourniquet around the distal radius and around the mid-metacarpus and injecting 50 mg bisphosphonate¹ diluted to 20 mL total volume with saline into the cephalic vein at the level of the carpus. Shockwave therapy consisted of 800 shocks delivered to the palmar aspect of the proximal third of the metacarpus at E6 energy with a 35 mm trode. This treatment regimen was repeated at 2-week intervals for a total of three treatments.

The horse remained persistently lame on the left forelimb (grade 3 of 5) following shockwave and bisphosphonate regional limb perfusion treatment. Perineural analgesic blocking was repeated, and the left forelimb lameness did not improve following abaxial sesamoid or low 4-point nerve blocks. The left forelimb lameness improved again >80% following a lateral palmar nerve block. The horse was referred to the CSU Equine Surgery Service for a nuclear scintigraphy scan and further evaluation and treatment at approximately 3 weeks following initial onset of lameness. Full body nuclear scintigraphy scan with a soft tissue phase of the left front proximal metacarpal region was performed. Severe focal increased radiopharmaceutical uptake in the dorsomedial aspect of the left third carpal bone and severe diffuse focal uptake in the palmar aspect of the entire length of the left and right third metacarpus were detected (**Fig 5**). Radiographs of the left carpus were repeated, which revealed no abnormalities. Ultrasound of the left metacarpal region was repeated, which identified very mild enlargement of the suspensory ligament at the level of zone 2A and 2B. Intra-articular analgesia of the left middle carpal joint was performed, which improved the left forelimb lameness by 90% from baseline, indicating the lameness was likely the result of middle carpal joint pain. Increased radiopharmaceutical uptake on nuclear scintigraphy scan in the region of the left third carpal bone was attributed to repetitive stress injury in this region. The diffuse radiopharmaceutical uptake along the entire length of the palmar aspect of the third metacarpal bones is of unknown aetiology but may represent adaptive or work-related remodelling. The owners revealed following nuclear scintigraphy that the horse frequently hits the stall door with the dorsum of his left carpus during feeding time. The left middle carpal joint was injected intra-articularly with 12 mg triamcinolone, 22 mg hyaluronic acid and 250 mg amikacin. The horse also received a bisphosphonate regional limb perfusion as described above, and systemic anti-inflammatories (1 g phenylbutazone³ by mouth every 12 h for

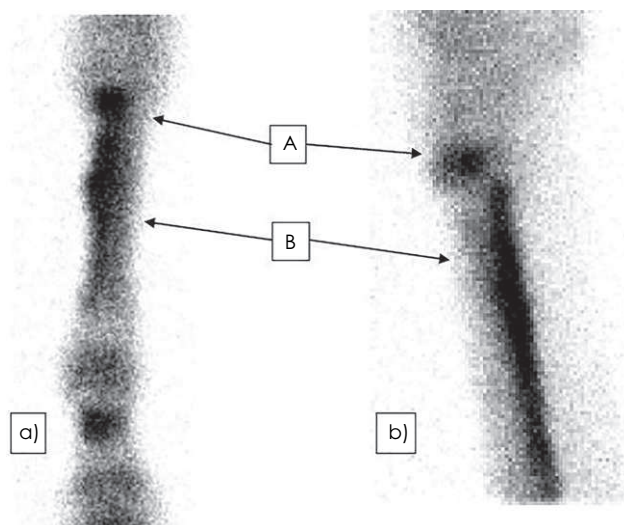


Fig 5: Nuclear scintigraphic images from a 7-year-old Warmblood gelding presented for left forelimb lameness of 3 weeks' duration at the time of scan, illustrating severe focal increased radiopharmaceutical uptake (IRU) of the left third carpal bone (A) and severe diffuse RU in the palmar aspect of the third metacarpal bone (B) on a) dorsopalmar view and b) lateral to medial view. Differential diagnoses for the IRU of the third carpal bone included possible fracture, bone contusion or severe focal adaptive or degenerative changes. Diffuse IRU along the length of the third metacarpal bone is of unknown aetiology but may represent adaptive or work-related remodelling.

3 days following intra-articular injection). The horse was rested for 2 weeks, and then gradually returned to full exercise.

Discussion

Diagnostic analgesia of the proximal metacarpus and metatarsus is not as specific as previously suggested. The challenge presented by diagnosis of lameness of this region is illustrated by this retrospective review of clinical cases evaluated for lameness. The second case example presented here illustrates how the overlapping anatomy of this region complicates diagnosis. This horse was initially suspected to have desmitis of the origin of the suspensory ligament based upon clinical impression of sensitivity to palpation and significant improvement following local analgesia of the lateral palmar nerve. However, ultrasonographic findings of the region did not correlate well with the severity of lameness and the horse did not respond to treatment as would be expected. Therefore, further advanced imaging (i.e. nuclear scintigraphy scan with soft tissue phase) was recommended by the clinician and pursued by the owner, which revealed increased radiopharmaceutical uptake in the left third carpal bone. The horse subsequently blocked following local analgesia of the middle carpal joint and improved with intra-articular therapy. The authors would use this case example to advocate for this approach in lameness diagnosis, i.e. thorough clinical examination, appropriate diagnostic analgesia and multimodal imaging with the pursuit of advanced imaging techniques (MRI, nuclear scintigraphy) in cases where ultrasound and radiographic findings do not seem to correlate with or fully explain clinical findings, or when patients do not respond to therapy as expected (Meehan and Labens 2016).

The current retrospective review was limited in that evaluation of efficacy of the lateral palmar or plantar nerve

block was restricted to clinical cases that underwent advanced diagnostic imaging following 60% improvement to local analgesia of the proximal metacarpus or metatarsus. Diffusion to the associated structures including the tarsometatarsal joint and tarsal sheath has been demonstrated following desensitisation of the DBLPN, potentially leading to incorrect interpretation of blocking patterns and ultimately incorrect or incomplete diagnosis of the source of lameness. In addition, if the DBLPN is blocked, loss of sensation of the distal condyle of third metatarsus and the plantar aspect of the fetlock joint may occur. Findings on MRI are consistent with previous reports suggesting that concurrent analgesia of the lateral plantar nerve is likely to occur when the DBLPN is blocked. Three of 18 (17%) of horses in our clinical population were identified on MRI to have clinically relevant abnormalities in the distal plantar limb in addition to the proximal metatarsal region, although their lameness did not previously improve >60% following low 4- or 6-point nerve blocks. Information gained from this retrospective review will be applied in future clinical cases in horses that improve following local analgesia of the proximal metacarpus or metatarsus.

The findings of this retrospective review support previous studies (Brokken *et al.* 2007; Labens *et al.* 2010) that have proposed MRI as a valuable diagnostic modality in diagnosis of lameness in horses that cannot be diagnosed using other imaging techniques. The clinical cases presented in this study further support the suggestion that examination of this region using nuclear scintigraphy may be useful to detect osseous changes (e.g. stress fractures, avulsion injuries or splint bone exostoses), and that diagnosis of PSD is not possible in a percentage of horses using ultrasound and nuclear scintigraphy (Dyson and Genovese 2003). Magnetic resonance imaging is therefore considered to be the preferred modality for soft tissue imaging and the 'gold standard' in the absence of histopathologic examination, which is not practical in clinical cases. In addition, several horses in this retrospective review with PSD had concurrent osseous changes at the origin of the PSL as evidenced on MRI. This supports the findings by Labens *et al.* (2010) where osseous changes at the origin of the suspensory ligament were observed more commonly with concurrent abnormalities of the suspensory ligament. Magnetic resonance imaging may be necessary to appropriately diagnose and make treatment recommendations in these cases.

Given our own clinical population and taking into account the current literature previously cited, consideration should be given to supplementary diagnostic analgesia in addition to further diagnostic imaging (e.g. radiography, sonography) in those horses in which lameness improves significantly following local analgesia of the proximal metacarpal or metatarsal region. This will include intrasynovial analgesia of the tarsometatarsal joint and/or tarsal sheath in the hindlimb, and carpometacarpal joint and/or carpal sheath in the forelimb. When possible, MRI of the proximal metacarpal or metatarsal region is advocated following supplementary diagnostic analgesia and initial diagnostic imaging (i.e. radiography, ultrasonography), particularly in cases in which initial diagnostic imaging is inconclusive. Magnetic resonance imaging allows the greatest potential as an imaging modality for accurate diagnosis and characterisation of disease processes of this region (Brokken *et al.* 2007; Labens *et al.* 2010). Sonographic examination can be challenging and difficult to interpret due to poor skin contact or artefacts from local vasculature, the adjacent overlying border of the deep digital flexor tendon or

inferior check ligament (Dyson 1994; Labens *et al.* 2010). In addition, sonography has been shown to underestimate on average the size of the PSL in comparison to magnetic resonance imaging (Bischofberger *et al.* 2006; Labens *et al.* 2010). Radiographic and scintigraphic findings are nonspecific and only relevant if changes to the bone are present. Abnormalities noted on radiographs and ultrasound may be subtle and considerable overlap between the appearance of normal and abnormal structures exists (Dyson 1991a,b, 1998; Smith and Webbon 1994). Magnetic resonance imaging allows more accurate quantification of suspensory ligament dimensions and more accurate identification of orientation of muscle fibres (Bischofberger *et al.* 2006). Without MRI, it might not be possible to differentiate soft tissue abnormalities such as desmitis of the accessory ligament of the deep digital flexor tendon vs. desmitis of the PSL (Brokken *et al.* 2007). Magnetic resonance imaging carries the greatest potential as a single-imaging modality in accurate characterisation of abnormalities in the subcarpal and subtarsal region.

In conclusion, accurate diagnosis of conditions of the proximal metacarpus and metatarsus presents a clinical challenge and diagnostic analgesia of this region is not specific to the proximal suspensory ligament. This may lead to incorrect interpretation of blocking patterns, potentiating incorrect diagnoses. Results of local analgesia should be examined carefully during clinical lameness evaluations due to the possibility of diffusion of local anaesthetic and inadvertent intrasynovial injection. Whenever perineural analgesia or infiltration of local anaesthetic solution into this region is performed, it is advisable to maintain strict adherence to aseptic technique due to risk of penetration of synovial structures. Supplementary diagnostic analgesia of surrounding anatomic regions and advanced diagnostic imaging, particularly magnetic resonance imaging, are recommended for most accurate diagnosis of lameness.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Retrospective analysis of case records. Owner consent for inclusion in study was not stated.

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Authorship

L. Pezzanite contributed to acquisition of data and draft of the manuscript. All authors contributed to study design, data interpretation and preparation of the manuscript. All authors approved the final version of the manuscript to be published.

Manufacturers' addresses

¹Ceva Animal Health, Lenexa, Kansas, USA.

²Pulse Veterinary Technologies LLC, Alpharetta, Georgia, USA.

³Vet One, Boise, Idaho, USA.

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Hypothesis Article

Real-time telehealth using ultrasonography is feasible in equine practice

C. Navas de Solis^{†‡*} , K. Bevevino[†], A. Doering[†], D. O'Gan[§], L. Teller[¶] and C. Underwood[‡]

[†]Department of Large Animal Clinical Sciences, Texas A&M, College Station, Texas; [‡]University of Pennsylvania New Bolton Center Hospital for Large Animals, Kennett Square, Pennsylvania; [§]Austin Equine, Austin, Texas; and [¶]Department of Small Animal Clinical Sciences, Texas A&M, College Station, Texas, USA

*Corresponding author email: crisnavasdes@gmail.com

Keywords: horse; telemedicine; ultrasound; remote assistance

Summary

Telehealth allows health care professionals to evaluate patients in remote locations using telecommunications technology. This manuscript presents a pilot experience with the goal of testing the feasibility and exploring the benefits for patients and veterinarians, technological challenges and perceived value of telehealth in ultrasound. In phase 1, experienced equine private practitioners and a sonographer performed diagnostic ultrasound examinations in collaboration using telecommunications technology. In phase 2, horses underwent two consecutive ultrasound examinations. One examination was performed by an inexperienced sonographer assisted by a remote expert, and all horses were then scanned by an expert sonographer on-site. Information about each interaction was collected, and a questionnaire was used at the end of the project to summarise practitioners' and trainees' experiences and perceptions. Thirty-six cases were evaluated using telecommunications technology. There were technological problems that were minor in 11 occasions, and in one case, the remote assistance had to be cancelled. Sonograms were longer when performed by an inexperienced sonographer aided remotely (40 ± 19 , [9–73] min) than when performed by a sonographer (24 ± 12 , [4–43 min], $P = 0.02$). Telehealth for ultrasound was feasible, and technological challenges could be solved. Telehealth for ultrasound was well received by private practitioners, house officers and sonography experts. The perceived benefits were the addition of clinically useful information, reassurance to practitioners and horse owners and education for practitioners. The results of this study support generating the hypothesis that telehealth could in the future increase the quality of equine medicine, and prospective studies are needed to confirm this. Rigorous care will be needed to ensure that implementation of telehealth technology prioritises equine health and the veterinary profession.

Introduction

Telehealth allows health care professionals to evaluate patients in remote locations using telecommunications technology. Telehealth is an evolving field that is radically changing human medical care (Combi *et al.* 2016; Weinstein *et al.* 2018) and will likely do so with veterinary care in the near future (Mechanic and Kimball 2018). Referrals in equine practice are often limited by the absence of specialty care near the animal location, inconvenience for owners, fear for loss of caseload or loss of the rewarding experience of

managing challenging clinical cases by the referring veterinarian, poor communication between the referral centre and the referring veterinarian and the perception that referral equals admission of lack of skill. The use of telehealth could solve many, or all, of the problems stated above. In regions, in which there is limited access to veterinary expertise, the development of methods to implement this technology effectively seems particularly important.

Telehealth has training and continuing education value. It is attractive to academic institutions because it can allow students and faculty access to training and collaboration with experts located in any area of the world (Arbeille *et al.* 2016). Moreover, students in academic veterinary referral practices often receive little training in primary care cases and are frequently exposed to only the most complex or intensive cases creating bias in their learning. The development of telehealth technology could increase exposure of students to a wider spectrum of cases and open possibilities for the development of newer models of education in which students receive a combination of remote instruction by university faculty and field practitioners while working on external rotations.

Teleradiology is currently the most common use of telehealth in veterinary medicine (Poteet 2008). Ultrasonography has traditionally been the less frequent imaging modality used in teleradiology due to the importance of real-time assessment and this modality being largely operator dependent (Lanowski *et al.* 2017). Technological advances that allow duplicating screens and the use of cameras or smart glasses that allow transmission of point of view video and two-way verbal communication are rapidly solving these problems. Previous studies in humans have documented the reliability of teleultrasound (Zennaro *et al.* 2016).

The overall goal of this study was to test the feasibility of remote assistance in ultrasound to equine private practitioners and trainees in medical and surgical specialties that had experience in sonography, but no advanced training, with the hypothesis that teleultrasound would be a feasible method of providing expert assistance to general practitioners. The study also explored the benefits for patients and veterinarians, technological challenges and perceived value of telehealth in ultrasound.

Materials and methods

The study was divided into two phases. In phase 1, experienced equine private practitioners and an expert sonographer

performed sonograms in collaboration using telecommunications technology. The purpose of phase 1 was to assess the feasibility of remote assistance in ultrasound to equine private practitioners. In phase 2, horses underwent two consecutive ultrasound examinations. One examination was performed by an inexperienced sonographer assisted by a remote expert sonographer (INEX-R), and all horses were then scanned by an expert sonographer on-site (EX) following the standards of care. A predefined checklist that specified the anatomical structures and ultrasound planes was used to collect data and report the ultrasound findings and diagnosis. Images from all sonograms were saved digitally and formal reports written by sonographers following clinical standards. The purpose of phase 2 was to assess the feasibility of remote assistance in ultrasound to specialty trainees and explore educational applications.

Both expert sonographers (remote and on-site) had received 2 years of specific Large Animal Ultrasound training, and each has over 10 years of specific experience in Large Animal Ultrasonography. The four equine private practitioners were clinicians with 5–15 years of experience in equine practice that perform ultrasounds on a routine basis but without specific training in sonography. Internal medicine and surgery residents of the American Colleges of Veterinary Internal Medicine and Veterinary Surgery approved programmes were the inexperienced sonographers (INEX) in the second phase. Client consent and permission from the appropriate Institutional Animal Care and Use Committee and Clinical Research Review Committee was obtained.

After each interaction, the body part examined, conclusion, duration of the sonogram and technological issues were logged. The equine practitioner answered (for each sonogram) the question: 'was the remote assistance useful?' and also provided comments about the main benefit and challenges of the consult. A phone interview at the end of the trial programme collected responses to the questions: (1) What were beneficial aspects of the programme? (2) Did sonograms change case management? (3) Would you use this service in a fee for service basis? (4) Would your clients be willing to assume the costs if the price of the assistance was similar to a sonogram performed in a referral facility? And (5) If remote assistance became a multispecialty service, which specialties are likely to use? The house officers in the second phase answered the questions: (1) What were beneficial aspects of the programme? (2) Do you consider the remote assistance of clinical value? (3) Do you consider the assistance of educational value? All participants were given the opportunity to comment on any aspect of the telehealth programme.

A telehealth system and support were provided by a telehealth platform (Aliquis Telepresence).¹ A GEMINI¹ unit was used to facilitate the communication between the private practitioner or house officer and the expert sonographer. The GEMINI unit provided on-demand communication via internet (using a wired router) between the sonographer in direct contact with the horse and the remote expert. The GEMINI solution includes a tower (containing two pair of Google Glass Enterprise Edition, a laptop (Microsoft Surface) and a speaker/microphone (Fig 1)). The result is a video conference with two-way verbal communication and two video feeds. The remote expert was able to see a duplicate of the ultrasound screen in the collaborating equine practice in real time and a simultaneous point of view image of the sonographer via the camera built in the glasses.

Data analysis

Categorical data are reported as the frequency of observation (of each category). Continuous data were reported as mean and (s.d.) when the data were distributed normally and otherwise as (median[range]). The results of practitioner/sonographer survey are reported as number cases (percentage). The duration of sonograms performed by INEX-R and EX was compared using a paired t-test, and significance was set at $P < 0.05$.

Results

Table 1 summarises the cases examined in Phases 1 and 2. The structures mentioned in **Table 1** were scanned using standard methods. For example, musculoskeletal regions were examined by imaging the tendinous, ligamentous, osseous and other soft tissue structures in the region of interest in the transverse and longitudinal planes. Abdomen and thoracic scans were performed by placing the probe in the intercostal spaces and imaging from dorsal to ventral. In the case of the abdomen, the paralumbar fossa was also imaged in this plane and the ventral abdomen in a longitudinal and transverse planes.

Phase 1: In all 25 cases (100%), the interaction was considered useful by the clinician performing the sonogram on site. The main value to the private practitioner was reported as follows: (1) Remote assistance added information that was used to manage the case (10 cases [40%]); (2) Remote assistance provided reassurance to the practitioner and/or owner about the clinical plan (10 cases [40%]); (3) Remote assistance helped improve ultrasound skills (5 cases [20%]).

Practitioners' response to the telephone survey at project completion indicated that the primary perceived benefits to the practitioner were increased reassurance for clients ($n = 3$), educational value ($n = 2$), information gained that impacted case management ($n = 1$) and same day specialist opinion without the need for travel ($n = 1$). Two practitioners felt that remote assistance impacted case management, one felt it did not and one was unsure. Three practitioners would use the remote assistance on a fee-for-service basis and one answered that would depend on the price. Three practitioners considered that their clients would willingly assume the costs of remote assistance (if priced similarly to a referral sonogram), and one was unsure/thought it would be owner dependent. When asked in which specialties they felt remote assistance would be beneficial, the response was internal medicine ($n = 3$), ultrasound ($n = 2$), cardiology ($n = 2$), neurology ($n = 1$), ophthalmology ($n = 1$) and reproduction ($n = 1$).

Phase 2: Response to the survey at project completion with the 3 INEX indicated that the primary perceived benefits were that it created new opportunities for scanning ($n = 3$). Surgical and medical residents felt the remote assistance was of clinical and educational value. The only negative comment regarding the process was that the technical issues were frustrating.

Discussion

Thirty-six cases were evaluated using telecommunications technology, demonstrating the feasibility of this technology in horses. There were technological issues in 12 instances (33%). These problems were mainly with internet connectivity and in

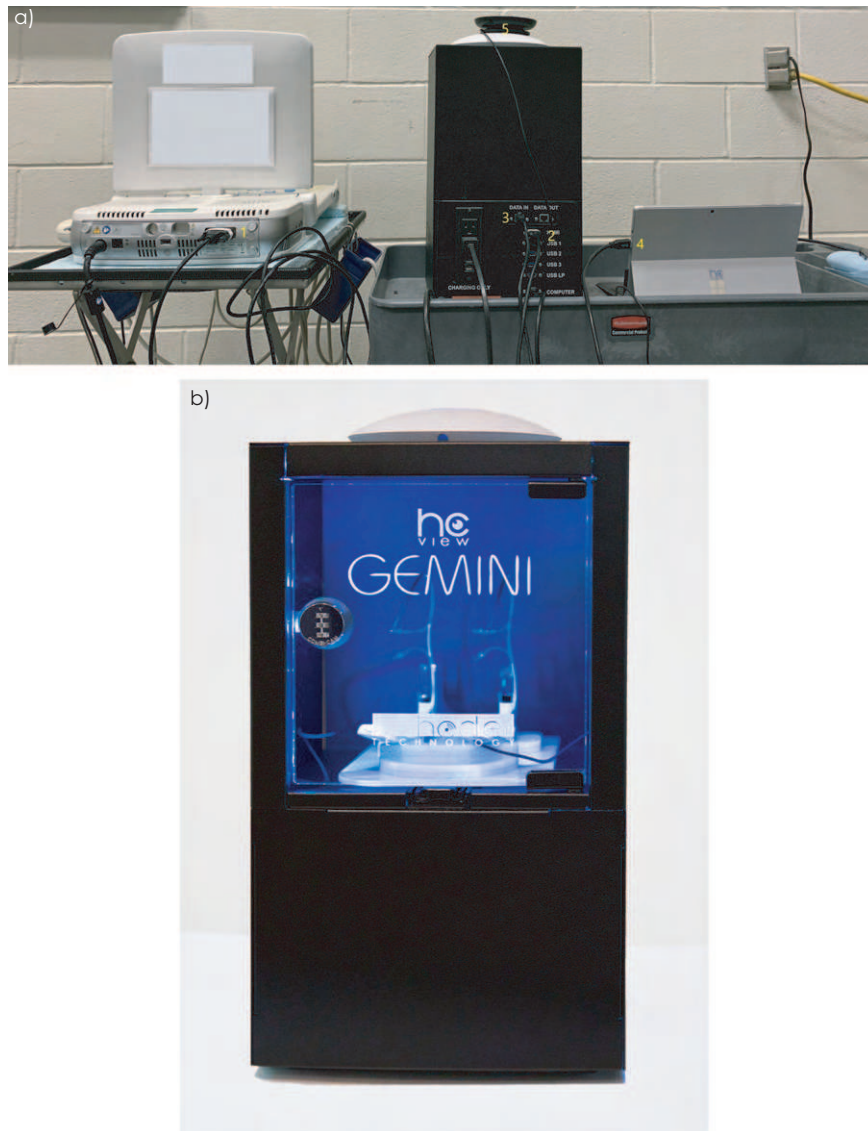


Fig 1: a) The video output (1) of the ultrasound equipment (left) is connected to the tower's HDMI port (2). The tower is connected to an Ethernet port (3) and a tablet that displays the videoconference software. An external microphone (4) is used to support audio. b) The tower stores and charges Google Glasses that provide a point of view video input.

general delayed the completion of the sonograms, and only in one case, the remote assistance could not be provided. Overall the problems were considered minor and reflect the status of a developing communications technology. The connectivity issues were likely due to variable or low upload speed of internet connections. The two videos feeds and audio require a high bandwidth with upload speeds in the Gigabits per second range. The speed of internet connections in some locations does not allow this type of communication. Interestingly, the practice located in the most rural area had the fastest internet connection and never experienced technological issues and the university setting with a more sophisticated IT support had problems more frequently. Methods to 'boost' internet speed are currently available and it is expected that 5G networks will be soon available widely. In the future, this technology will need to be tested with more varied types of internet connections, including mobile

networks, for its use to be widely available to equine clinicians. The authors felt that the anticipated upload speed based on the maximal speed of the connection and online tools to assess speed did not predict the quality of the connection but this was not formally analysed.

The mean duration of the sonograms was longer when performed using remote assistance than when performed by an expert sonographer on-site. This was to be expected. The longer sonogram often reflected time used in explaining how to perform or interpret specific images or communicating, discussing and agreeing in the interpretation of findings. It was our subjective impression that there was a period of adjustment in how to communicate guidance and findings. The number and heterogeneity of the cases do not allow testing the hypothesis that sonograms aided remotely become faster with time but the authors believe this is a plausible hypothesis. The on-site sonographers were

TABLE 1: Summary of sonograms performed using real-time telehealth

	No of cases	No of sonographers	Duration (min)	Area examined	Image quality	Technological problems
Phase 1	25	4	40 ± 16, [20–70]	10 abdomen, 1 thoraxes, 14 musculoskeletal [†]	Good in 24 cases and poor in one case [§]	Poor internet connectivity in 3 cases. [‡] Problems with pairing of Google Glasses in 3 cases.
Phase 2 INEX-R	11	3 on-site, 1 remote	40 ± 19, [9–73]*	4 abdomen, 2 thoraxes, 2 digital sheaths, 1 echocardiogram, 1 high-risk pregnancy and 1 fetlock	Good in 10 cases poor in one case [§]	Poor internet connectivity in 5 cases. [‡] Problems with server that supports communications precluded completion. Poor audio signal in 4 cases. [¶]
Phase 2 EX	11	1	24 ± 12, [4–43]*	4 abdomen, 2 thoraxes, 2 digital sheaths, 1 echocardiogram, 1 high-risk pregnancy and 1 fetlock	Good in 10 cases poor in one case [¶]	NA

EX, expert sonographer on-site; INEX-R, inexperienced sonographer assisted by a remote expert sonographer.

*Denotes statistically significant difference between groups, $P = 0.02$.

[†]Musculoskeletal examinations included five sonograms of the metacarpal/metatarsal area, 5 of the digital sheath and one sonogram each of the carpal sheath, stifle, pastern and pelvis.

[‡]In all instances the problems were solved by remote IT assistance and did not preclude completion of the sonogram. Eliminating the Google Glass input was necessary in all 5 cases of internet connectivity issues in order to have adequate internet speed.

[§]The poor-quality image was attributed to the hair coat and fat deposits in these cases.

[¶]Audio performed via telephone in these cases.

experienced equine practitioners with solid basic ultrasound skills. For many sonograms, the on-site veterinarians were able to obtain images without instruction. Some of the sonograms, or parts of the sonograms, were, however, of structures that would not have been imaged without guidance. In these cases, the sonogram becomes a continuing education exercise in addition to a clinical procedure. On-site veterinarians highlighted this aspect in questionnaires, and in 20% of the interactions, educational value was considered the most important aspect of the interaction. Interestingly house officers that receive ultrasound training on-site by expert sonographers also highlighted the educational value of the programme. Perhaps this programme made the training more structured in these cases or perhaps this just reflects excitement and a positive attitude towards new technologies. The potential of telecommunication technology for teaching in unconventional ways deserves attention (Becker *et al.* 2019).

In 40% of the interactions, the sonogram was perceived as useful for clinical management. In 40%, reassurance to veterinarians or owners was the reported main value. With 100% positive interactions, the trial was considered a success. There is a likely bias in this perception as costs of the trial were covered by the remote expert institution, and the on-site veterinarians and remote expert had a previous good working relationship. The mentioned biases could make the results of questionnaires more positive than in a situation in which this modality is used commercially or with a random population of on-site veterinarians. Controlled trials are necessary to prove many of these preliminary perceptions.

From the perspective of the remote experts that work in referral academic practice, the ability to communicate and collaborate with practitioners was a highlight of the study. The mission of many academic institutions includes to communicate and create new knowledge. Telecommunications technology opens novel and exciting

opportunities to improve equine health, foster a team approach to medicine and create new learning opportunities for equine veterinarians worldwide.

Telehealth is likely to replace part of the veterinary medical care, and we currently provide and expand the spectrum of veterinary work. The goal of a telehealth programme from the specialists involved in this pilot would not to be to substitute referrals, but to expand the spectrum of what both practitioners and specialists can offer. Reassurance to animal owners was highlighted by on-site veterinarians as a benefit of the remote consultations and perhaps telecommunications technology can help bridge gaps in communication between horse owners, practitioners and referral intuitions. The implementation of telehealth is likely to be fast and may disregard adequate testing of its shortcomings, due to the potential for large economic gains of this modality (Jackson and McClean 2012). We believe this initial pilot trial should be followed by controlled trials that can help design best practice guidelines and establish that the health and welfare of patients is not compromised by this medical modality. The experience gained with this pilot study makes us hypothesise that there will be good agreement between sonographic studies performed by inexperienced sonographers aided remotely by an expert and studies performed by an expert sonographer on-site. We also hypothesise that this will improve agreement between studies performed by inexperienced sonographers without assistance and studies performed by an expert sonographer.

These hypotheses can be expanded to many other fields of equine practice, and we believe that many specialties could be good candidates for telehealth programmes. Each specialty would need different tools but the principles may be shared and the real-time component of the current pilot is considered by the authors to be a big improvement when compared to interpretation of still images. Technology can be used in different ways to send live screen feeds to senior

clinicians and specialists. However, it should be stressed that security is of importance. The impression makes us hypothesise that real-time telehealth in which a remote expert and on-site veterinarian can communicate and exchange clinical information in real time provides higher quality medicine than remote consults that use a store-and-forward or asynchronous approach. This has been proven in some human medical fields in which the easier and often less expensive store-and-forward approach was less effective when compared to real-time telehealth (Loane *et al.* 2000). We also believe the best scenario remains to have the horse in the same room, and at the same time as the expert veterinarian and that telehealth should be considered an additional tool but not a substitution of traditional referrals. Prospective controlled studies will also be needed to prove these perceptions. The data presented here are heterogeneous in regards to the type of sonograms, equipment used, internet connectivity or sonographers' level of skill. This severely limits generalisations that can be made by this study. Extrapolation of information between specialties and between human and veterinary medicine needs to be viewed cautiously. It is likely that simple decisions could be made using less complex systems of communications that provide less information while complex cases may need more advanced telecommunications technology and/or on-site interactions.

In summary, telehealth for ultrasound was feasible, well received by horse owners, private practitioners, specialty trainees and sonography experts. There were technological challenges that could be solved. The perceived benefits of the telehealth programme were the addition of clinically useful information, reassurance to practitioners and horse owners and education for practitioners. We hypothesise that telehealth could increase the quality of equine medicine in the future by improving access to expert advice, and this hypothesis will need to be tested prospectively. It is very likely that telehealth will replace and expand the types of veterinary medical care we currently provide. The veterinary profession will need to determine how to implement changes while maintaining the priorities of animal health and evidence-based principles. If implemented wisely, changes could improve animal health, client satisfaction, the quality of veterinary care and the veterinary profession and provide new opportunities for learning and collaboration worldwide.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The study was approved by the Texas A&M Animal Care and Use Committee and the client owned animal research committee. Authors adhered to the Principles of Veterinary Medical Ethics of the AVMA.

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Authorship

C. Navas and C. Underwood contributed to the study design, study execution, data analysis and interpretation and preparation of the manuscript. D. O'Gan, K. Bevevino and A. Doering contributed to the study execution, data interpretation and preparation of the manuscript. L. Teller contributed to the data analysis and interpretation and preparation of the manuscript. All authors gave their final approval of the manuscript.

Manufacturer's address

¹Hodei Technology LLC, Indianapolis, Indiana, USA.

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Correspondence

Letter to the Editor: Comment on Editorial 'How to write a clinical case report'

I read with interest a recent editorial in your journal (How to write a clinical case report by Morresey 2019). I have a different perspective from Dr Morresey about case reports, and question some of the claims or statements made in this editorial.

Dr Morresey notes in the first sentence that “publication of case reports has decreased somewhat in the recent literature”. However, this claim is unsubstantiated and unreferenced. Based on my regular (almost daily) perusal of the veterinary clinical literature, I have not noticed any drop-off in publication of case reports and case series. Indeed, in recent years, several veterinary journals, dedicated to publishing case reports, have emerged (e.g. *Journal of Feline Medicine and Surgery Open Reports*, *Veterinary Record Case Reports*), suggesting the exact opposite to Dr Morresey's claim is occurring.

Case reports are published if they present cases that are rare, bizarre, previously unidentified or if they are approached and treated with techniques that have not gained widespread acceptance for a particular condition (because of novelty, availability, expense etc.). This rarity, by definition, reduces almost to zero the probability that a clinician reading the report will ever encounter an identical or remotely similar situation. Furthermore, the approach in a case report is anecdotal and uncontrolled – therefore, the reader cannot know whether the outcome was fortuitous, predictable, dependent on some undefined operator skill demonstrated by the author(s), or whether the reader could expect a similar outcome if faced with the exact same scenario.

In case reports that simply document a new condition, most clinicians faced with the same case, would probably approach it in a similar manner, based on their training for investigating diseases. A novel tumour, for example, will be biopsied, analysed histologically, possibly with special stains and/or genetic profiling etc., regardless of who obtains the initial sample. Therefore, the “learning” value of such case reports to most clinicians is minimal, because they would have used similar investigative methods to come to the same conclusions.

Rarely, a case report can be a sentinel case of a more widespread phenomenon (e.g. the first case of grape-associated renal failure, the first case of tent-caterpillar-induced abortion) or might document in more detail a phenomenon that has been recognised by clinicians but not described in the literature (e.g. expectoration of dirofilarial by infected dogs). However, mostly, case reports provide no guidance for day-to-day practice for most clinicians. Indeed, one might argue that the clinicians who benefit most from case reports are specialists, who are more likely to see similar rare and bizarre cases, or have access and skills required for novel therapeutic approaches!

Instead, case reports are mostly either professional bragging by experienced clinicians (essentially signalling to their colleagues how clever they were in identifying or treating the condition) or a means of satisfying publication requirements by young clinicians seeking specialty certification.

On the positive side, case reports are relatively harmless, specifically because they impact practice so little (either for better or worse). Consequently, I suggest that case reports be submitted to an indexed and searchable repository, left unreviewed (because there is no way for a reviewer to substantiate the authors' claims), and should garner no academic or scholarly credit. Essentially, they should be considered part of the public domain of “good Samaritan” contributions to veterinary medicine.

M. RISHNIW 

Department of Clinical Sciences, College of Veterinary Medicine, Cornell University, Ithaca, New York, USA

Reference

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Correspondence

Response to correspondence regarding 'How to write a clinical case report'

I am most grateful for the comments to my recent editorial (Morresey 2019; Rishniw 2020). This is the very debate among stakeholders on both sides of the issue that deserves the effort. The statement that the publication of case reports has diminished somewhat can be substantiated. If the wider medical literature is considered, it has been stated that '...Case reports are very rarely cited and thus, in general, publishing case reports is likely to reduce the impact factor. This has led many editors to delete case report sections from their journals...' (Warner 2005). It is therefore consideration of the impact factor of the journal that drives academic publication decisions. Case reports are considered less likely to be cited and therefore reduce a journal's impact factor. Removal or abbreviation of case reports in some journals does occur and is a tactical move to enhance status, not a comment on their ultimate utility (Moss 2008).

To this point, the arrival of the very journals highlighted in the comments to my editorial and others is, in fact, fully supportive of the conclusion that there is a great desire among the readership within the sphere of clinical veterinary medicine for the publication of case-based material, and a perception of its value to veterinarians in clinical practice. If there was no demand, there would be no supply. That said, the reader should be discriminating with respect to the presence of peer review and acknowledge case-based material is considered a lower quality of evidence (Murad *et al.* 2016).

It is true that the events of the case report cannot be substantiated as they are to some degree anecdotal. In contrast to basic research their results could be considered unable to be duplicated, a key criteria for experimental results. There is an implicit trust by both publisher and reader in the case conduct and outcome as written, as there is in all scientific journals. Recent retractions in the scientific literature of high-profile researchers that were found to have falsified their research means that basic science publications are themselves susceptible to unwitting dissemination of ultimately unsubstantiated information (Fanelli 2009; Steen 2011). The studies in question were subject to peer review and there was acceptance during that process of the integrity of the information as presented, just as there is with case reports.

Veterinary knowledge imparted to recent graduates is without doubt more advanced than ever. There has also been a move towards case-based learning in many veterinary schools. Actual clinical cases are presented as problems to be solved, with real-life complications and vagaries of clinical medicine. Could it not be argued that the publication of case reports, which are subject to peer review, is an extension of this process? I have yet to meet a patient syndrome that faithfully followed 'the book' in all presentations. It is called 'practice' for a reason.

I respectfully take a different view than the commenter. Basic science, evidence-based medicine and case reports have a symbiotic and mutually reinforcing role in the advancement of medicine, veterinary or otherwise. It is acknowledged that observations in a single case may not, in themselves, provide scientific proof of the reported clinical episode. However, presentation to a wider populace of interested individuals may become the genesis of larger and more significant studies that allow a better understanding of the condition, such as the commenter promotes as more worthy of publication (Nissen and Wynn 2014).

It is acknowledged that case reports can be produced for resumé padding and the sole purpose of credential requirements for specialty boards, as the commenter states. They are susceptible to overinterpretation, can be esoteric in nature, and not necessarily applicable to a wider audience. However, as stated by the commenter, the first reports of many disease agents, adverse medication reactions and what ultimately develops into a paradigm shift in the practice of clinical medicine can trace their origins to a single case observation or series from the prepared mind of a clinical practitioner, not a basic researcher. It is acknowledged that specialists benefit from case reports. I counter that generalists similarly benefit from case reports, for they may be the only exposure they receive to what is possible with clinical guidance, and should referral be an option, enhance their ability to provide the best care for their patients by raising awareness of veterinary advances.

P. R. MORRESEY

Rood and Riddle Equine Hospital, Lexington, Kentucky, USA

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