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EQUINE VETERINARY EDUCATION

American Edition | June 2021

EQUINE VETERINARY EDUCATION / AMERICAN EDITION

VOLUME 33 NUMBER 6



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

IN THIS ISSUE:

From the president: Maintaining progress as screen time becomes face time

Ultrasound findings in tendons and ligaments of lame sport horses competing or training in South Florida venues during the winter seasons of 2007 through 2016

Complex pastern injuries involving the scutum medium in ten horses

JUNE 2021

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References:

[1] Nogradi N, Couetil LL, Messick J, Stochelski MA, Burgess JA. Evaluation of an Omega-3 Fatty Acid Containing Feed Supplement in the Management of Horses with Chronic Lower Airway Inflammatory Diseases. J Vet Intern Med 2015; 29:299-306.

[2] Couetil LL, Cardwell J.M, Gerber V, Lavoie J.-P, Leguillette R, Richard E.A. Inflammatory Airway Disease of Horses. ACVIM Consensus Statement J of Vet Intern Med 2016; 30:503-515 p. 508-510.



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From the president: Maintaining progress as screen time becomes face time

By Scott Hay, DVM



Dr. Scott Hay

I hope this letter finds you happy, healthy and working toward some sense of normalcy from these times that have certainly been unprecedented for our generations. Fortunately, it seems that we are seeing more lights at the end of the tunnel every day.

The lifting of COVID-19 capacity limitations in Nashville in May has given us more confidence that the

AAEP Annual Convention and Trade Show will return to an in-person gathering (with a virtual option) in December. AAEP staff is moving full speed ahead with convention planning. Expect to see registration materials in August. I look forward to seeing you all there!

Among the good to emerge from the pandemic has been creation of our Virtual CE Summer Series to provide remote access continuing education at least until our summer Focus meetings resume in 2022. This year's 5-week summer series, entitled "United By The Horse: International Approaches to Optimizing Practice and Performance," will examine approaches to resolving common to complex medical challenges presented by horses in multiple disciplines. The series begins in late July and will run through August. You can view the program and its presenters through the Meetings page of aaep.org.

The Horse Racing Integrity and Safety Authority was in the news during May with the announcement of the members of its board of directors and two standing committees. AAEP members were among those announced. Dr. Susan Stover was named to the board of directors as well as chairperson for the Racetrack Safety Standing Committee. Joining Dr. Stover on that standing committee are Drs. Lisa Fortier and Paul Lunn. AAEP members on the Anti-Doping and Medication Control Standing Committee are Drs. Mary Scollay and Jeff Blea. Congratulations to each, and best wishes in creating a uniform approach nationwide to racetrack medication and safety issues. You can read more about these appointments on page IV.

During April, a robust and emotional discussion took place among members on the General Discussion listserv

regarding the DEI Task Force's statement on Diversity, Equity, and Inclusion as it relates to our organization. You can read the statement at aaep.org/position-dei-2021.

Many viewpoints were expressed openly and honestly, which is the only way to get to the root of any issues that may exist within the AAEP. We appreciate everyone's participation, which has been valuable to the task force to gauge members' feelings and thoughts.

The task force is continuing to work on discovery of the issues as they relate to our organization and members. Following is an excerpt from a statement I posted to the listserv on behalf of the board of directors that sums up where we stand on the work of the DEI Task Force.

"The adoption of the position statement affirming the AAEP's support for diversity, equity and inclusion is the first step. And while the listserv conversation has largely been focused on diversity as it concerns race and ethnicity, both the board and the Task Force see this as a broader issue which also encompasses gender, those with disabilities, the LGBTQ+ veterinary community, and other social identities within the profession."

The DEI Task Force has really just begun their work, and they are currently assessing items like the range of opportunities provided to our various member demographics, the paths to volunteer leadership, inclusivity at AAEP events, as well as further educational resources."

...the AAEP continues to make significant progress in these and other areas for the benefit of all thanks to the commitment and contributions of you—our dedicated members—and staff.

Despite the restrictions and challenges of the past 15 months, the AAEP continues to make significant progress in these and other areas for the benefit of all thanks to the commitment and contributions of you—our dedicated members—and staff. As society begins to reopen in the post-pandemic world, I look forward to the return of face-to-face meetings, beginning in late July when the board of directors plans to meet in-person in Lexington. I'm sure that will be followed by other work groups returning to in-person meetings. Little by little, we will get back to normal. I can't wait! It will be so good to see every one of you in person rather than on a computer screen! Please be safe.

Updated EHM/EHV resources and guidelines available

Stay vigilant against the threat of equine herpesvirus with updated resources and guidelines from the AAEP's Infectious Disease Committee.

The considerable impact of EHV, not only on horse health but also on commerce and competition, can be seen in the restrictions imposed following outbreaks in Europe and parts of the U.S. earlier this year. It was at that time that the Infectious Disease Committee convened a small task force to update available resources for practitioners.

The updated EHV Guidelines, accessible at aaep.org/document/equine-herpesvirus-ehv, include revised diagnostic and testing recommendations. Meanwhile, the EHV Resources page of the website, located at aaep.org/guidelines/infectious-disease-control/equine-herpesvirus-resources, has been updated to include historical and international references.

You can also point your clients to the Equine Disease Communication Center's EHV resources page for information on preventing, identifying and mitigating spread of the disease at equinediseasecc.org/disease-information/equine-herpesvirus.



Dr. Amy Grice

Nasal discharge is among the clinical signs of EHV respiratory disease.

AAEP members appointed to HISA board, committees

The Horseracing Integrity and Safety Authority's nominating committee on May 5 announced the members of its board of directors and two standing committees, all of which include representation by AAEP members.

Under the authority and oversight of the Federal Trade Commission, the Authority board of directors and standing committee members are responsible for developing, implementing and enforcing a series of uniform anti-doping, medication control, racetrack safety and operational rules to enhance equine safety and protect the integrity of the sport.

"The appointments of five equine veterinarians to the Horseracing Integrity and Safety Authority's governing bodies brings scientific expertise and devotion to equine health to this new era in U.S. horse racing," said AAEP President Dr. Scott Hay. "The AAEP has long-supported the creation of uniform rules in the sport, and we are thrilled that all racehorses will soon compete under the same stringent safety and integrity protocols."

Among the nine individuals serving on the board of directors is Dr. Susan Stover, professor of surgical and radiological sciences at the University of California, Davis School of Veterinary Medicine. A member of the AAEP's Racing Committee, Dr. Stover also chairs the Authority's Racetrack Safety Standing Committee.



Dr. Susan Stover



Dr. Lisa Fortier



Dr. Paul Lunn



Dr. Jeff Blea



Dr. Mary Scollay

Anne M. Eberhardt

Joining Dr. Stover on the Racetrack Safety Standing Committee are Drs. Lisa Fortier and Paul Lunn. A member of the AAEP's On Call program, Dr. Fortier is the James Law Professor of Surgery, Equine Park Faculty director and associate chair for Graduate Education and Research at the Cornell University College of Veterinary Medicine. Dr. Lunn is dean of the North Carolina State University College of Veterinary Medicine and a former member of the AAEP's Infectious Disease and Biological and Therapeutic Agents committees.

Serving on the Anti-Doping and Medication Control Standing Committee are Drs. Jeff Blea and Mary Scollay. Dr. Blea is equine medical director at the University of California, Davis School of Veterinary Medicine and a partner in Southern California racetrack practice Von Bluecher, Blea, Hunkin, Inc. He is a past president of the AAEP and a member and former chair of the Racing Committee. Dr. Scollay is executive director and chief operating officer of the Racing Medication and Testing Consortium. She also serves on the AAEP's Racing and Professional Conduct and Ethics committees.

5 things to know about AAEP this month

1. Acquire international best practices to resolve unique medical challenges among horses across a variety of disciplines by registering for the Virtual CE Summer Series at aaep.org/meetings/2nd-annual-virtual-ce-summer-series.
2. Nashville officials lifted COVID-19 capacity limitations on May 14, as AAEP accelerates planning for the return of in-person learning at the 2021 Annual Convention in December.
3. If you missed the 2020 Annual Convention, purchase an encore edition of the event or an a la carte package of related presentations at aaep.digitellinc.com/aaep/store/10/index/42.
4. Provide up to \$600 worth of free veterinary services to at-risk horses by signing up for The Foundation's Vet Direct Safety Net program at aaep.org/vet-direct-safety-net.
5. Renew your AAEP membership by the end of the membership year on June 30 at aaep.org/dashboard/renew.

Equine neglect, neurology on deck for virtual Round Tables

Acquire expert insight into the diagnosis and treatment of various neurologic conditions you could encounter in your equine patients during the July 14 Virtual Wednesday Round Table.

The Round Tables are available free to all members on the second and fourth Wednesday of every month through October; simply register in advance through AAEP Anywhere at aaepanywhere.org.

"These meetings are a fantastic idea and I appreciate the current platform," said a member from Maryland. "The computer and dial-in (phone) options are wonderful to have to enable attendance."

Each month's Round Tables feature one clinical and one non-clinical topic. Following is the tentative schedule of upcoming sessions:

June 23 – The Veterinarian's Role in Equine Neglect and Abuse

July 14 – Neurology



If unable to attend a live 90-minute Round Table, you can watch a recording of the session on-demand through AAEP Anywhere, the association's free-to-members online learning platform. On-demand sessions are available approximately 48 hours following the live session and include mentioned resources such as PowerPoint slides, images and more. CE credit is not offered for the Round Tables.

The Virtual Wednesday Round Tables are sponsored by Boehringer Ingelheim and CareCredit LLC.

New Practice Life podcast examines pregnancy in practice



With equine practice now a predominantly female profession and expected to become even more so given the demographics of veterinary school enrollment, the topic of pregnancy in practice will likely only grow in importance in the coming years.

In the latest episode of the AAEP Practice Life podcast, entitled "Mothers in Veterinary Practice," host Dr. Mike Pownall discusses issues surrounding pregnancy and maternity leave in practice with Dr. Laura Javicas, mother of two and a partner in Rhinebeck Equine in New York; Dr. Wendy Krebs, also a mother of two and a partner in Bend Equine Medical Center in Oregon; and Dr. Marisa Markey, an expectant mother and associate with McKee-Pownall Equine Services in Ontario.

Among the topics addressed during the 37-minute episode are factors and considerations to deal with as both a practice owner and a pregnant veterinarian, preserving client relationships while on maternity leave, physical challenges and safety considerations of working while pregnant, surprises when returning to practice following maternity leave, and tips for job-seeking veterinarians on assessing a practice's conduciveness to employees with family aspirations.

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

The AAEP Practice Life podcast is sponsored by Boehringer Ingelheim.



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Registration opens this summer at
convention.aaep.org



Summer Series returns with focus on discipline-specific diagnostic and treatment intricacies



No matter if your equine patients race, jump, slide, pirouette, work or simply are ridden recreationally, acquire international best practices to resolve their unique medical challenges during the AAEP's 2nd Annual Virtual CE Summer Series, "United By The Horse: International Approaches to Optimizing Practice and Performance."

During a pair of live two-hour sessions each week from July 27 through Aug. 26, an expert panel of U.S. and international practitioners will explore a different discipline using case examples to provide a depth and breadth of perspectives that will enhance your assessment, diagnosis and treatment of a variety of common to complex problems in the horse.

Live attendees are encouraged to participate in the real-time discussions and Q&A periods. Sessions will also be recorded and made available on-demand for those unable to attend any of the live sessions.

AAEP members can purchase the entire 5-week series (20 CE credits) for \$349 (\$50 for students) or register for an individual week (4 CE credits) for \$149. View the program or register at aaep.org/meetings/2nd-annual-virtual-ce-summer-series.

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The weekly schedule of disciplines and presenters follows.

Week 1: The Thoroughbred Racehorse

July 27 & 29, 7:00-9:00 p.m. ET

Presenters:

Moderator: Dr. Sara Langsam
United States: Dr. Ryan Carpenter
Australia: Dr. Rachael Smith
Argentina: Dr. Mauro Verna

Week 2: The Working Equid

August 3 & 5, 7:00-9:00 p.m. ET

Presenters:

Moderator: Dr. Leslie Easterwood
United States: Dr. Julie Wilson
United Kingdom: Dr. Francesca Compostella
Portugal: Dr. João Rodrigues

Week 3: The Everyday Horse

August 10 & 12, 7:00-9:00 p.m. ET

Presenters:

Moderator: Dr. Sarah Shaw
United States: Dr. Chris Huth
Canada: Dr. Maggie Turner
Australia: Dr. Paula Williams

Week 4: The English Sport Horse

August 17 & 19, 7:00-9:00 p.m. ET

Presenters:

Moderator: Dr. Erin Contino
United States: Dr. Cricket Russillo
Australia: Dr. Hayley Lang
United Kingdom: Dr. Christiana Ober

Week 5: The Reining Horse

August 24 & 26, 7:00-9:00 p.m. ET

Presenters:

Moderator: Dr. Sherry Johnson
United States: Dr. John Newcomb
Germany: Dr. Michael Schöberl
Israel: Dr. Ram Zveibil

Just because we can, does it mean we should?

By Ryan Carpenter, DVM, MS, DACVS



Dr. Ryan Carpenter

Occupational-related injuries occur in all athletic sporting events, and the Thoroughbred racehorse is not immune.

Racing's incessant pursuit of safety over the past decade has resulted in a significant reduction in fatalities and improved safety. These considerable improvements, however, may not quell societal concerns, which have the potential to affect our

social license to operate. We live in a world in which every fatal injury is significant and has a tremendous impact on our industry as a whole.

Many fractures that occur in racing are easily repaired. Surgical repair gives these horses an opportunity for a continued racing career or a rewarding second career. In fact, horses with injuries considered career ending not long ago are now going on to have competitive racing and post-racing careers. This change is the direct result of continual surgical advances that improve outcomes.

A practitioner considers many factors when discussing the appropriate treatment plan for a horse following an injury. As veterinarians, we are ethically obligated to consider humane euthanasia as a viable option when evaluating severe injuries. The AAEP has very specific guidelines for when humane euthanasia is indicated, and I would encourage you to review these recently updated guidelines at aaep.org/guidelines/euthanasia-guidelines. One criterion not in the guidelines but which often becomes part of the discussion, even subconsciously on the part of the veterinarian, is the value of the horse. We have all seen clients make treatment choices irrespective of cost. While this is nothing new in the small animal arena, it is becoming more common with horses. Many owners no longer view horses as working animals. As such, their status has been elevated to a level similar to a family pet in today's society.

So I ask: What is our obligation to the injured horse? Does it depend upon the severity of the injury alone or is latent monetary value a factor? For example, what happens when a horse sustains a complete displaced condylar fracture? Most veterinarians would advocate for surgical repair; this relatively simple and straightforward surgery has a high outcome for pasture soundness. Some veterinarians would recommend euthanasia as there is a

poor prognosis for a racing career and the horse inevitably will develop secondary osteoarthritis, ultimately affecting soundness years down the road.

Taken one step further, what if a horse sustains a more severe injury such as a catastrophic fetlock injury with biaxial sesamoid bone fractures? In my experience, financial value often becomes the center of the discussion driven by the trainer, owner and, often, the veterinarian. These types of injuries require a more involved surgical procedure (i.e., fetlock arthrodesis). While a complex procedure, this surgical technique has evolved considerably in recent years, resulting in better outcomes. However, these cases require significant commitment from a surgical and rehabilitation standpoint, and there is a higher rate of postoperative complications compared to a condylar fracture repair.

If this is a highly valuable breeding animal, then the long-term management, surgical and rehabilitation expenses often have less influence on the decision process. These horses typically have a high owner commitment due to the substantial financial return if surgery and recovery is successful. Additionally, it is assumed these horses will be properly cared for throughout their life, which often takes place on a breeding farm.

While a severe injury directly impacts both the owner and trainer, we must acknowledge that the racetrack—and the racing industry as a whole—is not immune. It's difficult to quantify the financial impact to the industry from a public relations standpoint when a fatality occurs on the track. It is reasonable to assume that as the number or frequency of fatal injuries increases, the financial burden grows exponentially. One recent example is the fatality cluster at Santa Anita racetrack in the winter of 2019. This event had a tremendous impact on the Southern California racing circuit and the entire racing industry. The impact went far beyond the surgical cost to any single horse.

So, what is the role of the veterinarian in this? Are we responsible for considering the financial aspects of surgery and the residual value of the horse? Are we to calculate the estimate value of a single injury on an entire industry? In this calculation, do we consider the social license granted for horse racing and the fact that many who question that social license do not distinguish between a "cheap" or "expensive" horse?

continued on next page



ETHICAL PRACTICE
Every Day-Every Time

Dr. Carpenter is a board-certified surgeon in Southern California and a member of the AAEP's Professional Conduct and Ethics Committee and Racing Committee.

Graduate-level researchers: Apply for Foundation fellows

Applications for annual scholarships due Aug. 2



Applications for The Foundation for the Horse Past Presidents' Research Fellow and the EQUUS Foundation Research Fellow are being accepted until Aug. 2.

The annual \$5,000 scholarships reward AAEP-member doctoral or residency students who have made significant progress in the field of equine healthcare research. Both recipients will be honored at the AAEP's 67th Annual Convention, Dec. 4–8 in Nashville, Tenn. Each will receive a \$500 stipend to support travel to the convention.

The scholarship application and descriptions are accessible at aaep.org/scholarships.

Dr. Lynn Pezzanite receives the 2019 AAEP Past Presidents' Research Fellow during the 65th Annual Convention from The Foundation for the Horse Vice Chair Dr. Anthony Blikslager, left, and Chair Dr. Rick Mitchell, right.

The Foundation appoints Wyatt as development officer

Summer Wyatt, a nonprofit executive with progressive experience in philanthropic leadership and program management, has joined The Foundation for the Horse as development officer.

"We are delighted to have Summer join our Foundation development team in this newly created position to support the continued growth of the AAEP's charitable arm," said David Foley, AAEP executive director.

In her new position, Wyatt engages current and prospective donors throughout the Southeastern, Mid-Atlantic and Northeastern regions of the U.S. to cultivate relation-

ships and invite financial support of The Foundation's mission to improve the welfare of horses. Wyatt most recently served as executive director of the Parelli Foundation, and she previously held management positions in the areas of animal welfare, community engagement and event management.



Summer Wyatt

Wyatt, who was raised with and continues to own and show American Saddlebreds, can be reached at swyatt@foundationforthehorse.org.

Ethics, continued

Instead, what if we evaluate a horse's injury solely from a medical standpoint? What if we removed finances from the equation? The result is a subset of horses that historically would have been humanely euthanized that could now be given a chance for survival with surgery. The two major immediate hurdles often encountered are: Who's going to pay for this and who's going to take care of my horse after? But what if there was a plan set forth by the racing industry to address these two common questions before the injury even occurs; a policy that gives horses a chance for survival without the owner bearing the entire burden of expense and aftercare; and a plan that brings various industry groups to the table to stand with the injured horse to ensure a lifelong commitment? If that existed, would you make different recommendations to your clients when faced with a catastrophic injury?

I realize this leaves you with more questions than answers, which is my intent! As an industry, and as veterinarians in the racing industry, we need to start thinking about this issue and discussing it with our colleagues and

industry partners. There is no one-size-fits-all approach to these difficult cases, and what works in one place might not work in another. But, simply put, we live in a world in which every horse fatality matters. As veterinarians, we might need to stop and pause before making a recommendation to the client. Ultimately, it is our job to put the horse first every time.

I've always said, "If we put the horse first, a lot of our problems will go away." To this end, we must ask important questions when it comes to injured horses: Why are we attempting this surgery? What is the industry's responsibility to the horse with a severe injury? What is the owner's responsibility to their injured horse? Is the easy choice always the best choice? What if my past experiences don't accurately reflect future outcomes? Should I always do things the way I have always done them?

And ultimately, just because we can, does it mean we should?

Benefit: Save money with The Veterinary Club

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Hundreds of AAEP-member practices are using The Veterinary Club purchasing program, benefiting from the



aggregated buying power of human hospitals combined with the veterinary class of trade. Many accrue annual savings that exceed the cost of their AAEP membership.

Register at www.theveterinaryclub.com to start saving today. If you have questions about this or other membership benefits, contact Megan Gray, member concierge, at mgray@aaep.org or (859) 233-0147.

Members in the News



Dr. Natanya Nieman elected officer of KTA/KTOB

Dr. Natanya Nieman, resident veterinarian at WinStar Farm in Versailles, Ky., has been elected to a two-year term as vice president of the Kentucky Thoroughbred Association/Kentucky Thoroughbred Owners and Breeders.

Dr. Natanya Nieman

Dr. Nieman, who received her veterinary degree from The Ohio State University, has been with WinStar Farm since 2002. She previously served as a director of KTA/KTOB, which promotes and protects the Thoroughbred industry by maintaining the highest levels of racing, breeding and training standards in the commonwealth.



Dr. Catherine Kohn named honorary distinguished alumna

The Ohio State University College of Veterinary Medicine recognized longtime professor Dr. Catherine Kohn as an Honorary Distinguished Alumna during a virtual ceremony on May 7.

Dr. Catherine Kohn

A veterinary graduate of the University of Pennsylvania, Dr. Kohn joined the faculty at Ohio State in 1976. While there, Kohn instructed more than 4,800 veterinary students, mentored 30 residents and served on the committees of 18 graduate students. Her funded research includes awards of approximately \$1.5 million. She has refereed over 75 peer-reviewed journal articles and authored a book and 20 book chapters.

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New *EVE* podcast focuses on tracheal perforation treatment



In the latest episode of the *Equine Veterinary Education* podcast, Dr. Alex Gillen discusses her clinical commentary, “Tracheal perforations: Finding the ideal treatment option.” Download or listen to the 13-minute episode at equineveterinaryeducation.podbean.com.

Tackle the heat with *EVJ* special collection

In advance of this summer’s COVID-19-delayed Tokyo Olympics, where temperatures are likely to reach 105° F, *Equine Veterinary Journal* is giving free-to-read access to a special collection of 11 previously published articles covering the health and welfare of horses competing in hot and humid conditions.

If your practice includes equine athletes that perform in heat and humidity, access the special collection at <https://tinyurl.com/3pcn7ctk>.



Dr. Joe Lyman

AAEP Educational Partner Profile: Merck Animal Health

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Dedicated to offering even more than a portfolio of exceptional products, Merck Animal Health invests in our industry, profession and communities. A few highlights:

- Merck Animal Health Veterinary Wellbeing Study II, continuing the discussion and search for solutions to the pressing industry issues of burnout and suicide
- More than \$800,000 in student scholarships granted annually
- More than \$55,000 raised for The Foundation for the Horse through Vet Story Night events at the AAEP Annual Convention
- More than 43,000 doses of life-saving vaccines donated to horses in rescue through the Unwanted Horse Veterinary Relief Campaign, a 13-year non-profit partnership with AAEP

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Highlights of recent clinically relevant papers

Absorbable implant for subchondral bone cysts

This retrospective case series by Paolo Ravanetti and co-workers in Italy and France evaluated an absorbable implant for the treatment of subchondral cystic lesions (SCLs) in young horses in different anatomical locations.

The implant (Osteotrans-OT) was composed of a composite of nano-hydroxyapatite and poly L-lactic acid. Thirty-eight horses with SCLs, aged 10–24 months, underwent debridement through a trans-cortical extra-articular approach and the absorbable implant was inserted in the cavity. Anatomical locations included the proximal phalanx, medial femoral condyle, radius and fourth carpal bone. Clinical and radiographic follow-up ranged from 28 to 46 months. In 36 of 38 horses treated, lameness resolved, and 77% average filling of the cyst was measured 120 days after surgery on radiographs. Surgical complications were recorded in two cases.

An extra-articular approach with insertion of an absorbable implant was successful, was feasible in different anatomical locations and may offer an alternative to treat SCLs in young horses. The implant is currently commercially available.

Bilateral ovariectomy for moody mares

This study by Daniel Melgaard and co-workers in Denmark evaluated whether ovarian removal in mares with unexplained unwanted behaviour improved the mare's behaviour or rideability from the owner's perspective.

Ovarian neoplasms may cause mares to change behaviour, but there is often no apparent reason for unwanted behaviour.

Surgical ovarian removal was performed in 28 mares; 14 mares had ovarian neoplasia in either one or both ovaries, 10 mares had normal ovaries, and the ovaries of the remaining four mares were not examined for the presence of cancer. Following ovariectomy, rideability improved in 80% (8/10) of mares with normal ovaries and in 57% (8/14) of mares with ovarian neoplasms. A behavioural improvement was observed in 40% (4/10) of mares with normal ovaries, and in 43% (6/14) of mares with ovarian neoplasms. Mares with unwanted behaviour not obviously related to the oestrous cycle and to painful conditions may benefit from ovariectomy to alter their behaviour and rideability.

Distal sesamoidean ligament desmitis

This retrospective case series by Alex Hawkins and co-workers at The Royal Veterinary College, UK, analysed oblique and straight distal sesamoidean ligament desmitis.

This study included 51 horses with a primary diagnosis of oblique (ODSL) or straight (SDSL) distal sesamoidean ligament injury confirmed with a combination of diagnostic analgesia and detection of a lesion on imaging (ultrasonographic ± advanced imaging).

Straight distal sesamoidean ligament injuries were more common in the forelimb (13/21, 62%), while ODSL injuries had equal frequency in fore- (15/30, 50%) and hindlimbs (15/30, 50%). ODSL injuries were more likely than SDSL injuries to

affect the proximal third of the ligament and often presented with periligamentar swelling and focal pain. Lesions were frequently detected using ultrasonography and sMRI examination. Only 27/49 cases (55%) returned to soundness, with only 15/49 (31%) returning to intended use. There were no significant associations between outcome and clinical features or treatment.

In contrast to previous studies, ODSL and SDSL injuries were readily identified ultrasonographically using appropriate views, and with sMRI. Given the limited availability, cost and general anaesthetic risks associated with high-field MRI, more focus should be placed on optimising the ultrasonographic examination. Owners of affected horses should be informed of the guarded prognosis for return to full use.

Aural haematomas

This retrospective study by Sophie Boorman and co-workers at Auburn University, USA, characterised the clinical features, treatment, and outcome of aural haematomas in horses.

Data including signalment, historical information, clinical signs, diagnostic procedures, and treatments were retrieved from medical records. Outcome was determined from the records or via telephone communication. Seven horses with one or two aural haematomas (8 ears in total) were identified.

Three horses were presented after recurrence of aural haematoma following treatment by the referring veterinarian. Four horses had a history of allergic skin disease prior to aural haematoma development. Most (6/7) horses were unilaterally affected. Diagnostic assessments included otoscopic evaluation (3 horses), ultrasonography (3 horses), cytologic examination of ear canal swab samples (3 horses), and histological examination of a pinna biopsy specimen (1 horse). Two of the eight pinnae were treated by nonsurgical needle drainage (one with concurrent corticosteroid injection) and the remaining six underwent surgical incision and placement of compressive sutures. Follow-up was available for six horses. All affected pinnae were fibrotic with four horses having permanent drooping of the pinna. One horse developed a haematoma in the contralateral pinna 1 year after discharge.

Equine aural haematoma is a rare condition. The main treatment is drainage, and treatment options commonly used in small animal practice can be successfully applied in horses. Permanent changes in the cosmetic appearance of the pinna are likely to develop owing to secondary fibrosis.

Survival in horses with peritonitis

This retrospective study by Stefanie Arndt and co-workers at the University of California-Davis, USA, investigated clinical and diagnostic findings, treatment, and short- and long-term survival in 72 horses with peritonitis.

Medical records were reviewed for horses diagnosed with peritonitis. The essential inclusion criterion was a peritoneal nucleated cell count of $\geq 25,000$ cells/ μ L. Gastrointestinal rupture and cases in which peritonitis occurred after abdominal surgery or castration were excluded. Information

retrieved included signalment, history, clinicopathological and peritoneal fluid variables, diagnostic imaging findings, inciting cause, treatment, and short- and long-term survival.

Colic was the most common presenting complaint (34/72, 48%). A definitive diagnosis could be made in 44/72 (61%) cases. The most common cause of peritonitis was infectious agents (31/72), followed by trauma (8/72), gastrointestinal thickening (3/72), and eosinophilic peritonitis (2/72). Idiopathic peritonitis was identified in 28/72 (39%) cases. Sixty (83%) horses survived to hospital discharge. Long-term follow-up was available for 49 horses, with 43 (88%) horses alive 1 year after discharge. Significant differences between nonsurvivors and survivors were history of colic, positive peritoneal fluid culture, and several haematological/peritoneal fluid variables.

Peritoneal fluid analysis was essential for a definitive diagnosis of peritonitis, and certain variables were useful for predicting outcome.

Post-race atrial fibrillation in Thoroughbreds

In this study Laura Nath and co-workers in Australia and Hong Kong investigated the outcomes after episodes of atrial fibrillation (AF) identified post-race and determined whether affected horses are at increased risk of further episodes.

Race records for Thoroughbred horses racing in Hong Kong (2007–2017) were reviewed. Horses that performed below expectation were examined by cardiac auscultation and ECG. Incidence and recurrence of AF were compared between horses with and without a history of AF and between horses with paroxysmal and persistent episodes.

There were 96,135 race starts during the study. Atrial fibrillation was identified in 4.9% of horses (4684 horses), with an overall incidence of 2.7 episodes per 1000 starts. The incidence of AF in horses after any previous episode (12.8/1000 starts) was higher than for horses with no previous episode (2.4/1000 starts). Recurrence was seen in 64% of horses previously treated for persistent AF, which was higher than recurrence in horses with paroxysmal AF (23%). Median duration between episodes was 343 days.

Thoroughbreds are at increased risk of recurrent AF after both paroxysmal and persistent episodes, but the duration of time between episodes varies widely.

Inhaled ciclesonide for equine asthma

This prospective, multicentre, placebo-controlled, randomised, double-blinded study by Scott Pirie, based at the University of Edinburgh, and co-workers in Germany was designed to assess the effectiveness and safety of inhaled ciclesonide for the treatment of severe equine asthma.

This study included 220 horses with severe equine asthma from 24 clinics in Germany, France and Switzerland. Horses were randomised to receive ciclesonide inhalation solution or placebo inhalation. No environmental modifications were implemented. Treatments were administered with a Soft Mist inhaler for horses at doses of eight actuations twice daily for 5 days and 12 actuations once daily for the following 5 days.

The ciclesonide group had a responder rate of 73% compared with 43% for the placebo group. The mean weighted clinical score reduction after 10 days of treatment was 7.2 ± 4.8 in the ciclesonide treated group, compared with

3.8 ± 4.5 in the placebo group. Horses with more severe clinical signs showed a greater improvement compared to those with mild/moderate clinical signs. Owners perceived an improved quality of life after 5 and 10 days of treatment in 60.2% and 69.3% of ciclesonide treated horses, compared with 32.7% and 43.4% of placebo treated horses.

Inhaled ciclesonide resulted in a clinical improvement and improved quality of life in horses with severe equine asthma after 10 days of treatment.

Autologous products in equine sports medicine

This systematic review by Francesca Tomlinson and co-workers at the University of Cambridge, UK, evaluated the current published evidence base regarding the efficacy of autologous products in soft tissue injuries and joint disease.

Fifty-eight papers were included in this review, 28 of which were randomised controlled trials. Significant benefit was reported under several parameters, most notably in the use of autologous chondrocytes in artificially induced cartilage defects on histology. One paper documented a significant clinical response under lameness examination.

The current literature shows that the treatment of soft tissue injury and cartilage disease with autologous products is safe and that the use of some products can give significant benefit on some outcome measures. True clinical significance is yet to be demonstrated with any product.

S. WRIGHT

EVE Editorial Office

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Editorial

Equine dental disease – no longer a neglected field of study

In the late 1800s and the early 1900s, a time when the importance of working horses was at its peak, most veterinary work was equine-related and the curriculum in veterinary colleges was largely oriented towards the horse. A great interest in equine dentistry also developed during this period. At least four equine dentistry books in the English language were published during this time (Easley 2020), including Merrillat's seminal equine dentistry text published in the USA in 1916 (Merrilat 1916). Merrillat was rightly sceptical about some of the quack dental 'treatments' performed at that time such as 'incisor reductions' that were allegedly performed 'to prevent the incisors from keeping the cheek teeth out of contact' but stated 'It was easier to trim the incisors and collect fees than to give a lecture on anatomy without pay' (Merrilat and Cambell 1935). Sir James Colyer, a human dentist and historian, who was Dean of The Royal Dental Hospital in London performed some important dental surveys on working horses in the early 1900s. He had plenty of subjects to choose from, with 100,000 carriage and dray horses working in London at that time, and he showed a high prevalence of periodontal disease in these working horses (Miles and Grigson 1960). During this same period, many innovative equine dental instruments were designed by veterinary surgeons including by Hauptner and Gunther in Germany and by Hausmann and McPherson in North America. Some of these outstanding instrument designs are still in use today (Easley 1999, 2020).

However, the advent of the internal combustion engine caused a major and continuous decline in horse numbers throughout the 1900s and this also caused a decline in most scientific equine studies, including in equine dentistry (Dixon 2017). One exception was the research and clinical work of Erwin Becker, an innovative German veterinarian who performed disease prevalence surveys and gross pathological studies on equine dental disorders (Becker 1962). Otherwise, most of the mid-1900s was a barren time for all types of equine studies. During this period, the university curricula reflected this trend with the emphasis now turning to farm animals and later to small animals. During this time, veterinary students were taught little or nothing about dentistry in the veterinary schools, for example, a single lecture on cheek teeth repulsion, was the total dental course in the author's veterinary school in the early 1970s. In general veterinary practice, dentistry was largely ignored except for a few veterinarians who repulsed apically infected and fractured teeth and cut and floated major dental overgrowths, i.e., all major disorders that were of such serious clinical concern that they could not be ignored.

The improving global economic climate in the second half of the 20th century and increased leisure time for many people led to a resurgence of interest in horses, no longer for transport and agricultural uses but now for recreation and sport. These increasing horse numbers led to a revival of equine veterinary attention. A new scientifically driven interest in the 1960s led in the founding of the American Association of Equine Practitioners (AAEP) and the British Equine Veterinary Association (BEVA). Subsequently, there were

major scientific and clinical developments in many equine specialities, especially in the orthopaedic, respiratory and reproduction fields. In contrast, with the exception of a handful of authors including Hofmeyr (1960), Honma (1962) and Baker (1970), minimal scientific advances were made in equine dentistry between the 1940s–1980s.

In 1993, Peter Rossdale, the editor of the Equine Veterinary Journal (EVJ), with his usual far-sightedness, recognised the deficit of scientific articles on equine dentistry and devoted an issue of EVJ's sister journal, Equine Veterinary Education (EVE) to equine dentistry that contained an editorial '*Equine dental disease – a neglected field of study*' (Dixon 1993). This edition of EVE contained some original scientific papers on equine dentistry (that were collected with great difficulty!) and included an article by John Walmsley in the UK, who was the first author to critically show the inaccuracy of ageing of horses by incisor examination (Walmsley 1993). More importantly, this EVE edition encouraged other veterinarians to research and report on equine dentistry.

Thankfully, there has been a major revival in scientific equine dental studies since that date including as follows: gross pathological studies by Wafa in Ireland (Wafa 1988). Seminal work by Drs Kilic, Dacre and du Toit (Kilic *et al.* 1997; Dacre *et al.* 2008; du Toit *et al.* 2008), and clinicians in Edinburgh (Dixon *et al.* 2000a, 2000b); Vlaminck (2008) in Belgium; Staszuk *et al.* (2006) and Bienert (Kern *et al.* 2017) in Germany; Simhofer *et al.* (2008) in Austria and from American authors including Easley (1999); Easley *et al.* (2016).

Hundreds of equine dental papers and textbooks devoted to equine dentistry have been published since the publication of that dental edition of EVE in 1993. The collection of 25 equine dental articles previously published by EVE in the current Equine Dental Disease online collection is testament to that revival in equine dentistry that thankfully, shows no signs of abating.

Acknowledgement

My thanks to Jack Easley for reviewing this editorial.

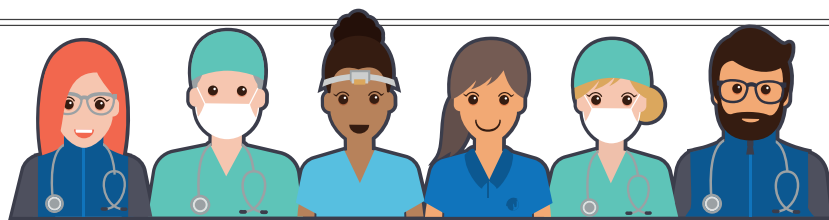
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The Royal (Dick) School of Veterinary Studies and The Roslin Institute, The University of Edinburgh, Midlothian, UK

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Case Report

Equine peripheral cemental defects and dental caries: Four case reports**T. Lundström* and D. Birkhed***Djurtandvårdskliniken, Norrköping, Sweden***Corresponding author email: torbjorn@djurtandvardskliniken.se***Keywords:** horse; equine dentistry; dental caries; infundibular caries; peripheral caries**Summary**

The cause of peripheral cemental caries/defects has been discussed during the last 10 to 15 years and they have also been recognised as an increasingly common oral problem in horses and ponies. This case report focuses on four cases that demonstrate the complexity of the condition, one of which is presented in this summary.

A 5-year-old gelding with a history of a completely healthy oral status in 2016 was examined at an annual check-up 1 year later (2017), when there was a documented general loss of peripheral cementum on all cheek teeth. The owner had moved the horse to another stable after the visit to the clinic in 2016. She claimed that there was no change in the feeding regime. The horse was moved back to the first property 6 months after the second visit. The local veterinarian examined the horse 6 months after its return to the first stable and reported to the clinic that the peripheral cementum was now returning on the teeth. This case suggested that changes in the premises for the horse can, during a relatively short period of time, result in a clinically observable loss of peripheral cementum. Unfortunately, in this case it is difficult to conclude which factors were different between the two stables as multiple variables are possible. The only differences reported were that the time spent on outdoor ground was less in the first stable and in a sand paddock. Although there is uncertainty about differences

between the two stables, it illustrates that the condition of the peripheral cementum can be reversible (**Fig 1**).

Key points

- The appearance of a caries lesion, both in man and horses, is determined by the co-existence of three main factors:
 - the acidogenic micro-organisms
 - the substrate, that is carbohydrates derived from the diet and
 - the host, that is the tooth surface.
- Dental cemental defects in horses (most often referred to as 'peripheral caries') also seem to have a multifactorial background.
- Predisposing factors may initiate an imbalance between micro-organisms–substrate–tooth, but there is a small threshold between predisposing and causal factors.



Fig 1: Intraoral pictures of the left mandibular cheek teeth from an initially 5-year-old gelding. The left picture shows the status in January 2016 and the right picture shows the oral condition in January 2017. There is almost complete destruction of the oral peripheral cementum in all cheek teeth. In between the two examinations, the horse changed stable which suggests that a change in living conditions can dramatically alter the conditions and health in the oral cavity.



Case Report

Complex pastern injuries involving the scutum medium in ten horses

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Keywords: horse; soft tissue injury; lameness; ultrasound; MRI

Summary

This case series describes the clinical findings, response to regional anaesthesia, diagnostic imaging, treatment and outcome of 10 horses with complex pastern injuries involving the scutum medium. Horses with scutum medium injury presented with septic synovial structures, acute lameness or chronic lameness. In all cases, scutum medium injury occurred with concurrent severe tendon, ligament or osseous injuries in the pastern region. The most common comorbidities were proximal interphalangeal joint sepsis, injuries to the straight sesamoidean ligament (SSL) and/or the superficial digital flexor tendon (SDFT) branches.

Diagnostic imaging of the scutum medium can be difficult and has not been well described in the veterinary literature. Due to the fibrocartilage composition of the scutum medium, radiographs can only identify damage to the osseous attachment(s). Injuries may not be identified on ultrasonographic examination, and magnetic resonance imaging (MRI) may be necessary. Ultrasonographically, lesions appeared as hypoechoic to anechoic regions in the fibrocartilage matrix of the scutum medium at the insertion of the SSL (**Fig 1**). Lesions affecting the SDFT branches and abaxial aspects of the scutum medium were characterised by areas of heterogeneous echogenicity, hypoechoic regions in the fibrocartilaginous matrix and osseous irregularity on the surface of the middle phalanx. On MRI, lesions in the scutum medium associated with injury to the SSL were seen as focal areas of abnormally increased signal intensity in the fibrocartilaginous matrix on short tau inversion recovery (STIR) or proton density-weighted (PD) sequences (**Fig 2**). MRI lesions involving the SDFT

branches were large, irregular, hyperintense areas that extended through the junction of the SDFT with the scutum medium. In horses with absence of lesions on pastern ultrasound or lack of improvement following treatment of SSL or SDFT injuries, MRI is indicated for improved evaluation of these structures, the scutum medium, and other concurrent osseous or joint injuries.

Return to function was dependent on concurrent injuries; horses with injuries to both the scutum medium and SSL tended to have worse outcomes compared to horses with scutum medium and SDFT branch injuries. Severe scutum medium injuries were associated with pastern subluxation, and proximal interphalangeal joint arthrodesis should be considered in these cases. Horses that present following an acute onset of lameness associated with injury to the scutum medium appeared to have the best prognosis for return to previous use.

Key points

- Scutum medium injuries occur most commonly in conjunction with other pastern injuries such as injuries to the straight sesamoidean ligament (SSL), superficial digital flexor tendon (SDFT) or proximal interphalangeal joint (PIPJ) sepsis.
- Severe scutum medium injuries, especially when they occur in conjunction with SSL injury, can lead to pastern destabilisation and PIPJ arthrodesis should be considered.
- Diagnostic imaging of the scutum medium is challenging. Lesions in the scutum medium can be detected using ultrasound but MRI may be necessary to accurately diagnose damage in the scutum medium.



Fig 1: Long-axis ultrasound of the pastern region at the level of the PIPJ; proximal is at top of the image. There is marked thickening of the distal SSL, with multifocal hypoechoic regions associated with a heterogeneous echogenicity within the scutum medium (blue arrows). The proximal palmar surface of the middle phalanx is smoothly but irregularly margined at the enthesis of the scutum medium (red arrow). Blue star denotes marked subcutaneous thickening.

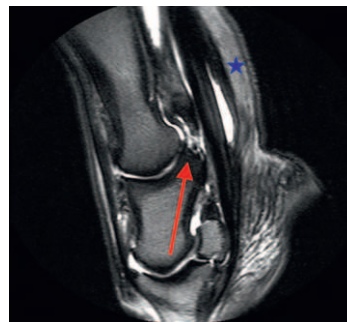


Fig 2: Sagittal plane proton density fast spin echo (PD FSE) sequence. An area of high signal intensity is observed within the fibrocartilaginous matrix of the scutum medium (red arrow). Marked subcutaneous thickening is denoted by the blue star.



Clinical Commentary

The middle scutum: Functional anatomy and normal images

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Introduction

The paper by Bergstrom *et al.* (2021) in this issue reports on ten horses with complex pastern injuries involving the middle scutum (MS, *scutum medium*). Lesions of the MS are uncommon, and their detection may be challenging with routine imaging examination. Indeed, the MS is a complex anatomical unit with relationship to the different anatomical structures of the palmar/plantar aspect of the proximal interphalangeal joint. This short clinical commentary will focus on the anatomy of the palmar/plantar aspect of the proximal interphalangeal joint, including the involvement of the MS in the functional anatomy of the pastern, and on the description of the normal appearance of the MS on ultrasound, magnetic resonance (MR) imaging and computed tomography (CT) scans.

Descriptive anatomy

A scutum provides a smooth gliding surface for the flexor tendons (Barone 2000). At the palmar aspect of the metacarpophalangeal joint, the proximal scutum is made of the proximal sesamoid bones and the wide and thick palmar ligament (Denoix *et al.* 1997). At the palmar aspect of the foot, the distal scutum is made of the distal sesamoid bone and the proximal and distal sesamoidean ligaments (Denoix 2019). The middle scutum is a thick fibrocartilaginous structure/pad strongly inserted onto the proximopalmar aspect of middle phalanx (P2) and attached to the distopalmar aspect of the proximal phalanx (P1), thanks to two strong and short medial and lateral scutocompedal ligaments (Fig 1, Denoix 2019). In addition to these insertions, the MS is attached to the distal third of P1 by a short axial and a thinner abaxial palmar ligament on both sides of the pastern. The latter is covered by the proximal insertion of the distal digital annular ligament and chondrocompedal ligament (Fig 2). Finally, the MS receives sagittally the distal insertion of the straight sesamoidean ligament (SSL) and the medial and lateral branches of the superficial digital flexor tendon (SDFT) end on its most collateral parts (Fig 1).

Functional anatomy

The first role of a scutum is to provide or extend a gliding surface for the flexor tendons, mostly for the deep digital flexor tendon. The MS achieves this function extending proximally the gliding surface of the flexor tuberosity of P2. Thanks to its strong insertion on distal P1 and proximal P2, the MS essentially contribute to the stability of the proximal interphalangeal joint (PIPJ). Kinematic analysis shows that the PIPJ achieves flexion during the first part of the stance phase

(reaching maximal flexion at about 14% of the stance) and extension during the mid-stance phase and last part of the stance phase (Chateau *et al.* 2004; Clayton *et al.* 2007). This extension is induced by the tension of the SDFT and SSL fully stretched during the mid-stance phase (Denoix 1994a; Crevier-Denoix *et al.* 2009). Thanks to its strong attachments, the MS reduces extension, avoiding hyperextension.

Moreover, being widely inserted lateromedially, the MS reduces collateromotion (mediomotion/lateromotion, Denoix 1999). Its full contact with the palmar aspect of the condyle of P1 reduces medial and lateral rotation of the PIPJ (Denoix 1987). As demonstrated using contact studies, collateromotion and rotation are systematically associated on turns or as a result of uneven foot placement (Fig 3).



Fig 1: Anatomy of the middle scutum: palmarolateral view of the dissected pastern. 1 – Middle scutum; 2 – Proximal scutum; 3 – Flexor tuberosity of the middle phalanx; 4 – Axial palmar ligament of the proximal interphalangeal joint (PIPJ); 5 – Abaxial palmar ligament of the PIPJ; 6 – Scutocompedal ligament; 7 – Straight sesamoidean ligament; 8 – Superficial digital flexor tendon branch (cut); 9 – Oblique sesamoidean ligament; 10 – Extensor branch of the third interosseous muscle (suspensory ligament); 11 – Proximal phalanx; 12 – Middle phalanx.

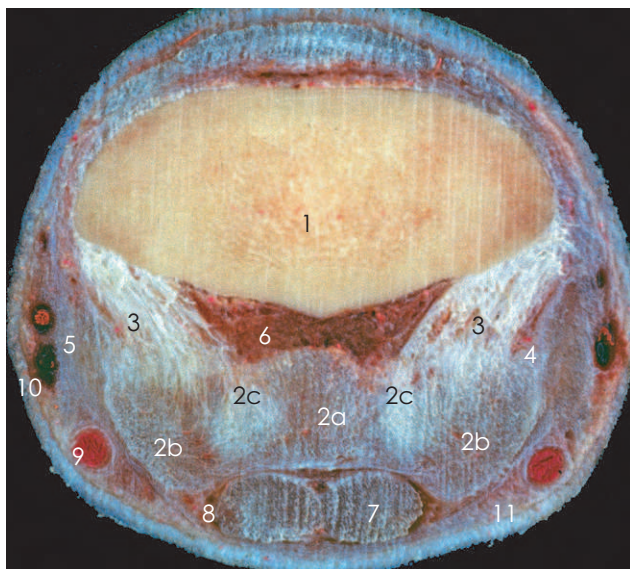


Fig 2: Anatomical cross section of the proximal interphalangeal joint at the level of the middle scutum. 1 – Proximal phalanx; 2 – Middle scutum: 2a – fibrous part continuing the straight sesamoidean ligament, 2b – fibrous part continuing the superficial digital flexor tendon branches, 2c – fibrous part continuing the axial palmar ligaments of the proximal interphalangeal joint (PIPJ) (see MR images on Supplementary Item 1); 3 – Scutocompedal ligament; 4 – Abaxial palmar ligament of the PIPJ; 5 – Proximal attachments of the chondrocompedal and distal digital annular ligaments (fused); 6 – Palmar recess of the PIPJ; 7 – Deep digital flexor tendon; 8 – Digital sheath wall and synovial cavity; 9 – Proper digital artery; 10 – Proper digital vein; 11 – Proper digital nerve.

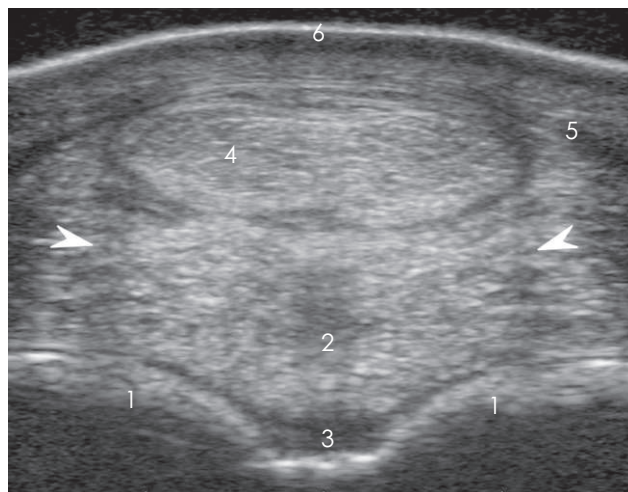


Fig 4: Transverse ultrasonographic section of the pastern at the level of the middle scutum using a palmar approach. 1 – Condyle of the proximal phalanx; 2 – Middle scutum; 3 – Palmar recess of the proximal interphalangeal joint; 4 – Deep digital flexor tendon; 5 – Distal digital annular ligament; 6 – Skin. Note the hypoechogenic sagittal zone in the middle scutum. Arrowheads: edge artefacts created by the deep digital flexor tendon.

Aetiopathogenesis of MS injuries

Injuries of the MS may result from extra-physiological movements of the PIPJ and/or by extreme tension of the structures attached to it.

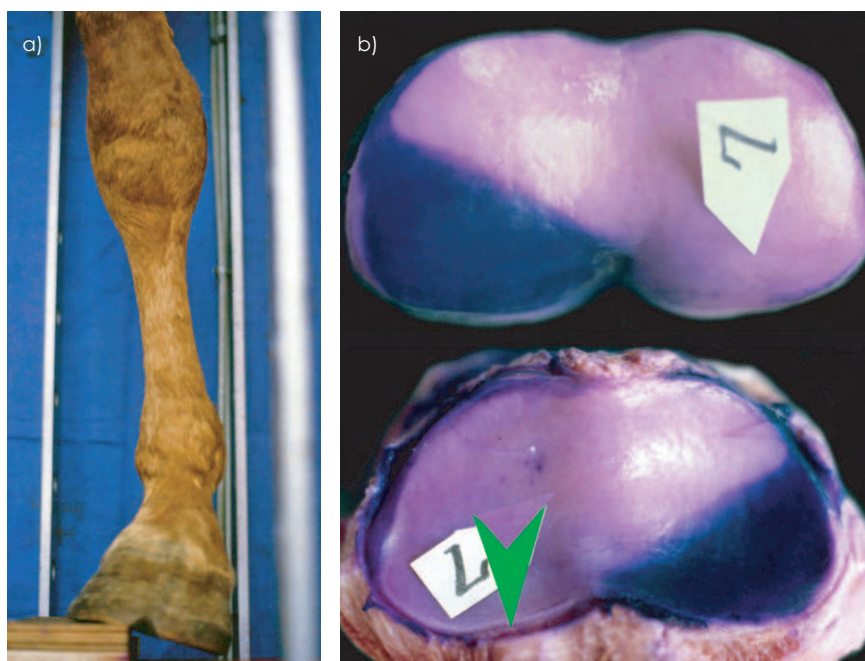


Fig 3: Functional anatomy of the proximal interphalangeal joint (PIPJ) on short turns. a) Isolated right thoracic limb under compression with asymmetrical placement of the foot to concentrate the weight on the lateral aspect of the hoof wall. b) Contact surfaces within the PIPJ; there was no contact on the coloured parts of the articular cartilage: pressure is concentrated on the lateral aspect of the distal articular surface of the proximal phalanx (P1-above) and proximal articular surface of the middle phalanx (P2-below). At the medial aspect of the joint, pressure is concentrated dorsally as a consequence of a medial rotation of P2 relative to P1.

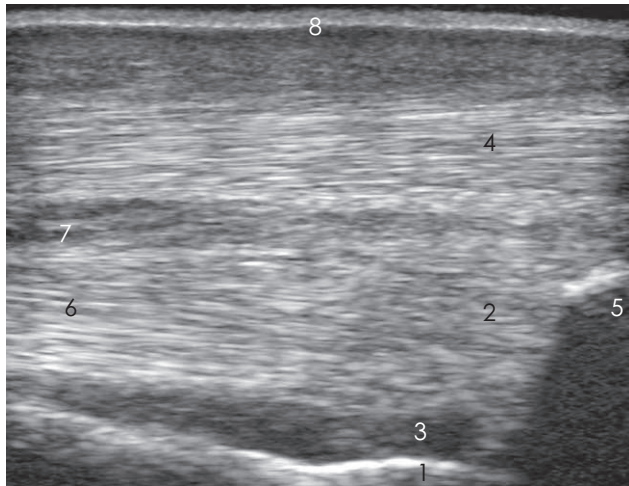


Fig 5: Sagittal longitudinal section of the pastern at the level of the middle scutum. 1 – Palmar bone surface of the proximal phalanx; 2 – Middle scutum; 3 – Palmar recess of the proximal interphalangeal joint; 4 – Deep digital flexor tendon; 5 – Flexor tuberosity of the middle phalanx; 6 – Straight sesamoidean ligament; 7 – Digital sheath synovial cavity; 8 – Skin.

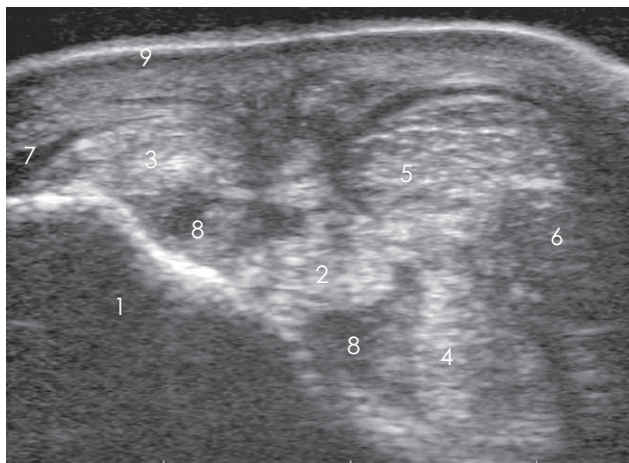


Fig 6: Transverse ultrasonographic section of the palmarolateral aspect of the pastern at the level of the palmar ligaments of the proximal interphalangeal joint. 1 – Bone surface of the proximal phalanx; 2 – Axial palmar ligament of the proximal interphalangeal joint (PIPJ); 3 – Abaxial palmar ligament of the PIPJ; 4 – Straight sesamoidean ligament; 5 – Lateral branch of the superficial digital flexor tendon; 6 – Deep digital flexor tendon; 7 – Proximal attachments of the chondrocompedal and distal digital annular ligaments (fused); 8 – Palmar recess of the PIPJ; 9 – Skin. Proper digital vessels are collapsed by the pressure on the probe and acoustic pad.

Hyperextension of the PIPJ increases tension on the SDFT and/or SSL. It can also produce symmetrical injuries of the palmar ligaments of the PIPJ. Collateration on one side (lateration or mediotion) can induce injuries of the opposite palmar and scutocompedal ligaments. Medial rotation of the PIPJ (e.g. limb inside a short turn) induces tension of the medial palmar and scutocompedal ligaments and pressure on the lateral part of the MS with lesion potentially extending in the body of the MS itself. The opposite happens with lateral rotation.

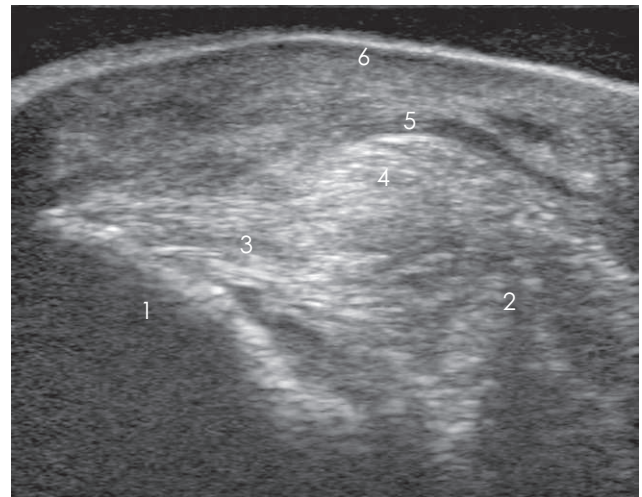


Fig 7: Transverse ultrasonographic section of the palmarolateral aspect of the pastern at the level of the scutocompedal ligament. 1 – Bone surface of the proximal phalanx; 2 – Middle scutum; 3 – Scutocompedal ligament; 4 – Most distal part of the superficial digital flexor tendon branch; 5 – Distal digital annular ligament; 6 – Skin. Proper digital vessels are collapsed by the pressure on the probe and acoustic pad.

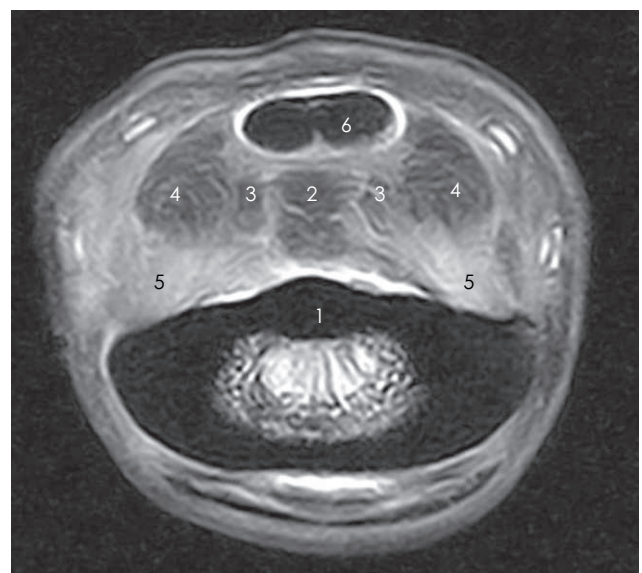


Fig 8: Tendon and ligaments attachments to the middle scutum in a transverse 3D high resolution mixed T1/T2 gradient echo sequence. Note the increased signal of both scutocompedal ligaments due to magic angle artefacts. For more details, see Supplementary Item 1. 1 – Proximal phalanx; 2 – Straight sesamoidean ligament attachment on the middle scutum (MS); 3 – Axial palmar ligaments attachments on the MS; 4 – Attachments of the superficial digital flexor tendon branches on the MS; 5 – Scutocompedal ligaments; 6 – Deep digital flexor tendon.

Normal appearance of the MS with different imaging techniques

Ultrasonography

The technique of the ultrasonographic examination of the palmar pastern has been previously described (Denoix *et al.* 1991; Dyson and Denoix 1995; Denoix 1994b, 1998; Carnicer, Coudry, Denoix 2013; Coudry, Denoix 2013). The MS is

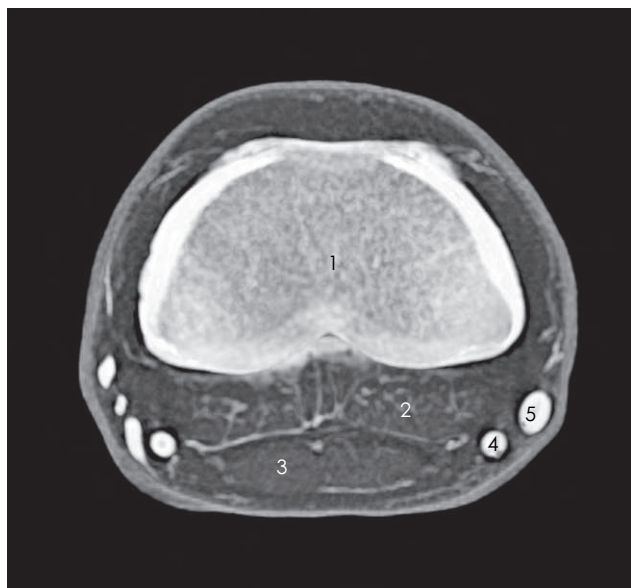


Fig 9: Transverse computed tomographic section at the level of the middle scutum. Maximal intensity projection (MIP) image demonstrating the global vascular pattern of the MS in a sound horse. For more details, see *Supplementary Item 3*. 1 – Proximal phalanx; 2 – Middle scutum; 3 – Deep digital flexor tendon; 4 – Proper digital artery; 5 – Proper digital vein.

assessed with a palmar approach on the weight-bearing limb: the limb should be in a slightly retracted position in order to verticalise the pastern and leave room to place the ultrasound linear probe perpendicular to it. The normal MS has a mildly heterogeneous echogenicity (**Figs 4 and 5**) and is slightly less echogenic than the SSL and the SDFT branches. The scutocompedal ligaments, axial and abaxial palmar ligaments can be evaluated using palmarocollateral approaches proximal to the distal insertion of the SDFT branches (**Figs 6 and 7**).

Magnetic resonance imaging

The paper of Bergstrom *et al.* (2021) described lesions of the MS identified on high field MR system scans. The MS and associated ligaments can also be evaluated with accuracy on low field MR systems, in sedated standing horse or under general anaesthesia, the latter allowing image acquisition of higher resolution compared with standing ones.

The normal MS has a heterogeneous pattern of signal on gradient echo sequences (T1- and T2*-weighted) (Dyson 2011) due to its fibrocartilaginous architecture as does the proximal scutum on MR images of the fetlock (*Supplementary item 1* and **Fig 8**). In spin echo sequences, particularly in T2 and fat suppression ones, the MS tends to have a more homogeneous and mildly lower signal intensity. In sagittal sequences, the aspect of the MS distal to the insertion of the SSL may present a higher signal (*Supplementary item 2*). The oblique orientation of the scutocompedal ligaments may present a diffuse increased signal due to magic angle artefacts particularly in low field MR systems (*Supplementary item 1*).

Computed tomography

On CT scans, the normal MS presents a homogeneous soft tissue density. An accurate evaluation of the MS

vascularisation pattern can be made using CT images acquired during intra-arterial contrast injection in the median artery. In sound horses, large vessels are visible in its distal entheses, close to the junction with the bone surface of P2 (*Supplementary item 3* and **Fig 9**).

Conclusion

The MS is a strong fibrocartilaginous pad adapted to withstand high tensile and compressive forces to stabilise the PIPJ and to provide a gliding surface for the deep digital flexor tendon lobes. The diagnosis of lesions of the MS may be complicated by its normal heterogeneous pattern on ultrasound and on MR images. In injured cases, palmar ligaments, SSL and branches of the SDFT should be evaluated. Comparison with the contralateral limb improves sensibility and specificity of diagnostic imaging techniques.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Authorship

All authors contributed to the preparation of the manuscript and figures. All authors approved the final version of the manuscript.

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Zimeta® (dipyrone injection)

500 mg/mL injection

For intravenous use in horses
Non-steroidal anti-inflammatory drug (NSAID)

CAUTION: Federal law (U.S.A.) restricts this drug to use by or on the order of a licensed veterinarian.

Before using this product, please consult the product insert, a summary of which follows:

Indication: Zimeta® (dipyrone injection) is indicated for the control of pyrexia in horses.

Dosage and Administration: Always provide the Client Information Sheet with the prescription. Administer Zimeta by intravenous injection, once or twice daily, at 12 hour intervals, for up to three days, at a dosage of 30 mg/kg (13.6 mg/lb). **See product insert for complete dosing and administration information.**

Contraindications: Horses with hypersensitivity to dipyrone should not receive Zimeta. Due to the prolongation of prothrombin time (PT) and associated clinical signs of coagulopathy, dipyrone should not be given more frequently than every 12 hours.

Warnings: For use in horses only. Do not use in horses intended for human consumption. Do not use in any food producing animals, including lactating dairy animals.

Human Warnings: Care should be taken to ensure that dipyrone is not accidentally injected into humans as studies have indicated that dipyrone can cause agranulocytosis in humans.

Not for use in humans. Keep this and all drugs out of reach of children. In case of accidental exposure, contact a physician immediately. Direct contact with the skin should be avoided. If contact occurs, the skin should be washed immediately with soap and water. As with

all injectable drugs causing profound physiological effects, routine precautions should be employed by practitioners when handling and using loaded syringes to prevent accidental self-injection.

Precautions: Horses should undergo a thorough history and physical examination before initiation of any NSAID therapy.

As a class, NSAIDs may be associated with platelet dysfunction and coagulopathy. Zimeta has been shown to cause prolongation of coagulation parameters in horses. Therefore, horses on Zimeta should be monitored for clinical signs of coagulopathy. Caution should be used in horses at risk for hemorrhage.

As a class, NSAIDs may be associated with gastrointestinal, renal, and hepatic toxicity. Sensitivity to drug associated adverse events varies with the individual patient. Consider stopping therapy if adverse reactions, such as prolonged inappetence or abnormal feces, could be attributed to gastrointestinal toxicity. Patients at greatest risk for adverse events are those that are dehydrated, on diuretic therapy, or those with existing renal, cardiovascular, and/or hepatic dysfunction. Concurrent administration of potentially nephrotoxic drugs should be carefully approached or avoided. Since many NSAIDs possess the potential to produce gastrointestinal ulcerations and/or gastrointestinal perforation, concomitant use of Zimeta with other anti-inflammatory drugs, such as NSAIDs or corticosteroids, should be avoided. The influence of concomitant drugs that may inhibit the metabolism of Zimeta has not been evaluated. Drug compatibility should be monitored in patients requiring adjunctive therapy.

The safe use of Zimeta in horses less than three years of age, horses used for breeding, or in pregnant or lactating mares has not been evaluated. Consider appropriate washout times when switching from one NSAID to another NSAID or a corticosteroid.

Adverse Reactions: Adverse reactions reported in a controlled field study of 138 horses of various breeds, ranging in age from 1 to 32 years of age, treated with Zimeta (n=107) or control product (n=31) are summarized in Table 1. The control product was a vehicle control (solution minus dipyrone) with additional ingredients added to maintain masking during administration.

Supporting information

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

Supplementary Item 1: Normal aspect of the MS and associated ligaments in a transverse 3D high resolution mixed T1/T2 gradient echo sequence (SHARC sequence, G-Scan Esaote 0.25 T) demonstrating the typical heterogeneous signal of the MS in echo gradient sequence. Note the increased signal of both scutocompedal ligaments due to magic angle artefacts.

Supplementary Item 2: Normal aspect of the MS and associated ligaments in a sagittal fat suppression sequence using a DIXON technique (X-Bone sequence, G-Scan Esaote 0.25 T). The scutocompedal and axial palmar ligaments of the PIPJ are clearly identified.

Supplementary Item 3: Normal transverse CT image (Aquilion LB, Canon Medical) with intra-arterial contrast demonstrating the vascular pattern of the normal MS. Most vessels are visible at the distal aspect of the MS close to the bone surface of the proximopalmar aspect of middle phalanx, the rest of the MS presenting only a faint vascular enhancement. In this horse, a larger vessel arises on both sides from the proper palmar digital artery and follows the palmar border of the MS before vascularising its deeper parts. Note the enhancement located proximally to the MS at the palmar aspect of P2 created by the proximopalmar synovial recess of the PIPJ.

Table 1: Adverse Reactions Reported During the Field Study with Zimeta

Adverse Reaction	Zimeta (dipyrone injection) (N=107)	Control Product (N=31)
Elevated Serum Sorbitol Dehydrogenase (SDH)	5 (5%)	5 (16%)
Hypoalbuminemia	3 (3%)	1 (3%)
Gastric Ulcers	2 (2%)	0 (0%)
Hyperemic Mucosa Right Dorsal Colon	1 (1%)	0 (0%)
Prolonged Activated Partial Thromboplastin Time (APTT)	1 (1%)	0 (0%)
Elevated Creatinine	1 (1%)	0 (0%)
Injection Site Reaction	1 (1%)	0 (0%)
Anorexia	1 (1%)	1 (3%)

See Product insert for complete Adverse Reaction information.

Information for Owners or Person Treating Horse: A Client Information Sheet should be provided to the person treating the horse. Treatment administrators and caretakers should be aware of the potential for adverse reactions and the clinical signs associated with NSAID intolerance. Adverse reactions may include colic, diarrhea, and decreased appetite. Serious adverse reactions can occur without warning and, in some situations, result in death. Clients should be advised to discontinue NSAID therapy and contact their veterinarian immediately if any signs of intolerance are observed.

Effectiveness: The effectiveness phase was a randomized, masked, controlled, multicenter, field study conducted to evaluate the effectiveness of Zimeta (dipyrone injection) administered intravenously at 30 mg/kg bodyweight in horses over one year of age with naturally occurring fevers. Enrolled horses had a rectal temperature $\geq 102.0^{\circ}\text{F}$. A horse was considered a treatment success if 6 hours following a single dose of study drug administration the rectal temperature

decreased $\geq 2.0^{\circ}\text{F}$ from hour 0, or the temperature decreased to normal ($\leq 101.0^{\circ}\text{F}$).

One hundred and thirty-eight horses received treatment (104 Zimeta and 34 control product) and 137 horses (103 Zimeta and 34 control product) were included in the statistical analysis for effectiveness. At 6 hours post-treatment, the success rate was 74.8% (77/103) of Zimeta treated horses and 20.6% (7/34) of control horses. The results of the field study demonstrate that Zimeta administered at 30 mg/kg intravenously was effective for the control of pyrexia 6 hours following treatment administration.

Refer to the Product Insert for complete Effectiveness information.

Storage Information: Store at Controlled Room Temperature between 20° and 25°C (68° and 77°F); with excursions permitted between 15° and 30°C (59° and 86°F). Protect from light. Multi-dose vial. Use within 30 days of first puncture.

How Supplied: Zimeta is available as a 500 mg/mL solution in a 100 mL multi-dose vial.

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For additional information, see brief summary of prescribing information on the following page.

References: 1. Zimeta® (dipyrone injection) [package insert], Rev. 12/2020. 2. Morresey PR, et al. Randomized blinded controlled trial of dipyrone as a treatment for pyrexia in horses. *Am J Vet Res.* 2019;80(3):294-299.

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Case Report

Acute non-ambulatory tetraparesis in a 6-month-old Standardbred weanling caused by a cervical vertebral epidural haematoma

K. MacMillan^{†*} , A. Bourque[‡], L. Perry[†] and W. Stoughton[†]

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Keywords: horse; neurologic; cervical vertebral haematoma; tetraparesis

Summary

Cervical vertebral epidural haematomas are rarely reported in horses with only 10 cases described in the literature and most being confirmed at necropsy. A 6-month-old Standardbred castrated weanling was presented to the Ambulatory Equine Service at the Atlantic Veterinary College for acute non-ambulatory tetraparesis. Ten days prior to presentation, the weanling was castrated on-farm, under field anaesthesia and no trauma or complications were encountered during induction or recovery. On presentation, the colt was recumbent and unable to stand with normal mentation, vitals, appetite, urination and defaecation. The owner reported that the day prior the colt was observed to be 'a little wobbly' when coming in from the field. Examination of spinal reflexes and muscle tone revealed mild hyperreflexia of the left patellar reflex and slightly decreased tail tone. His neck deviated mildly to the right in the mid cervical region, and there was a decreased cervicofacial reflex in the left caudal cervical area (C4-C6). Neuroanatomic localisation suggested that there was a focal C1-C5 spinal cord lesion. The colt was treated medically; however, his condition deteriorated rapidly over the next 48 h and the owner elected for humane euthanasia. The neurological signs expressed in this colt were attributed to a very discrete focal spinal epidural haemorrhage that was surrounded by a thick wall of fibrous

tissue at the level of C2-C3 (**Fig 1**). This reactive fibrous tissue fused to the adjacent bony wall of the spinal canal compressing the adjacent spinal cord, resulting in focal white matter degeneration. The cause of haemorrhage at this site was not apparent during the necropsy but was likely the result of past trauma and/or rupture of a focal congenital vascular malformation, although a malformation was not apparent. Microscopic examination revealed numerous large aggregates of macrophages laden with haemosiderin and abundant bright yellow haematoidin pigment within the stroma. Haematoidin generally takes weeks to form and may persist for several months, thus confirming that the extradural lesion was present prior to the castration. There is little information in the literature on the aetiology of epidural haematomas in the horse although trauma, biomechanical forces and vascular malformations would be the most likely causes. In this weanling, the most likely explanation for the acute, severe neurological deficits is that the lesion created a focally stenotic canal, and an acute trauma or even an exaggerated head or neck movement to this stenotic region caused spinal cord damage and resulting clinical signs. This case report describes a weanling with a compressive lesion in the proximal cervical spine (C2-C3) leading to severe neurological deficits. All other cases described in the literature were ambulatory at the time of presentation, whereas this weanling was recumbent with grade 5/5 ataxia. His clinical signs deteriorated rapidly, demonstrating the severity and fast progression of the lesion. The histological findings supported a chronic lesion while the clinical progression was acute, suggesting an acute on chronic pathophysiology. While surgical management has not been described in the literature, conservative medical management is reported to be fairly unsuccessful with only one of six treated horses responding favourably.



Fig 1: Cervical spine; as viewed from the dorsal surface with dorsal spinal processes removed and with the dura matter intact. A discrete, 2.5 × 1.5 cm and 1–2 cm thick, oval, mass-like, extradural lesion that was tightly adhered to the dura and the adjacent vertebral bone of the spinal canal.

Key points

- Medical management of cervical vertebral haematomas is often unsuccessful, and most cases are diagnosed definitively on post-mortem examination.
- Cervical vertebral haematomas should be on the differential list for horses presenting with acute tetraparesis even in a young horse with no history of trauma.
- Performing an extensive neurological examination with neuroanatomic localisation is especially important considering the limited diagnostic modalities available to field practitioners.



Clinical Commentary

Cervical haematoma

B. Grant

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The practice of veterinary medicine especially in a rural situation is often frustrating due to budget constraints and proximity to facilities necessary for a complete clinical work-up. The attending and referring veterinarians did an excellent work-up on this patient with a very unusual case presentation (MacMillan *et al.* 2021). The basic neurological examination on a recumbent horse is difficult at the best of times. When the patient is unable to be assisted to a standing position even after 12–24 h of intensive anti-inflammatory therapy, then a decision to cease efforts for the benefit of the patient and all concerned is essential. Convincing the owner to send a recumbent patient to a referral centre, especially when it was apparent the owner was reluctant to expend a significant amount of funds, is in itself a significant achievement.

Performing additional meaningful diagnostic tests which are compatible with the owner's/institution budget is another challenge. Choosing an AO tap over cervical radiographs would not have been my initial choice as I have a bias to first ruling out a skeletal abnormality or trauma. Cervical radiographs are the most efficient diagnostic modality to provide the information to make a decision on further intervention or euthanasia.

In retrospect, the cervical radiographs would have been normal. Now, the most likely rule out in a 6-month-old foal with tetraparesis would have been a soft tissue mass in which case an AO tap was indicated. The normal cerebrospinal

fluid (CSF) sample can be easily obtained from the traditional AO site or the recently described lateral approach using US Guidance (Pease *et al.* 2012). It would behoove us all to become familiar with using the lateral approach as it can be used on a standing patient at a reduced risk than a standing AO puncture.

The significance of the gin-clear CSF in this case is that epidural masses such as haematomas and neoplastic masses do not produce gross changes in colour or clarity.

Advancements of diagnostic techniques used in equine medicine seem to take decades to occur but they do happen. The first CT images were not reported until the 1980s (Allen *et al.* 1987), and then, imaging could only go as far caudal as the C4/C5 level. This was frustrating as the majority of lateral compressive lesions were caudal to C5/C6.

However, in the last 2 years, there has been a rapid increase in the availability of CT scanners capable of obtaining diagnostic images as far caudal as the first thoracic vertebra on patients weighing over 650 kg (Figs 1, 2 and 3) and the combined CT/myelogram procedure can be performed in less than an hour by an experienced team.

Computed tomography may not have been possible for this case as it was not available at the actual time this patient was presented. There are now more facilities in Europe, North America and Japan with the large bore CT units that are within a reasonable distance for referral of a recumbent horse.

I was not privy to the geographic or economic constraints placed on the veterinary team associated with this case so do not know if the possibility of doing a CT was discussed (would not even have to be a large gantry on this smaller patient).

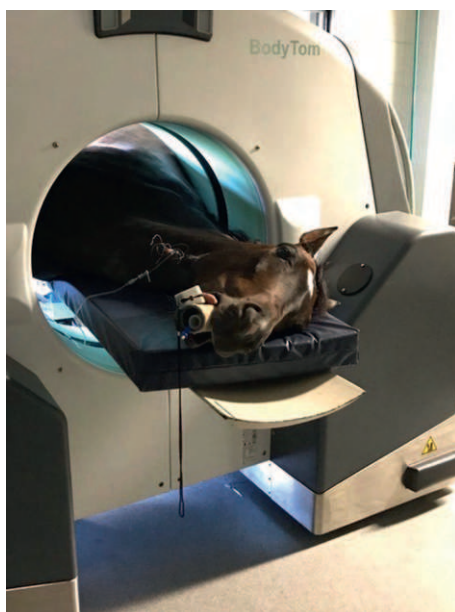


Fig 1: Horse in a Body Tom CT for imaging of caudal cervical spine. Image courtesy of Dr N.A. Huggons.

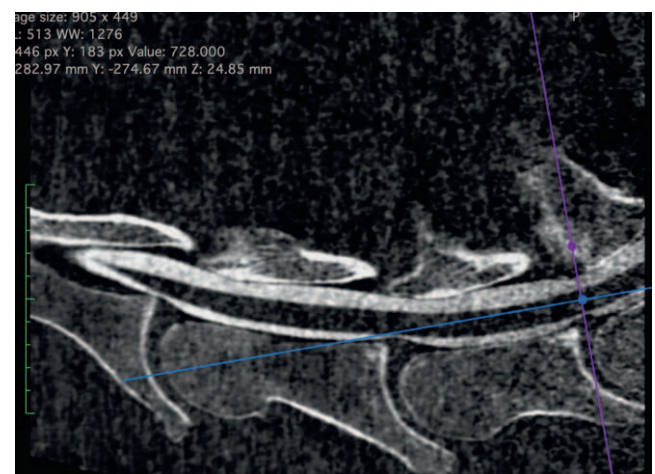


Fig 2: CT/myelographic image showing lateral image of cord compression at C7/T1. Image courtesy of Dr N.A. Huggons.

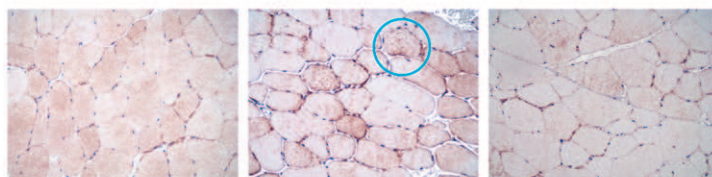
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¹Hunyadi L, Papich MG, Pusterla N. Pharmacokinetics of a low-dose and DA-labeled dose of diclazuril administered orally as a pelleted top dressing in adult horses. *J of Vet Pharmacology and Therapeutics* (accepted) 2014. doi: 10.1111/jvp.12176. The correlation between pharmacokinetic data and clinical effectiveness is unknown

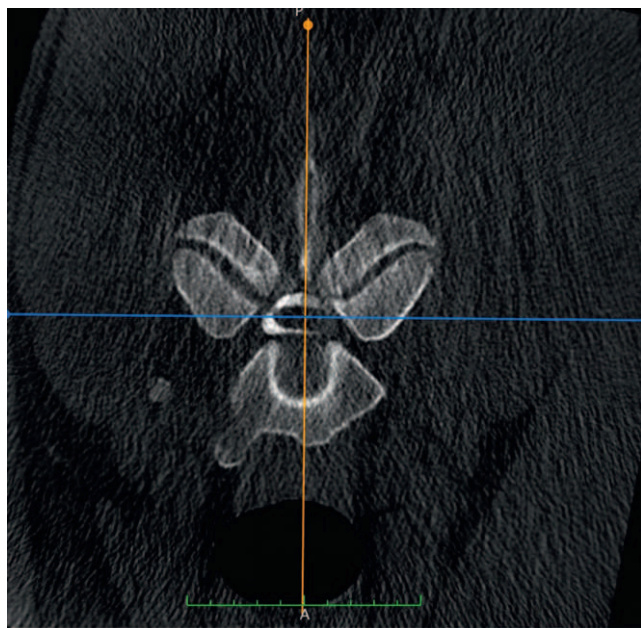


Fig 3: CT/myelographic cross section of same level showing the degree of lateral compression of the spinal cord. Please note the absence of a complete transverse process on the affected side. Image courtesy of Dr N.A. Huggons.

As a guideline in discussions of the clinical work-up with clients, it is my recommendation to inform them of the number one way to work up each case so the clients are the ones making a decision on how far they want to go. After over 40 years in a referral practice, one of the more common complaints by the clients about the referring veterinarians is that they were not informed of the ideal diagnostic tests and therapies which were available.

I need to commend the authors on a very well-presented case study with an excellent review of the literature and well-reasoned discussion of the pathogenesis.

I would be remiss before concluding my observations to not mention that doing a total or hemilaminectomy in the

horse is possible (Grant 1999; Walmsley and Grant 2012). The techniques have improved over the years, and, with the advent of the CT images, the accuracy of the approach is enhanced.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

None.

Source of funding

None.

Acknowledgements

Thanks to Dr N.A. Huggons of San Luis Rey Equine Hospital for the images contained in this commentary.

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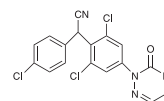
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Diclazuril is an antiprotozoal (antiprotozoal) compound with activity against several genera of the phylum Apicomplexa. PROTAZIL® (diclazuril) is supplied as oral pellets containing 1.56% diclazuril to be mixed as a top-dress in feed. Inert ingredients include dehydrated alfalfa meal, wheat middlings, cane molasses and propionic acid (preservative).

INDICATIONS
PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets are indicated for the treatment of equine protozoal myeloencephalitis (EPM) caused by *Sarcocystis neurona* in horses.

DOSEAGE AND ADMINISTRATION
Dosage: PROTAZIL® (1.56% diclazuril) is administered as a top-dress in the horse's daily grain ration at a rate of 1 mg diclazuril per kg (0.45 mg diclazuril/lb) of body weight for 28 days. The quantity of PROTAZIL® necessary to deliver this dose is 64 mg pellets per kg (29 mg pellets/lb) of body weight.

Administration: To achieve this dose, weigh the horse (or use a weigh tape). Scoop up PROTAZIL® to the level (cup mark) corresponding to the dose for the horse's body weight using the following chart:

Weight Range of Horse (lb)	Weight Range of Horse (kg)	Weight Range of Pellets
250-275	113-125	40
275-300	125-136	45
300-325	136-148	50
325-350	148-159	55
350-375	159-171	60
375-400	171-182	65
400-425	182-193	70
425-450	193-204	75
450-475	204-216	80
475-500	216-227	85

One 2.4-lb bucket of PROTAZIL® will treat one 1274-lb horse for 28 days. One 10-lb bucket of PROTAZIL® will treat five 1100-lb horses for 28 days.

CONTRAINDICATIONS
Use of PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets is contraindicated in horses with known hypersensitivity to diclazuril.

WARNINGS
For use in horses only. Do not use in horses intended for human consumption. Not for human use. Keep out of reach of children.

PRECAUTIONS
The safe use of PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets in horses used for breeding purposes, during pregnancy, or in lactating mares has not been evaluated. The safety of PROTAZIL® (1.56%

diclazuril) Antiprotozoal Pellets with concomitant therapies in horses has not been evaluated.

ADVERSE REACTIONS
There were no adverse effects noted in the field study which could be ascribed to diclazuril. To report suspected adverse reactions, to obtain a MSDS, or for technical assistance call 1-800-224-5318.

CLINICAL PHARMACOLOGY
The effectiveness of diclazuril in inhibiting merozoite production of *Sarcocystis neurona* and *S. falcatula* in bovine turbinate cell cultures was studied by Lindsay and Dubey (2000). Diclazuril inhibited merozoite production by more than 95% in cultures of *S. neurona* or *S. falcatula* treated with 0.1 ng/ml diclazuril and greater than 95% inhibition of merozoite production (IC₅₀) was observed when infected cultures were treated with 1.0 ng/ml diclazuril. The clinical relevance of the in vitro cell culture data has not been determined.

PHARMACOKINETICS IN THE HORSE
The oral bioavailability of diclazuril from the PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets at a 5-mg/kg dose rate is approximately 5%. Related diclazuril concentrations in the cerebrospinal fluid (CSF) range between 1% and 5% of the concentrations observed in the plasma. Nevertheless, based upon equine pilot study data, CSF concentrations are expected to substantially exceed the in vitro IC₅₀ estimates for merozoite production (Dinkov et al., 1997). Due to its long terminal elimination half-life in horses (approximately 45-65 hours), diclazuril accumulation occurs with once-daily dosing. Corresponding steady state blood levels are achieved by approximately Day 10 of administration.

EFFECTIVENESS
Two hundred and fourteen mares, stallions, and geldings of various breeds, ranging in age from 9.6 months to 30 years, were enrolled in a multi-center field study. All horses were confirmed EPM-positive based on the results of clinical examinations and laboratory testing, including CSF Western Blot analyses.

Horses were administered PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets at doses of 1, 5, or 10 mg diclazuril/kg body weight as a top-dress on their daily grain ration for 28 days. The horses were then evaluated for clinical changes via a modified Mayhew neurological scale on Day 48 as follows:

0. Normal, neurological deficits not detected.
1. Neurological deficits may be detectable at normal gait; signs exacerbated with manipulative procedures (e.g., backing, turning in tight circles, walking with head elevation, truncal swaying, etc.).
2. Neurological deficit obvious at normal gait or posture; signs exacerbated with manipulative procedures.
3. Neurological deficit very prominent at normal gait; horses give the impression they may fall (do not) or buckle or fall with manipulative procedures.
4. Neurological deficit is profound at normal gait; horse frequently stumbles or trips and may fall at normal gait or when manipulative procedures were utilized.
5. Horse is recumbent, unable to rise.

Each horse's response to treatment was compared to its pre-treatment values. Successful response to treatment was defined as clinical improvement of at least one grade by Day 48, a conversion of CSF to Western Blot-negative status for *S. neurona* or achievement of Western Blot-negative CSF status without improvement of 1 status grade. Forty-two horses were initially evaluated for effectiveness and 214 horses were evaluated for safety. Clinical condition was evaluated by the clinical investigator's subjective scoring and then corroborated by evaluation of the neurological examination videotapes by a masked panel of three equine veterinarians. Although 42 horses were evaluated for clinical effectiveness, corroborator of clinical effectiveness via videotape evaluation was not possible for one horse due to missing neurologic examination videotapes. Therefore, this horse was not included in the success rate calculation. Based on the numbers of horses that seroconverted

to negative Western Blot status, and the numbers of horses classified as successes by the clinical investigator, 28 of 42 horses (67%) at 1 mg/kg were considered successes. With regard to independent expert masked videotape assessments, 10 of 24 horses (42%) at 1 mg/kg were considered successes. There was no clinical difference in effectiveness among the 1, 5, and 10 mg/kg treatment group results. Adverse events were reported for two of the 214 horses evaluated for safety. In the first case, a horse was enrolled showing severe neurologic signs. Within 24 hours of dosing, the horse was recumbent, biting, and exhibiting signs of depression. The horse died, and no cause of death was determined. In the second case, the horse began walking stiffly approximately 13 days after the start of dosing. The referring veterinarian reported that the horse had been fed grass clippings and possibly had laminitis.

ANIMAL SAFETY
PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets were administered to 30 horses (15 males and 15 females, ranging from 5 to 9 months of age) in a target animal safety study. Five groups of 6 horses each (3 males and 3 females) received 0, 5 (0.5), 15 (1.5), 25 (2.5), or 50 (5.0) mg diclazuril/kg (2.27mg/lb) body weight/day for 42 consecutive days as a top-dress on the grain ration of the horse. The variables measured during the study included: clinical and physical observations, body weights, food and water consumption, hematology, serum chemistry, urinalysis, fecal analysis, necropsy, organ weights, gross and histopathologic examinations. The safety of diclazuril top-dress administered to horses at 1 mg/kg once daily cannot be determined based solely on this study because of the lack of an adequate control group (control horses tested positive for the test drug in plasma and CSF). However, possible findings associated with the drug were limited to elevations in BUN, creatinine, and SGOT and less than anticipated weight gain. Definitive test article-related effects were decreased grain-top-dress consumption in horses in the 50 mg/kg group. In a second target animal safety study, PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets were administered to 24 horses (12 males and 12 females, ranging from 2 to 5 years of age). Three

groups of 4 horses/sex/group received 0, 1, or 5 mg diclazuril/kg body weight/day for 42 days as a top-dress on the grain ration of the horse. The variables measured during the study included physical examinations, body weights, food and water consumption, hematology, and serum chemistry. There were no test article-related findings seen during the study.

STORAGE INFORMATION
Store between 15°C to 30°C (59°F to 86°F).

HOW SUPPLIED
PROTAZIL® (1.56% diclazuril) Antiprotozoal Pellets are supplied in 2.4-lb (1.1 kg) and 10-lb (4.5 kg) buckets.

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1. Lindsay, D. S., and Dubey, J. P. 2000. Determination of the activity of diclazuril against *Sarcocystis neurona* and *Sarcocystis falcatula* in cell cultures. *J. Parasitology*, 86(1):164-166.

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Original Article

The use of the hand-held infrared thermometer as an early detection tool for exertional heat illness in Thoroughbred racehorses: A study at racetracks in eastern Australia

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Keywords: horse; Thoroughbred racehorses; exertional heat illness; high skin surface temperature; hand-held infrared thermometer; tool for early detection heat illness

Summary

Thoroughbred racehorses perform exercise at maximal intensities and typically display a hyperthermic exercise response, which can drive core body temperature to critical levels. Despite extremely efficient thermoregulatory mechanisms, certain weather conditions may affect the horse's ability to cool and result in a syndrome referred to as exertional heat illness (EHI). This is characterised by central nervous system dysfunction, as well as cytotoxic effects of heat on cells, which can produce deleterious consequences. Early detection of exertional heat illness (EHI) in Thoroughbred racehorses can be difficult because signs are often vague and the measurement of rectal temperature as an indicator of hyperthermia is not practical. Best practice in the treatment of EHI in horses, as in human subjects, centres on early detection, rapid assessment and aggressive cooling. Research in human subjects has shown that EHI is manageable when recognised early and appropriate treatment provided. The aim of this study was to investigate the measurement of skin surface temperature (SST) by an infrared thermometer as an aid in the early detection of EHI. A skin surface temperature $\geq 39^{\circ}\text{C}$ in the immediate posttrace period is considered to be hot. It reflects the interaction of exercise-related metabolic heat production, physiological adjustments to the skin surface such as vasodilation and sweating, together with the effect of high ambient temperature. Most importantly, high SST is associated with a reduced core-to-skin temperature difference, which retards heat transfer from the deep body tissues to the skin and can hinder heat dissipation. Identification of horses with high SSTs can prioritise them for rapid cooling and curtail possible progression to EHI.

Introduction

Exertional heat illness is not a new disease. In people, it has been reported since ancient times (Casa *et al.* 2009, 2010), and in horses, there are many anecdotal reports of horses collapsing when working or competing in the heat, although it has been poorly documented in the academic literature until the last decade. Exertional heat illness has been reported in most athletic species, specifically human subjects (Armstrong *et al.* 2007), greyhounds (McNicholl *et al.* 2016) and a variety of sporting horses such as three-day eventers, endurance horses (McCutcheon and Geor 2008; Munoz *et al.* 2017) and Thoroughbred racehorses (MacDonald *et al.* 2008; Brownlow

et al. 2016; Nomura *et al.* 2019). The latter would appear to be at higher risk for EHI compared with other sport horses because of the amount of metabolic heat stored during racing, leading to a potentially critical elevation in core body temperature. For comparison, if all the metabolic heat is stored, the potential rise in core body temperature for each minute of exercise activity is 0.25°C for endurance horses, 0.30°C for three-day eventers and possibly up to 0.80°C for racing Thoroughbreds. Corresponding heat production is 400, 500 and 1250 kJ/min, respectively (Hodgson *et al.* 1993).

The pathophysiology of EHI is complex but similar in all species, involving central nervous system (CNS) effects (Sharma and Hoopes 2003), initiation of the systemic inflammatory response syndrome, and widespread coagulopathies (Bouchama and Knochel 2002). In most species, EHI occurs suddenly (Belval *et al.* 2018) and can represent a significant medical emergency, requiring prompt recognition and treatment if untoward sequelae are to be minimised (Armstrong 2003; Casa *et al.* 2012; Casa *et al.* 2015; Racinais *et al.* 2015; Adams *et al.* 2015). Recently, Marom and colleagues (2011) have suggested that aggressive treatment of human subjects should be initiated before clinical signs and hyperthermia are evident, that is when only a provisional diagnosis of EHI has been made, and that treatment at this very early stage could completely prevent EHI. Such an approach has produced successful outcomes with minimal sequelae in military trainees who have become heat-affected during intense physical exercise.

Diagnosis of EHI in people is typically based on an elevated rectal temperature, usually $>40.5^{\circ}\text{C}$ (Casa *et al.* 2017), measured using a thermistor inserted 15 cm past the anal sphincter (Miller *et al.* 2017), together with manifestations of central nervous system (CNS) dysfunction. In the early stages, however, CNS signs may be vague and include, in isolation or combination: confusion, dizziness, mood changes, and irrational or aggressive behaviours (Belval *et al.* 2018). In Thoroughbred racehorses, measuring rectal temperature poses a substantial risk to handlers and has proved unreliable as a guide to core body hyperthermia in the immediate post-exercise period (Hodgson *et al.* 1993; Geor *et al.* 1995). Manifestations of CNS dysfunction in Thoroughbred racehorses are also subtle and can be easily missed or misinterpreted. High levels of irritability are common, as is head nodding. Horses may become difficult to restrain, or overreact to any simple stimulation, often throwing themselves down with little provocation (Brownlow *et al.* 2016).

Observations over many years by the lead author have revealed that horses displaying overt symptoms of EHI typically had skin which was 'very hot' to the touch, and this was found to be the most reliable early indicator (Brownlow *et al.* 2016). The aim of this study was to investigate the use of the infrared thermometer (IRT) as a method of quantifying high skin surface temperatures (SSTs) and, more specifically, to establish whether it has a role in the identification of horses with emerging signs of EHI.

Materials and methods

Study protocol

The study covered five race meetings during the Australian summer racing seasons of 2016–2018. Horses arrived at the racetrack and were allowed to be hosed, walked and settled in their race-day stalls and then had their skin temperatures and heart rates measured by trained observers. Prerace measurements were taken approximately 1 h before racing. Postrace 1 measurements were taken as soon as possible after racing (less than 10 min) and before horses were hosed. Postrace 2 measurements were taken approximately 45–60 min later, before horses were being prepared to leave the racetrack. Prior to the study days, trainers had been briefed and verbal consent for participation obtained. All monitoring procedures were approved by the Racing NSW ethics committee (RP77).

Skin surface temperatures (SSTs) and heart rate measurements

Skin surface temperatures were measured using the Digitech Dual-IR infrared thermometer (IRT) (Instrument Choice, South Australia), calibrated for accuracy between 10 and 50°C. The IRT is a point-and-shoot device providing a reading in 150 ms. It has a distance-to-spot ratio of 12:1 and for the most accurate readings the IRT should be held perpendicular to the skin surface at a distance of 30 cm, corresponding to 2.5 cm between the laser dots. Emissivity was set at 1.0 in accordance with previous studies in horses (Mostert *et al.* 1996). All horses had short summer hair coats (Fig 1). Heart rate (HR) was measured with the Polaris heart rate monitor (Fig 2) (Polar Equine HealthCheck FT1 heart rate monitor).¹

Measurement of the thermal environment

All thermal environment measurements were taken in the vicinity of the race-day stalls. Measurements were taken at the time of each race, that is at intervals of approximately 35 min. Standard weather measurement equipment routinely used in human heat stress studies was used (Budd 2001, 2008; Brotherhood 2008). This included a battery-powered motorised fan psychrometer (Model Electro-V)², which measured dry (T_{db} °C) and wet bulb (T_{wb} °C) temperatures, and a 15-cm diameter blackened copper globe to measure globe (T_g °C) temperature (Bedford 1946; Parsons 2002). Natural wet bulb (T_{nwb} °C) measurements were based on an unshielded and naturally ventilated wet bulb thermometer. Wind speed (V_a) was measured using the Kestrel Heat Stress Tracker 5400³ anemometer with a wind vane to ensure that the instrument always faced into the wind.

Computations from standard weather measurements

From the above standard measurements, the following were computed: the water vapour pressure (P_w), that is absolute

humidity; the mean radiant temperature of the surroundings (T_r); and the added radiant heat ($ADRAD = T_r - T_{db}$). The WBGT index of heat stress was calculated as $0.7 T_{nwb} + 0.2 T_g + 0.1 T_{db}$ (Budd 2001, 2008; Brotherhood 2008). The environmental evaporative capacity (E_{max}) was calculated using the formula recommended by Belding and Hatch (1955).

$$E_{max} = 117v^{0.6}(P_{sk} - P_a) \text{ W/m}^2$$

where v is the air velocity over the body surface (m/s), P_{sk} the saturated vapour pressure at skin temperature (kPa) and P_a the ambient vapour pressure (kPa). Heat transfer in Watts per square metre.

The 'aggressive targeted cooling intervention' involves the use of ice-cold water (0–12°C) applied to most of the horse's body surface area, as well as using a stream of water to target-spray the major superficial blood vessels in a sequential manner: first the head and neck, concentrating on the jugular vein, passing on to the thorax and cephalic vein of the opposite leg, then rump and saphenous vein of opposite leg; ready to turn to the opposite side and repeat the process. Scraping is not considered to be necessary until the entire process has been completed. Effective cooling is usually achieved using this technique within a 10- to 15-min time frame. The development of a mobile spray unit (Fig 3) has been the cornerstone of treatment. Based on a 180-L plastic water container, it has a pump capable of providing 18 L per minute, feeding into a large diameter hose. The unit is powered by a 17.5-volt battery, enabling continuous use for approximately 5–6 h. On difficult days, 2 or 3 units may be necessary to cope with the number of horses that need aggressive targeted cooling.

Results

Participants

The 260 horses in the study included 135 geldings, 22 colts/stallions and 103 fillies/mares, ranging from 2 to 8 years of age (Fig 4a,b). Most races were of sprint distances (1000–



Fig 1: The hand-held infrared thermometer being used on the shoulder area of a horse for the prerace measurement. The baton is only used here to demonstrate the recommended distance of 30 cm, which corresponds to 2.5 cm between the laser dots. The horse must have a fine summer coat.



Fig 2: Measurement of heart rate immediately after racing using the Polaris heart rate monitor.



Fig 3: The cooling unit contains water and ice. Note the length of hose and trolley design so that the unit is mobile and can be taken anywhere in the horse stall area when required.

1300 m with 147 runners), then middle distance (1400–1800 m with 67 runners) and long distance (1900–2400 m with 37 runners) (Fig 4c).

Categorisation of weather conditions and number of horses with high SSTs detected

Table 1 shows the prevailing weather conditions categorised by consulting thermal experts into mild, hot/dry and warm/humid for summer climatic conditions in eastern Australia (Budd 2001, 2008; Brotherhood 2008). The number of horses with high SSTs was recorded, together with those which after early assessment needed to be aggressively cooled.

Mild days

There were three mild days with a mean ambient temperature of 26°C, mean absolute humidity 1.9 kPa, mean relative humidity 53%, mean radiant heat 52.8°C and mean WBGT of 24°C. Wind speed for the three days averaged 3.0 m/s. From **Table 1**, for the mild days, there were only four horses (2.3%) with skin temperatures $\geq 39^\circ\text{C}$ and on assessment none of these required cooling. Note that the evaporative capacity of the environment (E_{max}) was calculated as 843 Watts per square metre.

Hot day

On the hot day, the mean ambient temperature was 38.8°C with a range from 41.0°C at the commencement of racing to 31.2°C later in the day. Absolute humidity was 1.9 kPa; relative humidity 30.0%; mean radiant heat 61.0°C with a range up to 75.8°C, and WBGT $> 30^\circ\text{C}$. Wind speed was constant throughout the day at 2.7 m/s. On this day, there were 18 horses (47.4%) with postrace skin temperature $\geq 39^\circ\text{C}$, and a further two horses (5.3%) required cooling based on other signs of thermal strain, such as high levels of distress and elevated heart rates. Note that the calculated figure for E_{max} was 784 W/m², which was not substantially different from that recorded for the mild day.

Warm/humid day

On the warm and humid day, the mean ambient temperature was 31.1°C, with a range from 30.8 to 32.5°C; absolute humidity was 2.6 kPa with a highest reading of 2.77 kPa; relative humidity was 60.0%; mean radiant temperature was 57.9°C, and the WBGT was 29.3°C. Mean wind speed was 0.2 m/s (range from 0.1 to 0.4 m/s), which did not change throughout the day. From **Table 1**, there were six horses (16.0%) with skin temperatures $\geq 39^\circ\text{C}$, but after assessment 49.0% (18) horses actually required cooling. Note that the calculated figure for E_{max} was only 173 W/m², much lower than that for the mild and hot days.

The frequency and percentage calculations for high SSTs on mild, hot and warm/humid days

Table 2 shows the frequency and percentage calculations for SSTs on mild, hot and warm/humid days, and **Fig 5** presents the same data graphically. Among the 185 horses which raced on the mild days, there was a large spread in SST values, ranging from 33 to 39°C, but the majority (86.5%) had skin temperatures between 34 and 37°C. No horses required aggressive cooling. On the hot day, SST values of the 38 participating horses were skewed towards the higher extremes. The highest recorded was 42.3°C, with the majority of horses (28/38 or 73.1%) being above 39°C. Only 18 of these horses required aggressive cooling. On the warm/humid day, SST values were concentrated in the mid-range. Of the 37 horses participating, there were only 6/37 (16.0%) $\geq 39^\circ\text{C}$, with the remainder falling between 36 and 38°C (30/37 or 81%),

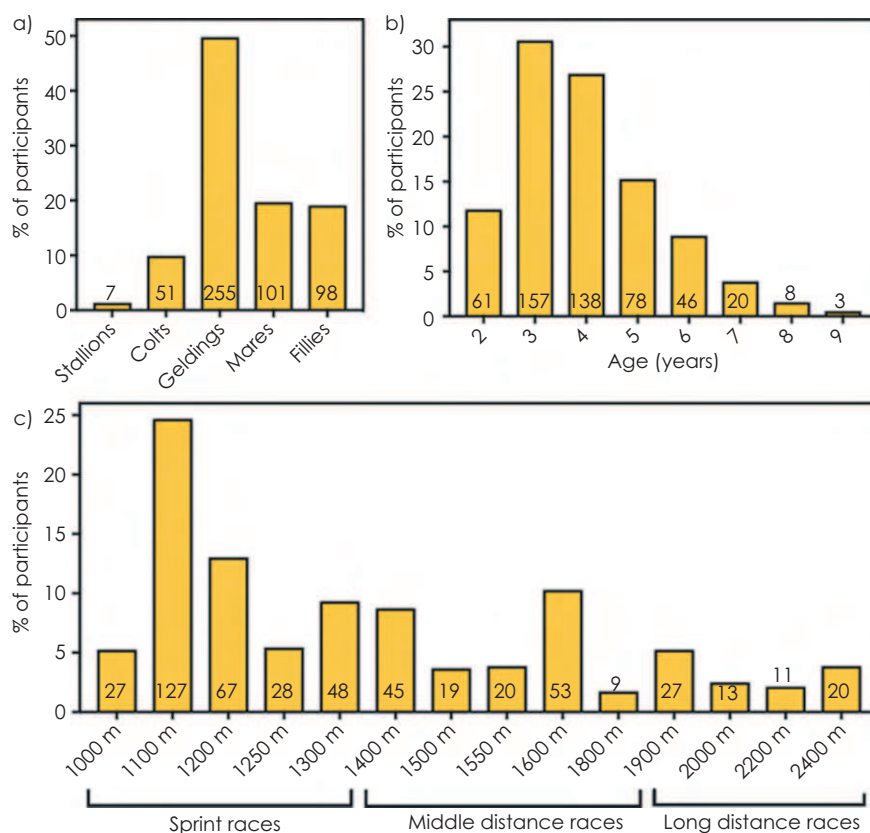


Fig 4: Characteristics of Thoroughbred racehorse participants: (a) relative frequency distribution of participant age; (b) relative frequency distribution of participant sex (colts, stallions, geldings, mares and fillies; and (c) relative frequency distribution according to race distance, with races under 1400 m classified as sprint races, 1400–1800 m as middle distance races, and those over 1800 m as long distance races. Note that absolute frequencies are also included in each column.

TABLE 1: Categorisation of weather conditions with the corresponding number of hyperthermic or 'hot' horses in the immediate postrace period based on infrared thermometry (IRT) $\geq 39^{\circ}\text{C}$

Weather category	No. horses	Temp $^{\circ}\text{C}$	Abs Humid kPa	MRT $^{\circ}\text{C}$	WBGT $^{\circ}\text{C}$	Emax W/m^2	Wind speed m/s	No. 'hot' horses	No. req cooling
Mild (3 days)	185	27.0	1.9	52.8	24.0	843	3.0	4	0
Hot (1 day)	38	38.8	1.9	61.0	>30.0	784	2.7	28/38	18/38
								73.8%	47.4%
Warm/humid (1 day)	37	31.1	2.6	57.9	29.3	173	0.2	6/37	18/37
								16.0%	49.0%

The final column shows the number of horses which required cooling after racing, based on IRT together with other indicators of thermal strain such as clinical distress, high heart rate and slow recovery time. The warm/humid day showed the largest discrepancy between the two groups.

but an increased number (18/37 or 49.0%) required aggressive cooling.

Postrace skin temperatures

Postrace SSTs were affected by distance raced under certain weather conditions (Fig 6). On mild days, the race distance was of little consequence and did not result in significant elevations to postrace SSTs. The highest postrace SST values were recorded on the hot day, but there was no significant difference between race distances from 1000 to 1800 m. Note that the outliers on the hot day occurred when the temperature plummeted and wind speed picked up

dramatically after an abrupt weather change. This is in contradistinction to the warm/humid day where there was a significant difference in SSTs over the different racing distances.

Skin temperatures affected by the thermal environment

Figure 7 shows skin temperatures at the three measurement stages. On mild days, prerae SSTs were lowest (33.5°C), became warm (36°C) immediately after racing and then dropped to a lower level, which was always above the prerae level (34°C). On the hot day, the prerae SSTs were

TABLE 2: Frequency and percentage calculation of postrace skin temperatures for mild, hot/dry and warm/humid days

Temperature categories	≥41°C	≥40°C	≥39°C	≥38°C	≥37°C	≥36°C	≥35°C	≥34°C	≥33°C
Mild									
No of horses: 185	0	0	4	10	27	44	51	38	11
Percentage (%)	0	0	2.2%	5.4%	14.6%	23.8%	27.6%	20.5%	5.9%
Hot/Dry									
No of horses: 38	8	8	12	9	1	0	0	0	0
Percentage (%)	21.1%	21.1%	31.6%	23.7%	2.6%	0	0	0	0
Warm/Humid									
No of horses: 37	0	2	4	15	11	4	1	0	0
Percentage (%)	0	5.4%	10.8%	40.5%	29.7%	10.8%	2.7%	0	0

The mild days had the greatest range of skin temperatures with very few (4, 2.2%) ≥39°C. The hot/dry day had skin temperatures which were skewed to the higher extremes with 8 (21.1%) above 41.0°C. One horse recorded 42.3°C at the postrace measurement. The warm/humid day showed a greater spread of values with only 6 horses (16.3%) ≥39°C.

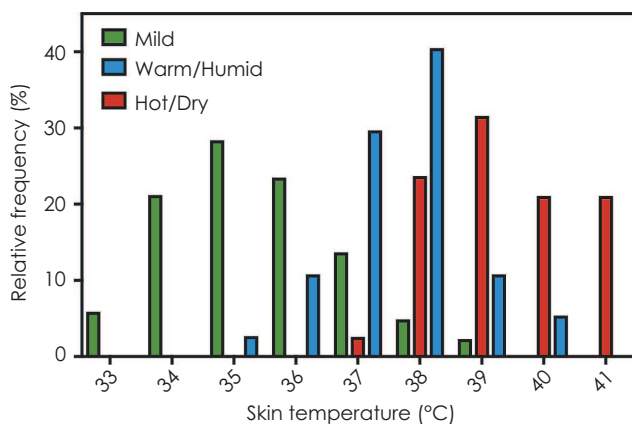


Fig 5: The relative frequency of skin surface temperatures immediately after racing. Note that the greatest range in values was seen on the mild days. The hot day was skewed towards the higher values and the warm/humid day centred on the middle values.

significantly higher (>36°C), increased to very hot (≥39°C) with some as high as 42°C, but then dropped to 35–36°C, which was lower than the prerace measurement. On the warm/humid day prerace SSTs were higher than on mild days (34°C), became hot after racing (>38°C), then dropped after recovery to a point above the prerace level.

Heart rates

Unlike skin temperature, heart rate was not adversely affected by the different weather conditions (Fig 8). Racing in warm/humid conditions produced only a small significant increase in heart rate immediately after racing, compared to those horses racing in mild conditions, but all three groups exhibited equal heart rate recovery capability.

Discussion

Use of the infrared thermometer as a potential screening tool for emergent EHI

This study is unique because it was carried out at the racetrack where Thoroughbred racehorses competed at maximal exercise intensities over various distances and in a range of weather conditions. It investigated whether the IRT could be used as a potential screening tool to identify horses

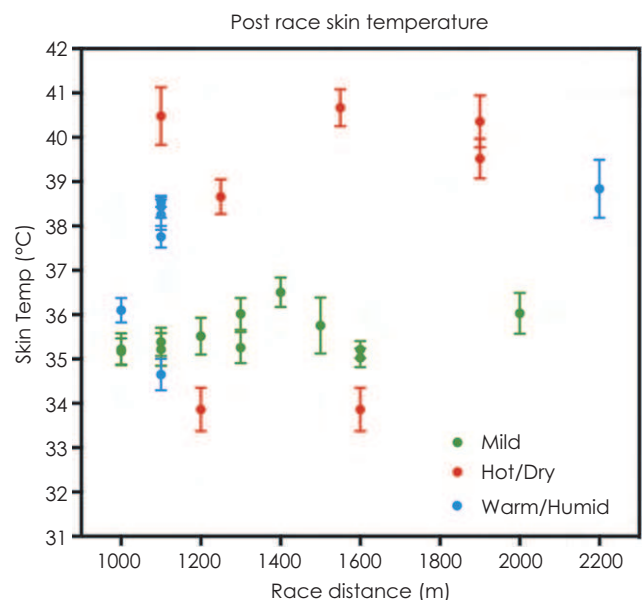


Fig 6: The relationship between postrace skin surface temperatures and distance raced. Statistical significance was determined using ordinary one-way ANOVA for each weather category. On mild days, the race distance did not affect postrace skin temperatures and although the skin temperatures were highest on the hot day, race distance had little effect. On the warm/humid day, however there was a significant difference in postrace skin temperatures, depending on the distance raced.

with high SSTs, which might be the very first indication of emergent EHI. The IRT is an inexpensive point-and-shoot device and its validity to measure skin temperature has been established in human subjects at rest and when exercising in cold, mild and hot conditions (Cuddy *et al.* 2013). In human subjects, mean skin temperature is calculated using multiple sites that represent the greatest percentage of body surface area (Parsons 2002). For this study, the horse's dorsal neck, shoulder and lateral thoracic rib cage were selected which represented 27.1% of the skin surface area (Jodkowska *et al.* 2011), and the mean calculated. To the author's knowledge, there are no reports of the hand-held IRT being used to monitor post-exercise SSTs in horses, although dynamic infrared thermography has been used in horses and greyhounds to investigate changes to skin and superficial

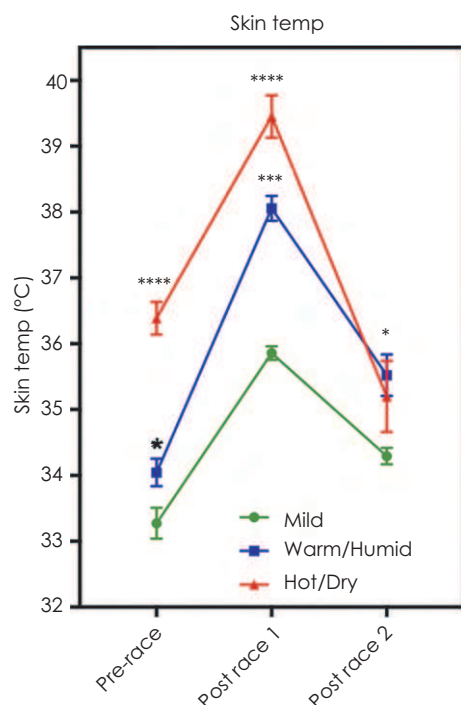


Fig 7: Skin temperatures at the three measurement stages were affected by the ambient weather conditions.

Mild				Warm/Humid			Hot/Dry		
Stage	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n
Pre Race	32.87	0.29	129	33.64	0.259	67	36.41	0.19	56
Post Race 1	35.59	0.41	129	37.85	0.193	41	38.65	0.38	49
Post Race 2	34.38	0.16	108	35.44	0.31	35	34.82	0.43	52

Statistical significance was determined using multiple t-tests with the Holm-Sidak post hoc method, with $\alpha = 0.05$. Computations assume that all rows were sampled from populations with the same scatter (SD). * $P < 0.05$; *** $P < 0.001$; **** $P < 0.0001$.

muscle temperatures (Marlin *et al.* 1999; Soroko *et al.* 2018). In people, researchers (Buller *et al.* 2008; Cuddy *et al.* 2013) have combined skin temperature and heart rate to predict physiological strain during exercise, enabling the development of risk categorisation as part of a multi-faceted EHI prevention system.

Skin temperature responses – mild day

On mild days, average SSTs were cool (33.0°C) at the prerace measurement, became warmer after racing (36.0°C) and then decreased (35.0°C) one hour later. The spread of values in the immediate postrace period was wide, although there were four horses (2.3%) considered to be hot (>39°C). This spread of values was an important finding. Racing in milder conditions with a reasonable wind speed is considered ideal for horses because of the expected balance between metabolic heat produced and efficient dissipation of heat to the environment. Metabolic heat production, however, is the

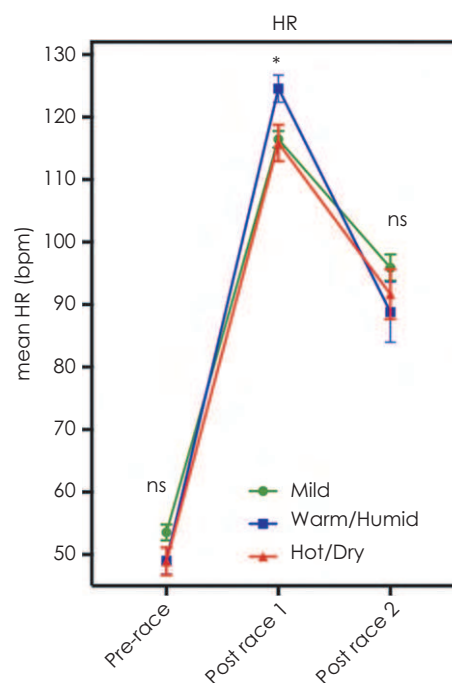


Fig 8: Relationship between heart rate and weather conditions showing that heart rates were not significantly affected by the different weather conditions. Racing in warm/humid conditions produced a small significant increase in heart rate immediately after racing compared to the other two weather groups.

Mild				Warm/Humid			Hot/Dry		
Stage	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n
Pre race	55	1.6	127	49	1.4	67	50	1.8	56
Post Race 1	116	1.6	130	123	2.1	41	116	2.3	52
Post Race 2	97	2.5	109	87	4.3	35	93	3.3	52

Statistical significance was determined using multiple t-tests with the Holm-Sidak post hoc method, with $\alpha = 0.05$. each row was analysed individually, without assuming a constant SD. NS $P > 0.05$; * $P < 0.05$.

major driver for EHI and demonstrates considerable individual variability. If certain human athletes who have comparatively higher metabolic rates and work intensities are pushed to higher levels of competitiveness, they may demonstrate a higher risk of EHI, even in cooler, more moderate weather conditions (Brotherhood 2008). This might explain why EHI in racehorses is sometimes seen unexpectedly on cooler days. Individual determinants might include fitness, fatness, acclimatisation variants, hydration status and feeding regimes, especially protein and supplement intake (Cramer and Jay 2016).

From the authors' experience, it is the fiercely competitive horses which usually experience EHI, as well as horses that are fat and relatively unfit for the race distance, or a combination of these. There are also 'repeat offenders' that are described by their trainers as being 'hot' and appear to be predisposed to a mild form of heat illness every time they race, in a variety of weather conditions but especially in the

TABLE 3: Skin temperature change where the skin is 'burning hot to the touch' is the most reliable early detection sign

Early detection for exertional heat illness enables rapid assessment and aggressive cooling, which will 'ABORT' EHI (after Marom *et al.* 2011).

Prioritisation of clinical manifestations enables an early detection logistical framework

Clinical manifestation	Method of detection	Physiological consequences
Skin is 'burning hot' to the touch. Considered a pathognomonic sign for emergent EHI.	IRT thermometer enables quantification of skin surface temperature. At levels $\geq 39^{\circ}\text{C}$ horse should be aggressively cooled. Levels of 43°C have been recorded.	Indicative of reduced core-to-skin temperature gradient Heat transfer from core to skin surface is reduced, so that hyperthermia may escalate
Elevated heart rate, >130 beats/min – not decreasing. Elevated respiration rate. Hyperaemic mucous membranes. Substantial skin vasodilation. Slow capillary refill time.	General clinical assessment of level of thermal strain following exercise.	Indicative of redistribution of cardiac output to skin for thermoregulation Cardiac output is reduced, which results in decreased blood pressure. Horses are slow to recover
In warm and humid conditions sweat may cover most of the animal's body but runs off dependent parts onto the ground	Assessment of level of absolute humidity using Vaisala app. Above 2.5 kPa there is restricted evaporation of sweat and horses' cooling can be compromised.	Indicative of failure of thermoregulation Occurs due to high levels of humidity causing restricted evaporation of sweat. Hyperthermia will tend to escalate.
Horses show irritability, head nodding, and are difficult to restrain. They may throw themselves down with little provocation	CNS symptoms associated with EHI can be subtle and easily missed or misinterpreted. Education is the key to best methods of detection	Indicative of cerebral dysfunction – a 'hot' brain. Early signs reflect cerebral ischaemia, which if not halted progresses to cerebral oedema.

Using the IRT enables a quantitative measurement, and 39°C has been chosen as the level at which aggressive cooling should be instigated. Whilst evaluation of level of thermal strain and sweating response is important, these tend to occur in a more random fashion. Recognition of early CNS dysfunction is extremely important but indicates that EHI is already.

hot summer months (M. Brownlow, personal communication). Horses with high SSTs in the mild weather group generally did not require assisted cooling and responded to routine management by their handlers. This was because the environmental conditions were amenable (E_{max} 843 W/m^2) to efficient heat loss.

Hot/dry day

On the hot day, horses arrived at the racetrack with significantly higher skin temperatures, which probably reflected both the higher ambient temperatures and the conditions of transportation. The average prerace measurement was 37°C , significantly different from both the mild days and the humid days. This was considered to be an important welfare finding, indicating that horse transport and distance travelled to race meetings might need further investigation to clarify best practice. Also, policy directives on hot days permit horses to arrive on course at a later time, but this may actually be counterproductive because horses probably require more time rather than less time to cool before racing. Importantly, the handlers with these horses were not aware that horses in their care were 'hot', so that education of this group is vital for best management of EHI.

Postrace SSTs on the hot day were skewed to the upper extreme. Of the 38 horses in this group, 28 (73.8%) had SSTs $\geq 39^{\circ}\text{C}$ but after identification and assessment only 18 (47.4%) required cooling. This was an important finding, because although it was very hot in terms of ambient temperature and mean radiant heat, absolute humidity was low and wind speed was moderate. This translated to environmental conditions which did not limit the evaporation of sweat (E_{max} 784) enabling some horses in the lower 'hot' group to cool quite efficiently without an aggressive cooling intervention. Horses with SSTs of 40°C and above were targeted for

assisted cooling interventions and none of these developed signs of emergent EHI.

Warm/humid day

On the warm and humid day, there were only six horses (16.2%) with SSTs $\geq 39^{\circ}\text{C}$, the majority (70.2%) registering SSTs between 37° and 38°C . After assessment, however, an additional 12 horses required aggressive cooling. Of this group, many had a skin surface saturated with sweat, which was running off dependant parts of the body onto the ground. Dripping wet skin indicates that the evaporative capacity of the environment is considerably lower than the rate of sweat secretion at the skin surface and therefore is not meeting the physiological requirements for heat loss. Under these circumstances, hyperthermia may continue to escalate and without aggressive cooling interventions horses may succumb to EHI. Horses in this group also showed the highest thermal strain in terms of level of distress and elevation in heart rates. This was explained by the ambient weather conditions. High levels of absolute humidity (2.6 kPa) and negligible air movement (0.2 m/s) combined to produce an extremely low value for E_{max} at only 173 W/m^2 , indicating restricted evaporation of sweat and failure to dissipate the heat load.

Although beyond the scope of the article, it is pertinent here to explain the use of absolute humidity rather than relative humidity. Absolute humidity (Pa) is the water vapour pressure in the air, and together with air movement directly affects the evaporation of sweat. Relative humidity (RH%), although commonly referred to, is the most misunderstood and misused humidity variable (Davis *et al.* 2016). Put simply, relative humidity represents the extent to which the air is saturated, but scrutiny of its calculation reveals that whilst the numerator depends on humidity, the denominator varies with

air temperature. This means that relative humidity can change quite markedly throughout the day whilst the air's actual moisture content (absolute humidity) remains constant. A measurement of absolute humidity is accessible without recourse to expensive monitors. The following link provides access to the Vaisala humidity calculator 5.0. <http://go.vaisala.com/humiditycalculator/5.0?utm>.

From predictive weather sites close to where horses are racing, selection of temperature and relative humidity allows a calculated absolute humidity measurement expressed as vapour pressure (pw) in kPa.

Final skin measurements

The final skin measurement stage provided similar readings in all three groups: lower than the immediate postrace measurement but higher than the prerace measurement. This should probably be regarded as a normal response to strenuous exercise, especially in warm conditions, and probably reflects the residual stored heat, which, according to Hodgson *et al.* (1993), is maintained for at least 40 min after exercise.

Heart rate responses

It was expected that heart rate response might substantially reflect the degree of thermal strain experienced by individual animals, but HR was only minimally affected on the humid day. The Polaris heart rate monitor proved useful, with minimal interference and stress to the animal. It has been shown to provide reliable results in stationary horses when compared to a simultaneously recorded electrocardiogram and is widely used in elite equine sporting events (Barnes *et al.* 2010). The lack of heart rate variability in response to thermal strain probably attests to the elite athletic status of the Thoroughbred racehorse, and the fact that the race distances involved were not particularly gruelling. It is important to note, however, that in all thermal environments heart rates were elevated for a substantial period of time (at least 60 min) after racing.

Study limitations

This study was unique in having been carried out at the racetrack under real racing conditions, but that did place significant limitations on methodology. It has been suggested here that horses with high SSTs might signal early identification for emergent EHI, and **Table 3** presents a summary of the most critical clinical manifestations associated with EHI which enables a logistical early detection framework. It is acknowledged, however, that to test this hypothesis, horses thus identified would have needed to be left without cooling interventions, to observe whether they escalated to higher EHI levels. Obviously, this was not ethically possible due to welfare considerations. Another major limitation of this study was the lack of correlation of high SSTs with rectal temperatures and the fact that weather conditions during the course of this study were unstable, resulting in the abandonment of several of the study meetings before completion.

Conclusions

Skin temperature is not presented here as a surrogate for rectal temperature but rather as a 'marker' for increased risk of EHI. If a high SST is not corrected it could exert a profound influence on the dynamics of cooling because it reduces the

core-to-skin temperature difference, decreasing the drive for internal heat transfer from the 'hot' core to the skin surface for heat dissipation. Physiologically, the IRT value provides insight into the heat transfer dynamics operating at the body core-skin-air interface. Skin temperature is the result of a number of independently acting variables: ambient temperature and air flow over the skin surface, the exercise-related metabolic heat production, the dynamic physiological processes acting at the skin surface to increase or decrease skin blood flow and the initiation of sweating. The value of the IRT stops here.

The key finding of this study concerns the relationship between the IRT value and the prevailing weather conditions, which dictate whether or not the sweat produced can be evaporated to achieve efficient cooling. On hot/dry days with an ample wind speed, most horses with high SSTs can cool effectively, but if the air flow ceases horses will experience difficulties.

Warm/humid days create the most perilous conditions because certain levels of absolute humidity restrict the evaporation of sweat, and all horses, regardless of their immediate postrace skin temperature, may experience difficulty cooling effectively. These horses will require continuous hands-on observation and monitoring with the IRT on several occasions to ensure that skin temperature is decreasing and not rising.

Best practice informs that early recognition of emergent EHI in all species is essential, because it is the duration of hyperthermia rather than its magnitude that determines outcome. This study showed that the IRT enabled the measurement of skin temperature in seconds, so that horses with high SSTs ($\geq 39^{\circ}\text{C}$) could be identified early, rapidly assessed and targeted for immediate aggressive cooling interventions. Although this study could not definitively correlate high skin temperatures with emergent EHI because of the obligation to treat on welfare grounds, it can be stated that none of the horses that were actively cooled following high SST detection progressed to display signs of EHI. Two of the study days were particularly challenging, the expectation having been that horses would have difficulties cooling, but the use of the IRT enabled best management practice. This study has also provided benchmark values for SSTs in mild, hot and warm/humid conditions.

Finally, EHI is potentially life-threatening and heightens the public perception of risk associated with horse racing. Minimal intervention strategies such as the use of the infrared thermometer as a scanning device could improve animal welfare and provide transformational changes to the care of horses racing in hot and humid conditions. It is difficult to study EHI in the laboratory because the risk involved in exposing horses to substantial levels of exercise-related hyperthermia is ethically unacceptable. Thus, our knowledge of this condition presently depends on the judicious use of field documentation by veterinarians working at racetracks, and upon simple studies such as this.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Racing NSW Animal Care and Ethics Committee (RNSW ARA 66).

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Authorship

M. Brownlow contributed study design, study execution, and preparation of the manuscript. T. Smith contributed data analysis and interpretation. Both authors gave their final approval of the manuscript.

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Original Article

Ultrasound findings in tendons and ligaments of lame sport horses competing or training in South Florida venues during the winter seasons of 2007 through 2016

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Keywords: horse; sport horse; lameness; ultrasonography; suspensory ligament; inferior check ligament; superficial and deep digital flexor tendons

Summary

Knowledge of common soft tissue lesions in sport horses in training should prove beneficial for evaluating lameness and developing training and management regimens to avoid injury and aid rehabilitation. Medical records were reviewed from 2007 to 2016 to describe tendon/ligament lesions in lame sport horses training and competing at the same venues during the winter show circuit and identified by lameness and ultrasonographic examinations. Season, discipline, breed, age, gender, limb and ultrasound findings were recorded. Descriptive statistics were used to describe the population of horses. Significance of association of gender, discipline and limb with lesion type was evaluated using chi-squared analyses. Values were considered significant at $P \leq 0.05$. Lesions were identified in 296 horses: 176 dressage and 120 hunter/jumpers. Ninety-two horses (31%) had multiple lesions. Suspensory ligament lesion locations ($n = 281$) were categorised as proximal ($n = 144$), body ($n = 22$) and branches ($n = 115$). Superficial digital flexor tendon (SDFT; $n = 37$), deep digital flexor tendon (DDFT; $n = 27$), inferior check ligament (ICL; $n = 34$), digital flexor tendon sheath ($n = 17$), distal sesamoidean ligament ($n = 10$), lower limb collateral ligament ($n = 14$), carpal sheath ($n = 2$), superior check ligament ($n = 2$) and tarsal sheath ($n = 1$) lesions were noted. Remaining lesions identified were medial branch SDFT ($n = 2$), lateral branch SDFT ($n = 2$), palmar annular ligament ($n = 3$), lateral plantar ligament ($n = 2$) and inter-sesamoidean ligament ($n = 1$). Rear limb proximal suspensory abnormalities, specifically the right hindlimb ($n = 68$), were significantly over-represented ($P = 0.03$). Suspensory origin, suspensory branch, ICL, SDFT and DDFT accounted for 82% of the abnormal findings identified. SDFT, DDFT and ICL lesions were most often identified in the front limb. The lesion type and location may provide insight in assessing training regimens, patient monitoring and rehabilitation guidelines.

Introduction

Tendon and ligament injuries of the distal limb occur frequently in various disciplines of equine sport (Thorpe *et al.* 2010). Racing disciplines are most commonly cited for frequency and type of injuries; however, the sport horse disciplines of showjumping and dressage are not so well

documented as to relative frequency of occurrence. Reports of an association of type of sport and performance level with anatomical site of orthopaedic injury diagnosis are in the literature (Murray *et al.* 2006); however, an opportunity to document soft tissue abnormalities in lame horses seen in a venue with similar activities and competition conditions over an extended period could produce useful information as to the type and frequency of sport horse tendon and ligament injuries. The competition venues of south Florida, USA, more specifically those centred around the horse community known as Wellington, Florida, are well known for attracting thousands of sport horses each winter season. According to the Chronicle of the Horse, a well-known equestrian publication based in Middleburg, Virginia, the Winter Equestrian Festival, held at the Palm Beach International Equestrian Center in Wellington, Florida, typically has 12 weeks of horse shows from January through March and hosts approximately 3000 horses each week. Concurrently, Global Dressage, a partner venue, hosts competitions to hundreds of dressage horses as well. There are multiple other venues in the Wellington region which conduct dressage and jumping competitions during the winter season. Many horses are relocated to the region during the winter months simply for training purposes and are typically in significant work relative to their individual disciplines during that time.

Objective

A retrospective study was conducted over a 10-year period to assess ultrasound findings of tendon and ligaments in lame, active sport horses in training and competition within similar venues. The lesions identified were compared among discipline of sport, gender and limb affected.

Materials and methods

Medical records of horses competing in the Winter Equestrian Festival and examined in the Wellington, Florida region by the first author from December through April during the years of 2006 (2007 season) through 2016 were reviewed. Those horses that were examined for lameness and had musculoskeletal ultrasonography were included in the study, and horses were selected that had developed lameness while training in the south Florida environment. Data collected from the medical

record included age, breed, gender, discipline, affected limb (s) and diagnosis. Those with incomplete information were not included in the study. Lameness examinations were performed on each horse and the source of lameness in each case was isolated regionally to the affected structure. Examinations included visual inspection, palpation of the limbs, motion examination of the horse in hand and under saddle with flexion tests during each phase, and diagnostic anaesthesia when appropriate. Historical information, when available, as well as obvious physical findings, often guided the investigator to perform diagnostic ultrasound without the additional information provided by diagnostic anaesthesia. Diagnostic anaesthesia was performed by the investigator in 185 of 435 lesions diagnosed (42.5%). Diagnostic ultrasound was performed in all cases, and radiography, nuclear scintigraphy and MRI were used for further evaluation/confirmation in selected cases (Mitchell 2013). It should be noted that 31% of described horses were found to have multiple lesions, and therefore an identified lesion may not have been the sole source of lameness in specific individuals. Description and assessment of ultrasonographic lesions were based on historical characteristics of ultrasound appearance which has been related to tissue damage and inflammation (acute and chronic); that is hypoechoic lesions indicative of fibre pattern disruption, fluid infiltration, peripheral oedema, osseous surface disruptions and hyperechoic lesions indicative of fibrosis and enlargement, peri-ligamentous fibrosis and dystrophic mineralisation and osseous proliferation. Angle contrast, nonweightbearing and dynamic nonweightbearing imaging was performed where appropriate (Rantanen *et al.* 2001; Werpy and Denoix 2012; Denoix and Bertoni 2015). When an abnormality was identified ultrasonographically, the structure was examined on the contralateral limb for comparison. All examinations were done by the same investigator with over 25 years of experience in ultrasonography including advanced training and certification by the International Society of Equine Locomotor Pathology (ISELP).

Descriptive statistics were used to describe the population of horses and, where appropriate, the association between putative risk factors (gender, discipline and limb) by lesion location was evaluated using chi-square analyses (SysStat Software)¹. Values were considered significant at $P \leq 0.05$.

Results

During the study period, 2115 lameness examinations and recheck lameness examinations were performed by the primary author. A total of 815 ultrasound examinations (including rechecks) were performed by a single examiner. Two hundred and ninety-six horses were determined to have tendon or ligament abnormalities of the distal limb (carpus/tarsus and distally), and a total of 435 lesions were identified ultrasonographically. Of those 296 horses, 176 horses (59.5%) competed in the discipline of dressage and 120 (40.5%) competed as hunters or jumpers. As compared to the distribution of the different disciplines within the overall practice during the same time period (7736 horses, 50.8% of which were dressage horses and 49.2% were hunter or jumpers), significantly more of the horses found to have an abnormality in this study were dressage horses ($P = 0.003$). A total of 210 geldings (71%), 67 mares (22.6%) and 19 stallions (6.4%) were examined with a mean age of 11.7 years. The

population of breeds was almost entirely European/American Warmblood breeds (291) (98.3%) with only five cross-bred ponies (1.7%) among the injured horses/ponies. The competing population of horses in Wellington (7751 in a single season) had a mean age of 11.2 years and was comprised of 66.7% geldings, 28.1% mares and 5.2% stallions (Equestrian Sport Productions, Wellington 2017).

Multiple lesions ($n = 281$) of the suspensory ligament were identified and separated into categories of proximal suspensory ($n = 144$), suspensory body ($n = 22$) and suspensory branches ($n = 115$). Further lesions were identified in superficial digital flexor tendon (SDFT, $n = 37$), deep digital flexor tendon (DDFT, $n = 27$), inferior check ligament (ICL, $n = 34$), distal sesamoidean ligaments (DSL, $n = 10$) and various collateral ligaments of the lower limb ($n = 14$). Also identified was tenosynovitis of the digital flexor tendon sheath (DFTS, $n = 17$). DFTS tenosynovitis was seen alone in seven horses and accompanied other lesions in 10 horses including DDFT ($n = 5$), SDFT ($n = 1$), palmar annular ligament ($n = 3$) and one inter-sesamoidean ligament ($n = 1$). Less frequently, carpal sheath ($n = 2$), superior check ligament ($n = 2$) and tarsal sheath ($n = 1$) lesions were noted. Two lateral plantar ligament lesions ($n = 2$) were identified, and lastly, medial ($n = 2$) and lateral ($n = 2$) superficial flexor tendon branch abnormalities were identified for a total of 435 lesions.

Eighty proximal suspensory ligament lesions ($n = 80$) were seen in dressage horses (55.6%), whereas 64 lesions ($n = 64$; 44.4%) were seen in hunter/jumpers, with no significant difference in prevalence of these lesions by discipline ($P > 0.05$) in the injured population. One hundred and five horses with proximal suspensory ligament lesions were geldings, 29 were mares and 10 were stallions. Abnormalities of the right hind suspensory origin was identified in 68 horses (47.2%; $P = 0.03$) compared to other limbs (RF $n = 20$; LF $n = 22$; LH $n = 34$), and proximal suspensory ligament lesions were identified in 102 ($n = 102$) hindlimbs (70.8%) as compared to 42 (29.2%) forelimbs, with hindlimbs significantly over-represented ($P < 0.00001$). Twelve horses (16.7% of limbs) had bilateral proximal suspensory ligament lesions identified at the initial examination. Of 144 proximal suspensory lesions identified, 82 (56.9%) were localised as the probable source of lameness by diagnostic anaesthesia and 96 (66.7%) suspected proximal suspensory regions were radiographed, and 9 (6.3%) cases were examined with nuclear scintigraphy to further substantiate the diagnosis and establish the extent of pathology. Subtarsal direct infiltration of the suspensory origin with anaesthetic was used in the hindlimb after more distal regional anaesthesia did not eliminate lameness. Similarly, the deep branch of the lateral palmar nerve or direct infiltration of the suspensory origin was utilised in the forelimb.

One hundred and fifteen ($n = 115$) suspensory branch lesions were identified with a relatively even distribution, including lateral branch (59) and medial branch (56) ($P > 0.05$). Twenty-two (19%) of the 115 suspensory branch lesions were localised using diagnostic anaesthesia. The probability of lesions in the remainder of suspect cases was determined by local palpation, enlargement and flexion responses prior to ultrasound. Dressage horses demonstrated 59.1% of lesions and 40.9% occurred in hunter/jumpers, which is almost identical to the relative population of horses identified as injured, therefore showing no discipline predilection for pathology of suspensory branches in this review ($P > 0.05$).

Suspensory body lesions were identified in 22 horses ($n = 22$) with an even distribution among limbs (RF, $n = 7$; LF, $n = 4$; RH, $n = 6$; LH, $n = 5$, $P > 0.05$) and were identified in 19 dressage horses and 3 hunter/jumpers, with a significantly higher distribution of these lesions in dressage horses ($P = 0.0008$). Diagnostic analgesia was used to localise lesions in 11 of lesions (50%), and the remainder were identified prior to ultrasound as likely injured by thickening, pain on palpation and significant response to distal limb flexion. Dressage horses demonstrated 86.4% of suspensory body lesions identified.

SDFT lesions were identified in 37 horses ($n = 37$) and were significantly over-represented in the forelimb ($n = 32$) or 86.5% as compared to hindlimbs ($n = 5$), ($P = 0.00006$). Nine lesions were localised with diagnostic anaesthesia (24.3%), and the remaining 28 were identified for ultrasound examination because of significant oedema and enlargement as well as sensitivity to palpation. Fifty-nine and a half per cent ($n = 22$) of the SDFT injuries were identified in dressage compared to jumpers (40.5%; $P > 0.05$) which parallels the population of lame horses identified. Twenty-nine horses with SDFT lesions were geldings (78.4%), 5 were mares and 3 were stallions, and the mean age of horses with SDFT abnormalities was 12 years. There was no significant association of gender with SDFT injury ($P > 0.05$).

Twenty-seven ($n = 27$) deep digital flexor tendon lesions were identified in 20 forelimbs and 7 hindlimbs. Fourteen of these injuries ($n = 14$) were in hunter/jumpers, and 13 were present in dressage horses ($n = 13$; $P > 0.05$). Twelve of 27 DDFT lesions (44.4%) were localised with diagnostic anaesthesia, one was examined with nuclear scintigraphy and one with MRI, and the remainder were suspected based on significant digital flexor tendon sheath effusion, pain on palpation and distal limb flexion responses.

Tenosynovitis of the DFTS with gross enlargement and tissue thickening was associated with lameness in 17 limbs ($n = 17$), 10 forelimbs and 7 rear limbs. As previously mentioned, DFTS tenosynovitis of varying degrees often accompanied DDFT, SDFT and ligament injuries but despite obvious palpation responses, enlargement, effusion and synovial thickening apparent on ultrasound, a clear relationship to tendon or ligament injury was not always apparent. DFTS tenosynovitis was seen alone in 7 limbs, 3 of which were further localised by diagnostic anaesthesia. Severe DFTS tenosynovitis accompanied lesions of DDFT ($n = 5$), SDFT ($n = 1$) and palmar annular ligament (PAL; $n = 3$), and an inter-sesamoidean ligament lesion ($n = 1$) in a total of 10 limbs. A total of 5 of 17 (29.4%) identified DFTS lesions were confirmed with diagnostic anaesthesia to be associated with lameness. Again, significant effusion, palpation sensitivity and pain on flexion guided the decision to perform an ultrasound examination in those cases not blocked. Lesions of the SDFT, DDFT, or PAL were identified with ultrasound in 58.8% of severe DFTS tenosynovitis.

Inferior check ligament lesions were identified in 22 right forelimbs ($n = 22$) and 12 left forelimbs ($n = 12$), with no significant difference in distribution between the forelimbs. In addition, inferior check ligament injury was noted in 25 dressage horses ($n = 25$; 73.5%) compared to 9 horses used as jumpers and was significantly over-represented in dressage horses ($P = 0.008$). Inferior check ligament lesions were initially suspected based on thickening and sensitivity in the proximal aspect of the palmar metacarpal region.

Ten distal ($n = 10$) sesamoidean ligament lesions were identified, 7 forelimbs and 3 hindlimbs, and 4 (40%) were localised initially with diagnostic anaesthesia. Marked thickening of the palmar or plantar pastern was often noted as well as significant lameness following distal limb flexion tests.

Collateral ligament lesions ($n = 14$) were identified in the metacarpophalangeal joint ($n = 2$), proximal interphalangeal joint (PIPJ; $n = 1$) and the distal interphalangeal joint (DIPJ; $n = 11$) and were identified in 12 forelimbs and 2 hindlimbs. Fourteen of 14 lower limb collateral ligament lesions (100%) were localised initially with diagnostic anaesthesia. Of 11 DIPJ collateral ligament lesions noted, 8 were also investigated with radiography and 6 of those radiographed were also examined with MRI. Carpal sheath ($n = 2$) and superior check ligament ($n = 2$) and tarsal sheath ($n = 1$) lesions were also identified. The superior check ligament abnormalities identified responded to carpal sheath anaesthesia in 2 of 2 (100%). Two lateral plantar ligament lesions ($n = 2$) were identified but no diagnostic analgesia was utilised as the lesions created a significant deformation at the plantar tarsal level and were palpably oedematous.

Medial ($n = 2$) and lateral ($n = 2$) superficial digital flexor tendon branch lesions were identified and 3 of 4 (75%) of these lesions were localised with diagnostic anaesthesia.

Three palmar annular ligament lesions ($n = 3$) were observed, two (67.7%) of which were first regionalised with local anaesthesia. Digital flexor tendon sheath effusion was present in all cases.

Discussion

Proximal suspensory ligament injury is a common sport horse injury (Dyson 2014; Plowright and Dyson 2015) and was the most common abnormality ($n = 144$) recognised in this population of horses. Proximal suspensory ligament lesions were more frequently seen in dressage horses in this study but paralleled the distribution of disciplines examined over the study period. Interestingly, there was a greater incidence of right hind (RH) proximal suspensory lesions compared to other limbs, and suspensory origin lesions were more common in the hindlimb than the forelimb. This frequency suggests the need for careful evaluation of mild to moderate hindlimb lameness. Lameness presumed to be of hock or stifle origin could be attributable to the proximal suspensory ligament and diagnostic anaesthesia can be valuable in evaluating such cases as well as thorough ultrasound studies (Toth *et al.* 2009). The frequency of right hind involvement should raise questions as to the origin of this phenomenon, and if it could be related to training techniques, horse asymmetry, or perhaps rider habits. This is yet to be determined. The possibility of operator examination technique affecting outcome cannot be completely ruled out. Suspensory branch lesions were the second most frequent category of lesions noted but appeared to have an even distribution in the population of lame horses identified.

As might be expected from information on other athletic equine injuries (Thorpe *et al.* 2010), SDFT lesions were the most common tendon lesion diagnosed, with 59.5% identified in dressage horses and 40.5% were seen in jumpers, with no apparent discipline predilection based on the affected population. It is interesting, however, to note that SDFT lesions were not very common in this group of sport horses

accounting for only 37 of 435 total lesions (8.5%). Of the 37 SDFT lesions identified, 78.4% occurred in geldings, while mares only comprised 13.5% of cases and stallions comprised 8.1% of SDFT abnormalities. Geldings represented 71% of the examined horses and 66.7 % of the total population of competing horses, and even though 78.4% of the SDFT lesions were identified in geldings, a predilection for SDFT injury in geldings could not be statistically substantiated in this population ($P > 0.05$).

Next, in order of frequency were lesions of the inferior check ligament ($n = 34$) which were encountered with a nonsignificant difference in distribution between the forelimbs, but which were more prevalent in dressage ($n = 25$, 73.5%) than in jumping disciplines ($n = 9$, 27.5%; $P = 0.008$). It was interesting to note that no lesions of the accessory ligament of the DDFT of the hindlimb were observed in this study (Eliashar *et al.* 2005).

Suspensory body lesions, while next in order of frequency ($n = 22$) did not demonstrate a predilection for a specific limb but appeared to be more common in dressage horses ($P = 0.0008$) based on population (dressage $n = 19$, jumping $n = 3$) at 86.4% to 13.6% of lesions identified.

Lesions of the DDFT were significantly more common in the forelimbs ($n = 20$) as compared to the hindlimbs ($n = 7$, 74.1% vs. 25.9%, $P = 0.004$) in the mixed population but no discipline predilection could be identified (dressage $n = 13$ /jumping $n = 14$ or 48.1–51.9%; $P > 0.05$).

There was no significant difference in distribution of lesions of the DFTs in the forelimbs ($n = 10$) as compared to hindlimbs ($n = 7$; $P > 0.05$) while desmopathies of collateral ligaments were significantly more commonly identified in the forelimbs (12 of 14 collateral ligament lesions) as compared to the hindlimbs ($P = 0.02$). DFTs tenosynovitis often accompanied DDFT, SDFT and PAL lesions but a clear relationship to tendon or ligament injury was not always apparent.

Conclusion

Several interesting comparisons arise from this study. The type of tendon and ligament lesions that were most common and their distribution raise some interesting questions related to the diagnosis of lameness, management and conditioning of dressage and jumping horses. An important benefit of this review is that horses were training or competing on the same or very similar surfaces throughout the study.

Proximal suspensory ligament lesions were the most common finding in this group. A high incidence of proximal suspensory lesions in the hindlimb appears to occur in both dressage and jumping disciplines. Subtle hindlimb issues that develop during training should be carefully monitored for proximal suspensory problems based on trends seen in this review.

Suspensory body lesions and inferior check ligament lesions were found to be more common in dressage horses in this study. Suspensory branch lesions did not demonstrate a discipline predilection.

SDFT lesions occurred more commonly in the forelimb, and the average age was 12 years.

Results of this study may be of benefit in evaluating sport horse lameness cases with respect to prevalence of abnormal findings in tendons and ligaments of the lower limb.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Authorship

All authors contributed to this manuscript and gave approval to the final version.

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Review Article

Review of the use of transrectal ultrasonography for evaluation of the caudal lumbar – including lumbosacral – intervertebral discs and symphyses: Normal and abnormal ultrasonographic appearance

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Summary

Transrectal ultrasonography of the lumbosacroiliac area is routinely performed for the diagnosis of the cause of low back pain and poor hindlimb impulsion and engagement. The ventral aspect of the caudal lumbar intervertebral discs and vertebrae can be easily assessed transrectally with ultrasound while other imaging modalities have limitations for diagnosis of intervertebral disc injuries. This paper is a review of the ultrasonographic procedure for imaging the ventral aspect of the caudal lumbar and lumbosacral symphyses, especially the intervertebral discs. Normal images, findings and lesions of the three caudalmost lumbar intervertebral discs are described (between the 4th lumbar and the 1st sacral vertebrae).

Introduction

Lumbosacroiliac pain in horses is a common cause of poor performance and lack of power in the hindlimbs (Jeffcott *et al.* 1985; Denoix 1998; Dyson 2010; Peters 2012; Barstow and Dyson 2015; Boado *et al.* 2020). As in humans (Dansie and Turk 2013) objective assessment of low back and pelvic pain, and clear identification of its cause(s) are not easy in horses (Denoix *et al.* 2005; Denoix and Dyson 2010; Dyson 2010; Haussler 2010; Denoix 2017). The diagnosis of lumbar, lumbosacral and sacroiliac injuries requires a complete clinical examination with special consideration of physical and dynamic abnormalities (Denoix 1999; Denoix and Dyson 2010; Dyson 2010; Boado *et al.* 2020).

Local analgesia by infiltration of local anaesthetic solution close to the lumbosacroiliac area has been described (Dyson and Murray 2003; Haussler 2010; Boado *et al.* 2020; Nagy and Dyson 2020). Nevertheless, this diagnostic approach has been questioned as it may lack sensitivity and specificity, especially for lumbosacral intervertebral disc (L6D) disease due to its ventral position (Nagy *et al.* 2010), and its use is limited in practice because of the risk of complications such as sciatic or femoral nerve paresis (Haussler 2010; Nagy and Dyson 2020; J.-M. Denoix, personal communication). Therefore, localisation of the source of pain remains challenging (Denoix 1998; Bergman *et al.* 2013).

Transrectal ultrasonographic examination of the sacroiliac joints and the intervertebral discs between the fourth lumbar vertebra (L4) and the first sacral vertebra (S1) was developed in the late 90s (Denoix 1998, 1999) and is now routinely used in the diagnosis and documentation of lumbosacroiliac

injuries (Denoix and Coudry 2005; Denoix *et al.* 2005; Denoix *et al.* 2006; Denoix and Jacquet 2008; Bergman *et al.* 2013). The technique described for the evaluation of the sacroiliac joints (Denoix 1998; Bergman *et al.* 2013; Tallaj *et al.* 2019) is also used for evaluation of the caudal lumbar intervertebral and lumbosacral symphyses (Denoix 1999; Nagy *et al.* 2010; Bergman *et al.* 2013; Boado *et al.* 2020). Lesions have also been documented in clinical cases and confirmed post-mortem in experimental studies (Denoix 1999; Haussler *et al.* 1999; Krueger *et al.* 2016; Boado *et al.* 2020).

The general objective of this paper is to provide a literature review of the transrectal ultrasound technique to evaluate the caudalmost lumbar intervertebral symphyses of the horse.

After a short reminder of basic anatomy, the aims are to present a review of (i) the technique and procedure to examine these discs, (ii) their normal ultrasonographic appearance and (iii) the ultrasonographic findings reported.

Review of basic anatomy

The lumbosacral junction between the sixth lumbar vertebra (L6V) and the first sacral vertebra (S1V) is composed of six different joints (Barone 2000; Denoix 2019). In the median plane, a symphysis is made of the caudalmost intervertebral disc of the back (L6D), between the L6V fossa and the S1V head (**Fig 1**). The cranioventral margin of S1V is usually prominent forming the promontorium. Two small synovial joints between the caudal articular processes of L6V and the cranial articular processes of S1V are located dorsal to the vertebral canal on the left and right sides. Dorsally, the L6 and S1 spinous processes are connected by the supraspinous ligament and two interspinous ligaments. Finally, the transverse processes of L6V and S1V articulate on each side through a synovial lumbosacral intertransverse joint that is covered by a dorsal and a ventral intertransverse ligaments (Barone 2000; Denoix 2019).

The L6D is usually the thickest disc of the vertebral column between the first thoracic vertebra and the sacrum (**Fig 2**) and is very deformable (Townsend *et al.* 1983; Townsend and Leach 1984; Denoix *et al.* 2005; Stubbs *et al.* 2006). Made of peripheral circumferential dense fibres with a softer central part (Jeffcott and Dalin 1980; Townsend and Leach 1984; Barone 2000; Bergmann *et al.* 2018), it adheres to the hyaline cartilage covering the L6V fossa and the S1V head. As the L6V fossa is not concave but flat or slightly convex, the L6D has a

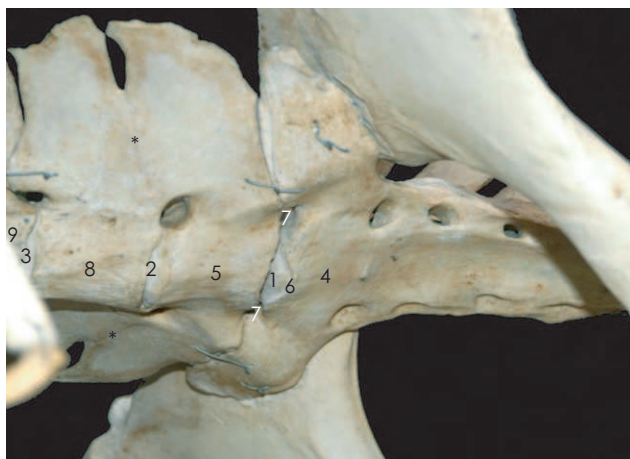


Fig 1: Cranioventrolateral aspect of the lumbosacroiliac area of a bone specimen (cranial is to the left). Note the normal intertransverse synostosis between the 5th and the 6th lumbar vertebrae (asterisks). 1: lumbosacral intervertebral disc space; 2: L5-6 intervertebral disc space; 3: L4-5 intervertebral disc space; 4: ventral aspect of the 1st sacral vertebra; 5: ventral aspect of the 6th lumbar vertebra; 6: lumbosacral promontorium; 7: lumbosacral intervertebral foramens; 8: ventral aspect of the 5th lumbar vertebra; 9: ventral aspect of the 4th lumbar vertebra.

specific biconcave shape (Barone 1999; Denoix 1999). It is crossed ventrally by a thin ventral longitudinal ligament and dorsally by a thin dorsal longitudinal ligament (Barone 2000).

The fifth lumbar intervertebral disc between L5V and L6V (L5D) is usually much thinner than the L6D (Denoix 2019), and usually, the transverse processes of the L5V and L6V are fused. The fourth intervertebral disc between L4V and L5V (L4D) is generally slightly thicker than the L5D (Denoix 1999; Barone 2000).

Review of equipment and technique

As for any rectal examination, safety measures have to be taken before any transrectal ultrasonographic examination on

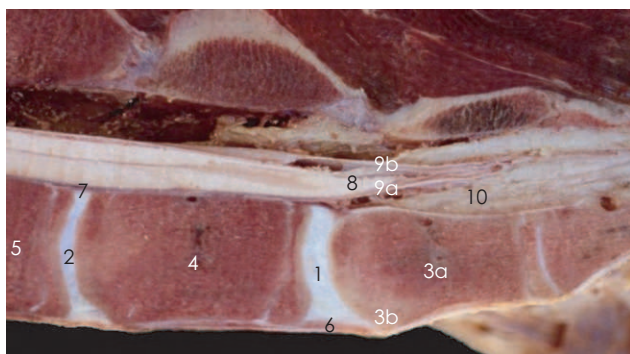


Fig 2: Median anatomical section of the lumbosacral junction (cranial is to the left, dorsal is to the top). 1: lumbosacral intervertebral disc; 2: L5-6 intervertebral disc; 3a: body of the 1st sacral vertebra; 3b: promontorium; 4: body of the 6th lumbar vertebra; 5: body of the 5th lumbar vertebra; 6: ventral longitudinal ligament; 7: dorsal longitudinal ligament; 8: spinal cord (medullary cone); 9a: dura mater: ventral wall; 9b: dura mater: dorsal wall; 10: epidural fat.

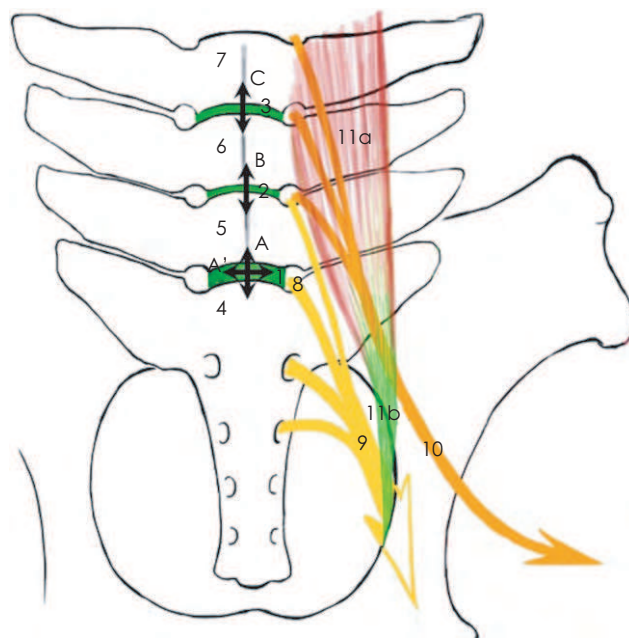


Fig 3: Schematic drawing of the ventral aspect of the lumbosacroiliac area (cranial is to the top). Depending on the transducer position, different parts of the ventral aspect of the area can be imaged (A, A', B, C). 1: lumbosacral intervertebral disc; 2: L5-6 intervertebral disc; 3: L4-5 intervertebral disc; 4: 1st sacral vertebra; 5: 6th lumbar vertebra; 6: 5th lumbar vertebra; 7: 4th lumbar vertebra; 8: ventral ramus of the left L6 segmental nerve; 9: left lumbosacral truncus; 10: left femoral nerve; 11a: left minor psoas muscle body; 11b: left minor psoas tendon.

the standing horse (Bergman *et al.* 2013; Tallaj *et al.* 2019). Ideally, the horse should be placed in stocks. The first concern is to avoid any traumatic injury of the rectal wall. Sedation and anti-spasmodic agents can be used if the horse is nervous to make the procedure safer and to reduce rectal contractions. Faeces are removed from the rectum with all the necessary precautions to preserve its mucosa with adequate lubrication. As reported by Tallaj *et al.* (2019), the practitioner should take care to handle the transducer properly without putting too much pressure on the rectum wall and to adapt his movements to the horse's reactions. One finger should be placed at the cranial aspect of the transducer to avoid any direct contact between the transducer and the rectum wall (J.-M. Denoix, personal communication).

Ultrasonography of the equine caudal lumbar intervertebral discs is performed with a 5–7.5 MHz curvilinear rectal transducer or with a 5–10 MHz small linear rectal probe (e.g. 5 cm long) which is more often available in field practice (Denoix 1998, 1999; Tallaj *et al.* 2019). A stand-off pad is not required but can be occasionally used to improve visualisation of the superficial (ventral) aspect of the S1V to L4V bodies and the corresponding intervertebral discs (Denoix 1999). To match the anatomical orientation and to facilitate interpretation, the ultrasound images can be rotated 180° so that the ventral aspect of the vertebrae is to the bottom of the image displayed on the screen (Nagy *et al.* 2010; Bergman *et al.* 2013), as it was done for the figures of this paper.

Tallaj *et al.* (2019) described the promontorium (prominent ventral margin of the head of S1V at the lumbosacral

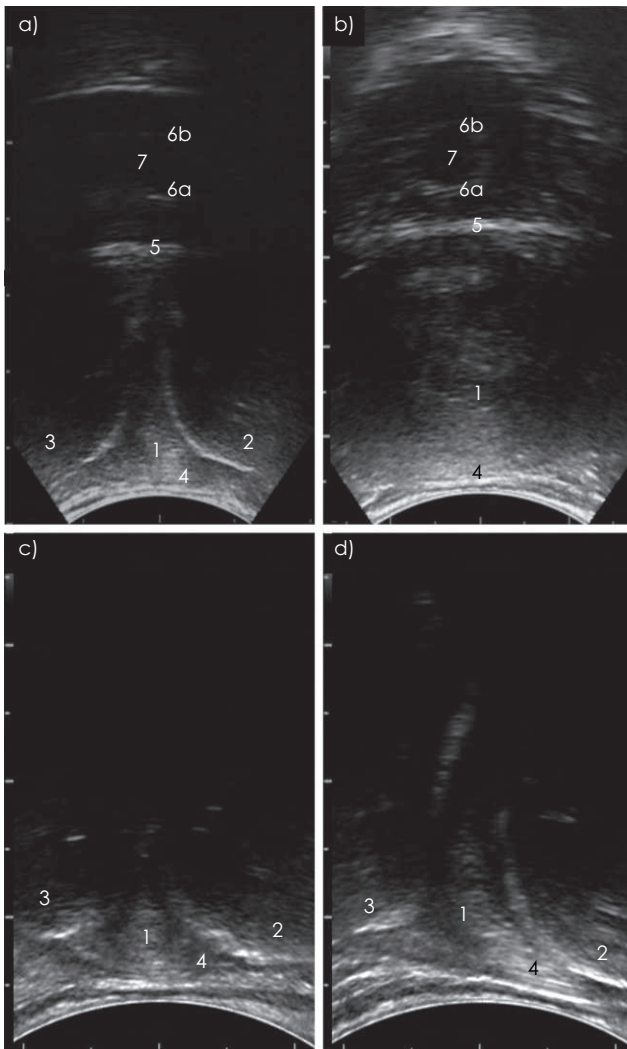


Fig 4: Ultrasound scans of the ventral aspect of a normal lumbosacral intervertebral disc. (a,c,d: Cranial is to the left, and dorsal is to the top; b: Left side is to the left and dorsal is to the top). Images acquired with a small curvilinear transducer. a) Median ultrasound scan performed on a horse in neutral lumbosacral position. b) Transverse ultrasound scan. c) Median ultrasound scan performed on a horse examined in lumbosacral flexion. d) Median ultrasound scan performed on the same horse examined in lumbosacral extension. 1: lumbosacral intervertebral disc; 2: ventral bone surface of the first sacral vertebra; 3: ventral bone surface of the 6th lumbar vertebra; 4: ventral longitudinal ligament; 5: dorsal longitudinal ligament; 6a: dura mater: ventral wall; 6b: dura mater: dorsal wall; 7: spinal cord (medullary cone).

angulation) as a landmark during transrectal ultrasonography. The probe facing up is placed horizontally in the median plane at the level of the promontorium to visualise the L6D between the L6V and the S1V (position A, **Fig 3**). By slightly moving the probe alternatively to the left and to the right sides of the vertebral column, maintaining a paramedian orientation of the probe, the whole ventral part of the disc is scanned (Bergman *et al.* 2013). When moving the transducer more laterally, the lumbosacral intervertebral foramen is imaged with the echogenic ventral ramus of the L6 segmental nerve that contributes to the lumbosacral truncus

(Espinosa *et al.* 2017). A real-time dynamic examination of the lumbosacral junction can be achieved by inducing alternative movements of lumbosacral flexion and extension, with cutaneous reflex stimulation near the tuber sacrale (extension) and then near the tuber ischiaticum (flexion) (Denoix 1999; Werp 2007). In sedated horses, this mobilisation can be difficult because of the low response to cutaneous stimulation (Denoix 1999). Bergman *et al.* (2013) described the possibility of performing transverse sections of the L6D with a small curvilinear transducer by rotating the probe perpendicular to the median plane (position A', **Fig 3**). Due to the risk of rectal laceration, this technique should not be done with long linear rectal probes (Denoix 1999).

Imaging of the ventral aspect of the L6V and then the L5D (position B, **Fig 3**) is performed by moving the probe cranially in the median plane. When moving the probe more cranially, the terminal part of the aorta is imaged ventrally to the L5V body or the L5D. More cranially, the ventral part of the L4D can be imaged in relaxed horses (position C, **Fig 3**).

Normal ultrasonographic images

Denoix was the first to describe the normal appearance of the caudal lumbar intervertebral discs in 1999. With the development of the technique, more consideration has been given to the L6D in the literature in the past two decades (Denoix and Coudry 2005; Denoix *et al.* 2005, 2006; Werp 2007; Denoix and Jacquet 2008; Denoix 2017) in particular with studies describing the ultrasonographic appearance of the L6D in horses without clinical signs of back pain or hindlimb lameness (Nagy *et al.* 2010) or in horses with lumbosacroiliac region pain (Bergman *et al.* 2013; Boado *et al.* 2020).

On normal ultrasound scans performed in the median plane (position A, **Fig 3**), the ventral bone surfaces of L6V and S1V are imaged as regular and smooth shadowing hyperechogenic curved lines. In an average standing horse, the lumbosacral joint dorsal angle ranges from approximately 140°–150° (Bergman *et al.* 2013); more precisely in 2010, Nagy *et al.* reported that the mean angle of the lumbosacral joint was 147° (range: 118–165°, median: 150°) in a study on 43 horses. It should be noted that this angulation changes according to the horse positioning and lumbosacral flexion–extension movements. Between the L6V fossa and the S1V head, the L6D is imaged as a uniformly echogenic or mildly heterogeneous echogenic structure with different portions (**Fig 4a**) (Denoix 1999; Nagy *et al.* 2010). The ventral part is triangular with a convex ventral border limited by the ventral longitudinal ligament; in the median plane, some parallel horizontal curved fibres can be identified. The central portion of the disc is a 2- to 6-mm-thick homogenous poorly echogenic structure with less apparent architectural organisation. Dorsally, the disc is separated from the vertebral canal by the dorsal longitudinal ligament. In cases of thick L6D, the vertebral canal and its content can be seen through the acoustic window made by the disc: the epidural and subdural (subarachnoid) spaces are anechogenic and separated by the ventral and dorsal walls of the dura mater, which can be imaged on a median section as thick echogenic lines. Inside the epidural space, echogenic linear structures represent the cauda equina.

As firstly reported by Denoix in 1999, dynamic examination of the lumbosacral disc is useful to assess the structures and

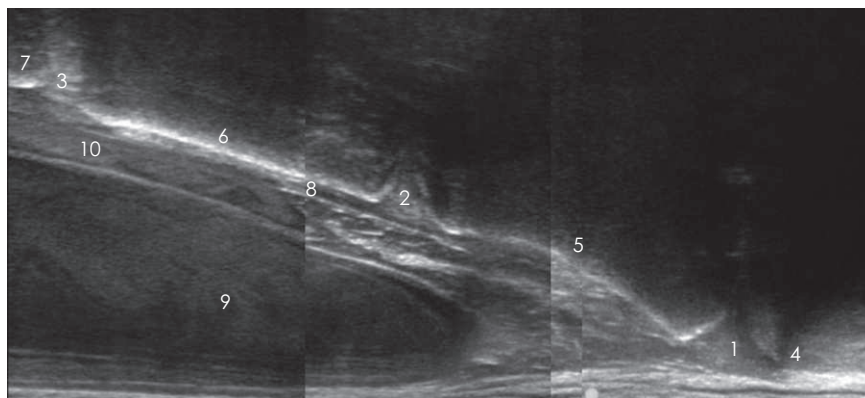


Fig 5: Median ultrasound scans showing the normal appearance of the ventral aspect of the caudalmost lumbar vertebrae and lumbosacral junction (cranial is to the left, and dorsal is to the top). Images acquired with a short rectal linear transducer. 1: lumbosacral intervertebral disc; 2: L5-6 intervertebral disc; 3: L4-5 intervertebral disc; 4: ventral bone surface of the 1st sacral vertebra; 5: ventral bone surface of the 6th lumbar vertebra; 6: ventral bone surface of the 5th lumbar vertebra; 7: ventral bone surface of the 4th lumbar vertebra; 8: ventral longitudinal ligament; 9: aorta; 10: caudal vena cava.

mobility of the lumbosacral symphysis. During lumbosacral flexion, the L6D bulges ventrally and its ventral thickness decreases as the lumbosacral joint angulation decreases (**Fig 4c**). During lumbosacral extension, the ventral aspect of the intervertebral disc straightens due to increased tension and the disc ventral thickness increases, as the lumbosacral joint angulation increases (**Fig 4d**) (Denoix 1999; Werpy 2007). The total amount of the *in vivo* lumbosacral joint mobility in flexion and extension can reach 10°–15° depending on the cooperation and flexibility of the horse (Denoix 1999).

On transverse sections described by Bergman *et al.* (2013) (position A', **Fig 3**), the whole disc is imaged as a circular echogenic structure, limited ventrally by the ventral longitudinal ligament and dorsally by the dorsal longitudinal

ligament. The latter separates the disc from the vertebral canal imaged as an anechogenic circular area centred on the echogenic dural cone (**Fig 4b**).

Progressing cranially in the median plane (positions B and C, **Fig 3**), the ventral part of L5D and L4D can be identified as triangular echogenic structures between the hyperechogenic ventral bone surfaces of L6V, L5V and L4V (**Fig 5**). In normal horses, the L4D and L5D spaces are thinner than the L6D space. Only the ventral triangular portion is consistently imaged as an echogenic material covered by the ventral longitudinal ligament, which is always distinct in the median plane at the level of the L4V but gets thinner caudally (Denoix 1999; Denoix *et al.* 2005).

On normal ultrasound scans performed in a paramedian plane, the ventrolateral aspect of the vertebral bodies appears more concave. As the probe is moved laterally at the level of the L6D, the intervertebral foramen is identified as a smoothly demarcated concavity in the bone surface containing the echogenic ventral ramus of the L6 segmental nerve (**Fig 6**) (Espinosa *et al.* 2017).

Ultrasonographic findings and lesions

As the L6D can be easily and completely examined in the horse, it may serve as a model for diagnostic interpretation for ultrasound examination of the other intervertebral discs of the caudal lumbar area. To simplify the presentation, description of ultrasonographic findings and lesions is focused on the L6D examination and further information about the L5D is given when necessary. As no finding has yet been reported on the L4D at transrectal ultrasonographic examination (Denoix 1999; Werpy 2007), no specific data are given for this disc.

Intervertebral alignment, size and position of the disc

With reference to the type 1 (normal) appearance described in the previous paragraph (Denoix 1999; Denoix *et al.* 2005, 2006; Denoix and Jacquet 2008; Nagy *et al.* 2010; Bergman *et al.* 2013; Denoix 2017), four types of abnormal L6D shape have been described (Denoix 1999) and observed, depending on the severity and extent of the disc thinning

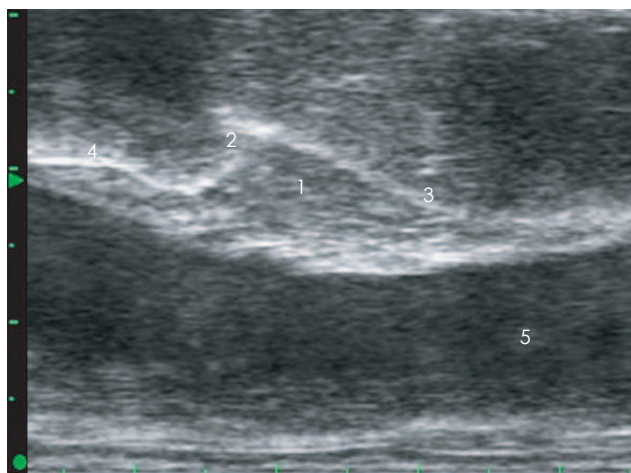


Fig 6: Paramedian ultrasound scan in the left side of the normal lumbosacral symphysis imaging the lumbosacral intervertebral foramen (cranial is to the left, and dorsal is to the top). Image acquired with a small curvilinear transducer. 1: ventral ramus of the left L6 segmental nerve; 2: left lumbosacral intervertebral foramen; 3: ventral bone surface of the 1st sacral vertebra; 4: ventral bone surface of the 6th lumbar vertebra; 5: left caudal gluteal artery.

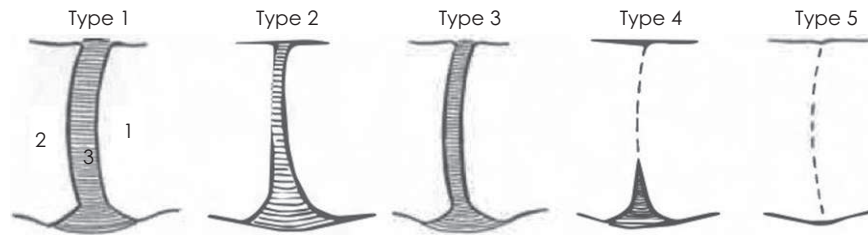


Fig 7: Schematic drawing showing 5 types of intervertebral disc shape that can be encountered at the lumbosacral junction. Type 1: normal appearance; Type 2: dorsal thinning; Type 3: dorsal and ventral (overall) thinning; Type 4: dorsal (partial) lumbosacral synostosis; Type 5: complete lumbosacral synostosis (Modified, from Denoix 1999). 1: 1st sacral vertebra; 2: 6th lumbar vertebra; 3: lumbosacral intervertebral disc.

(**Fig 7**). On median section, the L6D can be observed with only its dorsal portion thinner than 2 to 6 mm (type 2), or with global thinning of both the dorsal and ventral portions of the disc (type 3). In other cases, only the ventral part of the disc is imaged because of dorsal and incomplete lumbosacral intervertebral synostosis (type 4) (**Fig 8a**), or no disc material is seen when the intervertebral synostosis is complete (type 5)

(Denoix 1999; Denoix *et al.* 2006; Werpy 2007; Bergman *et al.* 2013).

In case of lumbosacral synostosis, the L5D has been frequently found thicker than normal (**Fig 8b**) (Denoix 1999; Werpy 2007; Boado *et al.* 2020). Complete L5-L6 synostosis with no disc material has also been described (**Fig 9**) (Denoix 1999; Denoix *et al.* 2005, 2006). In a recent study on horses

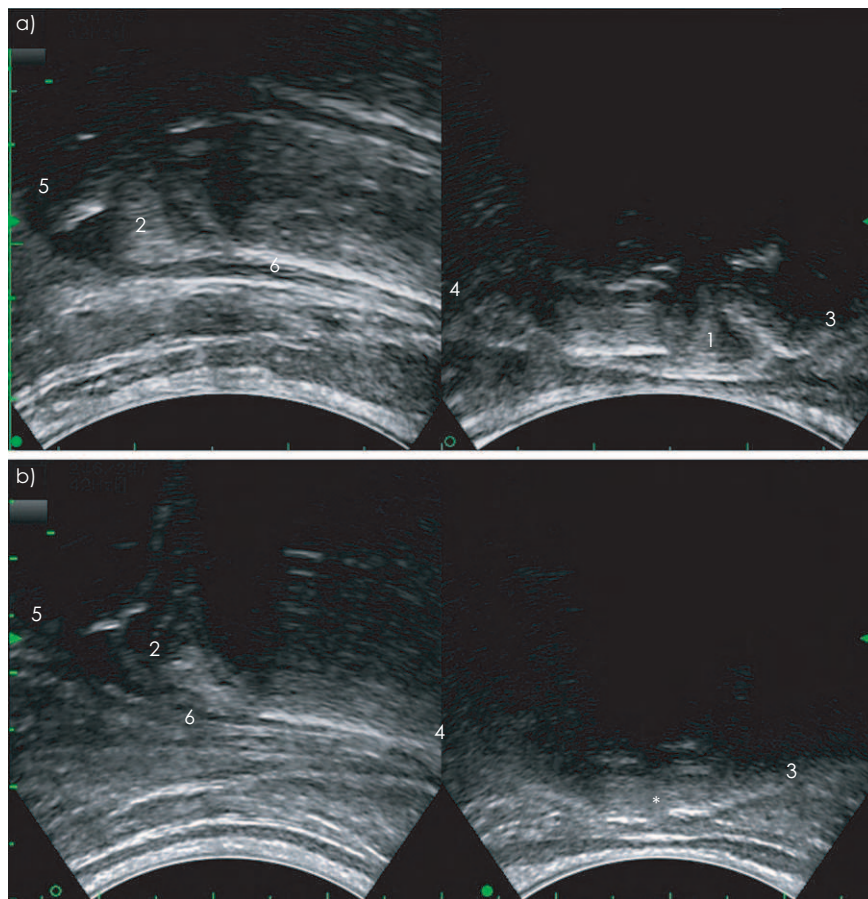


Fig 8: Median ultrasound scans of the ventral aspect of the lumbosacral junction from the 5th lumbar to 1st sacral vertebrae (cranial is to the left, and dorsal is to the top). Images acquired with a small curvilinear transducer. a) Partial lumbosacral synostosis (type 4) with a thin lumbosacral disc and a thick L5-6 intervertebral disc. b) complete lumbosacral intervertebral synostosis (type 5, sacralisation of L6) and thick L5-6 intervertebral disc. 1: lumbosacral intervertebral disc; 2: L5-6 intervertebral disc; 3: ventral bone surface of the 1st sacral vertebra; 4: ventral bone surface of the 6th lumbar vertebra; 5: ventral bone surface of the 5th lumbar vertebra; 6: ventral longitudinal ligament; *: lumbosacral synostosis.

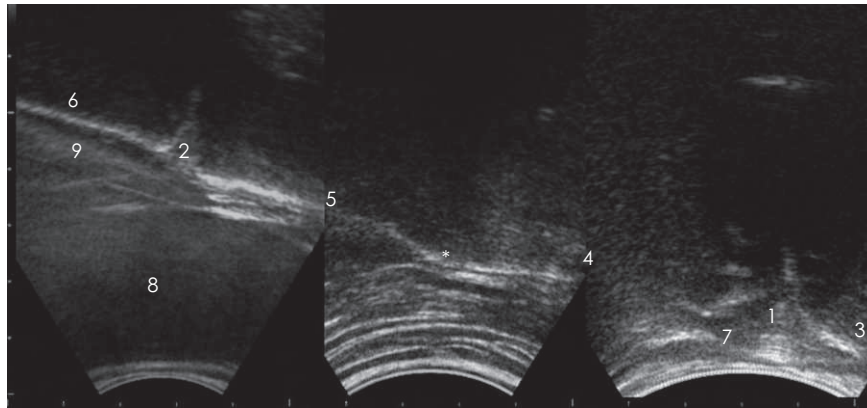


Fig 9: Median ultrasound scans of the ventral aspect of the caudalmost lumbar vertebrae and lumbosacral symphysis on a horse showing L5-L6 synostosis (cranial is to the left and dorsal is to the top). Images acquired with a small curvilinear transducer. 1: lumbosacral intervertebral disc; 2: L4-5 intervertebral disc; 3: ventral bone surface of the 1st sacral vertebra; 4: ventral bone surface of the 6th lumbar vertebra; 5: ventral bone surface of the 5th lumbar vertebra; 6: ventral bone surface of the 4th lumbar vertebra; 7: ventral longitudinal ligament; 8: aorta; 9: caudal vena cava; *: L5-L6 synostosis.

with clinical signs indicative of lumbosacroiliac pain (Boado *et al.* 2020), 25% of horses had congenital variants of the L6D and 6.3% had fusion of the L5-L6 symphysis.

Abnormal intervertebral alignment of the lumbosacral junction has been described (Denoix *et al.* 2005). Spondylolisthesis refers to displacement of one vertebra relative to another (Resnick and Niwayama 1988) (listhesis meaning 'sliding'). Lumbosacral spondylolisthesis or (sub) luxation is identified when ventral displacement of the S1V or L6V is observed (**Fig 10**) (Boado *et al.* 2020). In those cases, the vertebral malalignment is associated with thinning of the intervertebral disc, especially dorsally.

In advanced cases of degeneration with dorsal narrowing of the disc, an associated ventral protrusion of the disc has been described (Nagy *et al.* 2010; Boado *et al.* 2020). The ventral part of the disc is bulging ventrally with a convex shape of its ventral border and of the ventral longitudinal ligament (**Fig 11**). Nagy *et al.* (2010) described a method of evaluation of the degree of ventral protrusion of the disc by measuring the distance between the most ventral aspect of the L6D and the line drawn between the most ventral aspects of the opposing surfaces of the L6 and S1 vertebrae. While a mild ventral protrusion of the L6D (≤ 2 mm) was found in 74.4% of horses without clinical signs of low back pain or

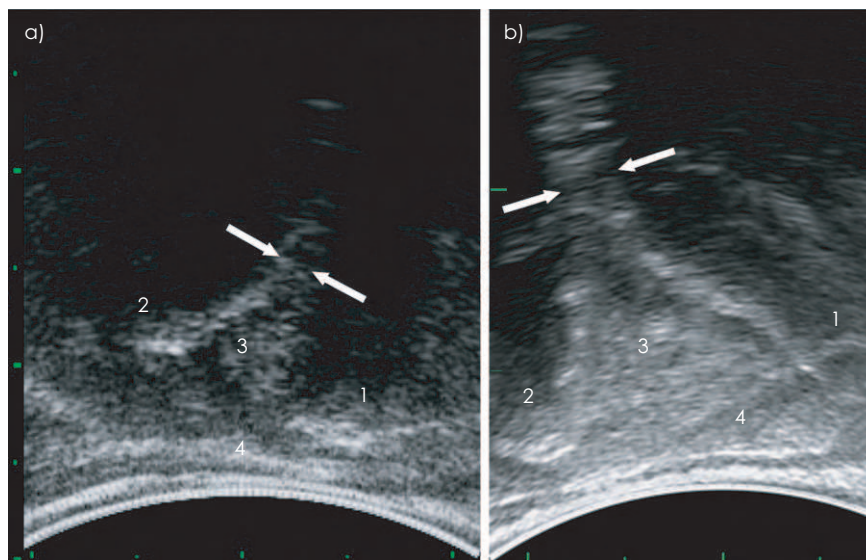


Fig 10: Median ultrasound scans of the ventral aspect of the lumbosacral symphysis showing abnormal vertebral alignment (cranial is to the left, and dorsal is to the top). Images were acquired with a small curvilinear transducer. a) Lumbosacral subluxation with dorsal displacement of the 6th lumbar vertebra and ventral displacement of the 1st sacral vertebral head in a 13-year-old showjumping mare. b) Lumbosacral subluxation with ventral displacement of the 6th lumbar vertebral fossa in a 10-year-old showjumper gelding. Note the dorsal narrowing of the lumbosacral intervertebral disc (arrows) in both cases and absence of ultrasound penetration through the intervertebral disc space to the vertebral canal. 1: ventral bone surface of the 1st sacral vertebra; 2: ventral bone surface of the 6th lumbar vertebral; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament.

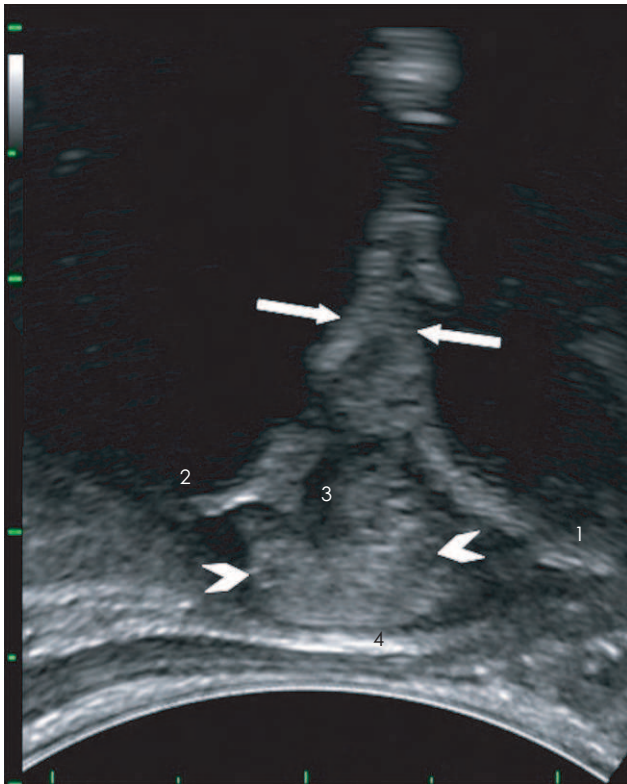


Fig 11: Median ultrasound scan of the ventral aspect of the lumbosacral symphysis of a 10-year-old showjumping gelding showing a dorsal narrowing (arrows) of the lumbosacral intervertebral disc with ventral prolapsus of the disc and increased echogenicity corresponding to diffuse fibrosis of its ventral part (arrowheads). Image was acquired with a small curvilinear transducer (cranial is to the left and dorsal is to the top). 1: ventral bone surface of the 1st sacral vertebra; 2: ventral bone surface of the 6th lumbar vertebra; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament.

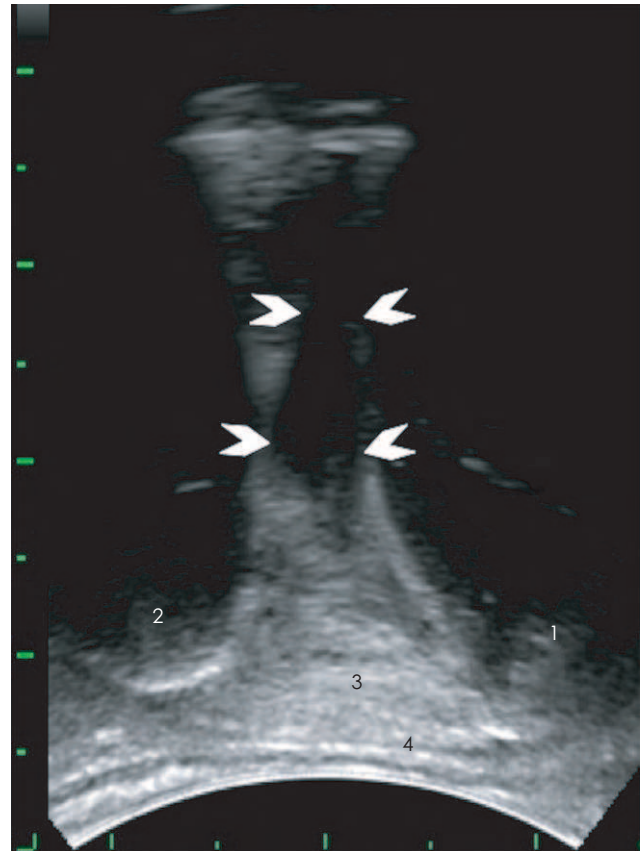


Fig 12: Median ultrasound scan of the ventral aspect of the lumbosacral symphysis (cranial is to the left, and dorsal is to the top) of a 6-year-old showjumping mare showing a large hypoechoic area in the depth of the intervertebral lumbosacral disc corresponding to a wide dorsal cavitation of the disc (arrowheads). Image was acquired with a small curvilinear transducer. 1: ventral bone surface of the 1st sacral vertebra; 2: ventral bone surface of the 6th lumbar vertebra; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament.

hindlimb lameness, significant ventral protrusion was defined when this distance was >5 mm (Nagy *et al.* 2010; Boado *et al.* 2020). Using this measure, Boado *et al.* (2020) found 56% of ventral protrusion of the L6D in a group of horses with clinical signs indicative of lumbosacroiliac pain confirmed by diagnostic anaesthesia of the sacroiliac region. However, it should be kept in mind that the size of the most ventral part of the disc depends on the position of the horse (lumbosacral flexion vs. extension or neutral position) (Denoix 1999; Werpy, 2007).

Echogenicity of the discs

On median and transverse sections, several variations of the echogenicity of the disc have been described (Denoix 1999; Denoix *et al.* 2005, 2006; Werpy 2007; Denoix and Jacquet 2008; Bergman *et al.* 2013). In 43 horses with no clinical signs of back pain or hindlimb lameness, Nagy *et al.* (2010) reported uniform or mildly heterogeneous echogenicity of the L6D in the majority of cases (79.1%), but also identified mild to moderate variations in echogenicity (hyperechogenic areas with or without acoustic shadowing). One of the main ultrasonographic findings in a population of horses with clinical signs indicative of lumbosacroiliac pain was

heterogeneous echogenicity of the lumbosacral disc (82.1–100%) with either anechoic areas within the disc or with hyperechogenic foci (Boado *et al.* 2020).

A diffuse loss of echogenicity is usually suggestive of a degenerative process with loss of fibre architecture or disc fissures. Mild and limited fibre disruption is imaged as focal hypoechoic spots, and more extensive hypoechoic areas are suggestive of disc cavitation with liquid infiltration (**Fig 12**) (Denoix 1999; Werpy 2007; Nagy *et al.* 2010; Bergman *et al.* 2013).

Hyperechogenic areas in the disc can be associated with healing tissue and fibrosis (**Fig 11**) and, in advanced and chronic L6D disease, some hyperechogenic spots casting acoustic shadows may represent dystrophic mineralisation (**Fig 13**) (Denoix 1999; Werpy 2007; Nagy *et al.* 2010; Bergman *et al.* 2013).

Variations of the echogenicity of the L5D has been most often described when the disc is wider than normal (>10 mm) (Boado *et al.* 2020). In most cases, abnormal L5D is associated with lumbosacral synostosis, which could presumably induce overstress of L5-L6 junction during locomotion and secondary predisposition to L5D injuries (Denoix 1999; Werpy 2007; Boado *et al.* 2020).

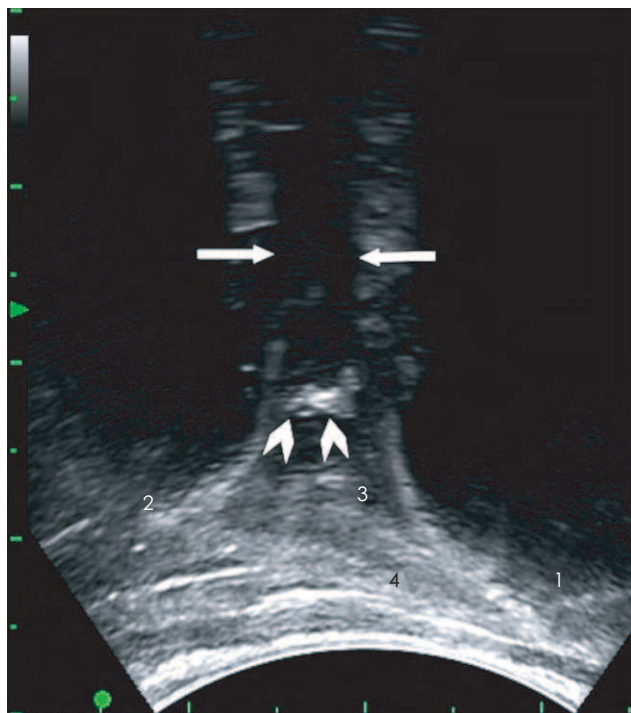


Fig 13: Median ultrasound scan of the ventral aspect of the lumbosacral symphysis of a 12-year-old showjumping pony showing focal hyperechogenic area (arrowheads) casting acoustic shadows (arrows) corresponding to a dystrophic mineralisation of the lumbosacral intervertebral disc. Image was acquired with a small curvilinear transducer (cranial is to the left and dorsal is to the top). 1: ventral bone surface of the 1st sacral vertebra; 2: ventral bone surface of the 6th lumbar vertebra; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament.

Bone margins

L6D enthesopathy with or without avulsion fragmentation has been described as bone remodelling of the L6V fossa (**Fig 14a,b**) or of the S1V head (**Fig 15**) (Denoix 1999; Nagy *et al.* 2010; Bergman *et al.* 2013). In these cases, enthesophytes are imaged as bony proliferation, most often near the ventral margins of the symphysis (Denoix 1999; Boado *et al.* 2020). Subchondral bone irregularity with osteolysis is also reported when an ultrasound beam penetrates deep to the bone surface.

In rare cases, marked bone remodelling with hyperechogenic material casting an acoustic shadow is indicative of an avulsion fracture of the L6V fossa or S1V head (Denoix 1999).

Comparative imaging

Diagnostic imaging tools that can be used to identify lesions of the caudal lumbar intervertebral discs in horses are limited (Denoix 1999; Nagy *et al.* 2010). Although a laterolateral radiographic projection of the lumbosacral area can be performed on the standing horse with a powerful radiographic machine, the presence of the *tuber coxae* impedes severely the diagnostic value of this imaging approach. Informative radiographic examination of this region requires a ventrodorsal projection, the horse being placed on dorsal recumbency under general anaesthesia (Denoix *et al.* 2005; Bergman *et al.* 2013). However, this view has limited clinical ability to identify soft tissues and especially intervertebral disc degenerative lesions because of superimposition of abdominal viscera. Thus, this procedure is not routinely used (Denoix *et al.* 2005).

Nuclear scintigraphy has been frequently reported as a useful imaging diagnostic procedure to localise injuries in the thoracolumbar and pelvic region (Townsend *et al.* 1986;

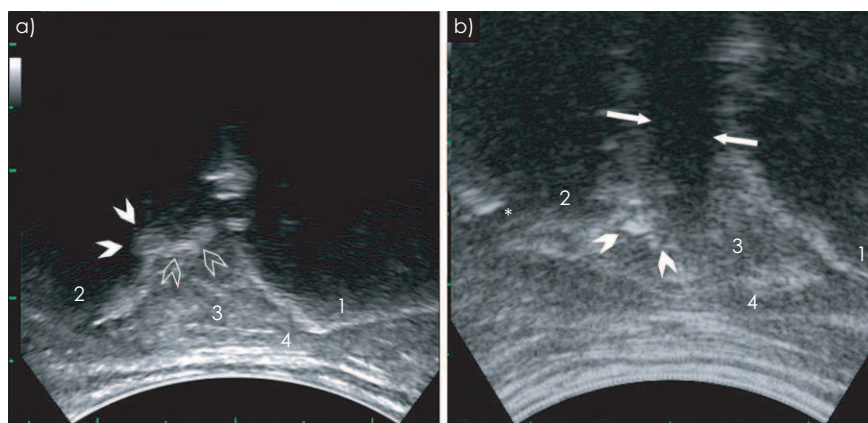


Fig 14: Median ultrasound scans of the ventral aspect of the lumbosacral symphysis (cranial is to the left, and dorsal is to the top). Images were acquired with a small curvilinear transducer. a) Severe enthesopathy of the lumbosacral intervertebral disc of the 6th lumbar (L6) vertebral fossa in a 13-year-old dressage mare. Note the irregularity of the bone surface of L6 vertebral fossa with penetration of ultrasounds in the subchondral bone (arrowheads) separating an avulsion fragment from the fossa (open arrowheads). b) Enthesopathy of the lumbosacral intervertebral disc of L6 vertebral fossa with a small avulsion fracture fragment (arrowheads) casting acoustic shadow (arrows) in a 3-year-old Thoroughbred male. Note the caudal vertebral growth plate of the 6th lumbar vertebra just cranial to its fossa. 1: ventral bone surface of the 1st sacral vertebra; 2: ventral bone surface of the 6th lumbar vertebra; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament; *: Growth plate of the 6th lumbar vertebral fossa.

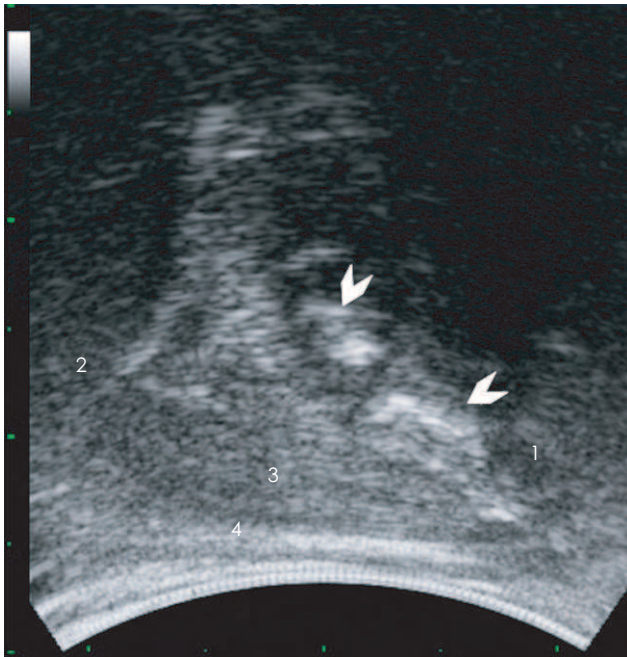


Fig 15: Median ultrasound scan of the ventral aspect of the lumbosacral symphysis on a 9-year-old French Standardbred trotter mare showing caudal enthesopathy of the lumbosacral intervertebral disc on the head of the 1st sacral vertebral, with marked remodelling of bone surface (arrowheads). Image was acquired with a small curvilinear transducer (cranial is to the left and dorsal is to the top). 1: ventral bone surface of the 1st sacral vertebral; 2: ventral bone surface of the 6th lumbar vertebra; 3: lumbosacral intervertebral disc; 4: ventral longitudinal ligament.

Tucker *et al.* 1998; Erichsen *et al.* 2002; Dyson *et al.* 2003a,b,c; Coudry *et al.* 2006; Bergman *et al.* 2013). It can be valuable in some cases to localise bone pathology in the lumbosacroiliac region, but superimposition of the ilium limits the evaluation of the region of interest. Moreover, due to their deep position at the ventral aspect of the vertebral column, radiation captation from the last lumbar vertebral symphyses is very limited and nuclear scintigraphy does not provide information on the intervertebral discs or other soft tissue structures (Nagy *et al.* 2010).

Computed tomography can be useful to examine the lumbosacroiliac area of horses (Krueger *et al.* 2016) but its use is limited by the size of the machine. Currently, it is only available for small and/or young horses.

Considering the limitations of other imaging modalities, ultrasonography is the technique of choice to evaluate vertebral soft tissues in routine practice, and, as the caudalmost lumbar intervertebral discs are at the ventral aspect of the vertebral column, a transrectal approach is appropriate.

However, it has some limitations. With this technique, good visualisation of the ventral part of the discs can be obtained but the dorsal part is more difficult to image. It is more difficult for the L4D and L5D that are thinner than the L6D, because of the curved shape of the lumbar vertebral extremities. In contrast to the lumbosacral junction where L6V fossa and S1V head are flat or slightly convex allowing a good penetration of the ultrasound beam into the whole

thickness of the L6D, the fossae of L4V and L5V are concave and the corresponding heads of L5V and L6V are convex (Barone 1999). The curvature of these vertebral extremities obscures the L4D and L5D spaces (Werpy 2007). For the same reasons, it is also difficult to assess completely the bone surface of the vertebral fossa and the head of the concerned vertebrae.

The technique and interest in transrectal ultrasonography in the evaluation of horses showing lack of hindlimb impulsion, lumbosacral stiffness or poor performance is now well documented in the literature. Nevertheless, diagnosis of lumbosacroiliac injury remains challenging and findings seen at transrectal ultrasonography should be interpreted in conjunction with clinical features at work, complete clinical examination and results of diagnostic procedures and other imaging modalities.

Authors' declaration of interest

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All authors contributed to the preparation of this manuscript.

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Review Article

Diagnosis and treatment of mastitis in mares

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Keywords: horse; mastitis; mammary gland disproportion; udder enlargement

Summary

Infection and inflammation of the udder (mastitis) is a common condition affecting all domestic mammals, but it appears to be less prevalent in mares than in dairy cows and dairy goats. The seemingly reduced incidence of mastitis in mares can be partially explained by the smaller size and relatively concealed location of the mare's udder, coupled with a smaller storage capacity than cows and goats. Mastitis can affect lactating, peripartum, dry mares, mares at dry-off or prepubertal foals. Common clinical signs include swollen mammary tissue, abnormal mammary gland secretion, fever and anorexia; less common signs are hindlimb lameness and a swollen mammary vein. On rare occasions, mastitis pathogens can severely affect the nursing foal and mares may develop fibrotic tissue and consequent agalactia in the side(s) or quarter(s) affected. Based on the clinical presentation, mastitis can be classified as acute or chronic, and clinical or subclinical. Diagnosis is based on the clinical signs aided with aerobic culture and cytological evaluation of the gland secretion. In addition, these ancillary tests can also be used to assess prognosis and duration of treatment. Mares suffering from mastitis may present neutrophilia and hyperfibrinogenaemia. Treatment for mastitis includes antimicrobial therapy (systemic and/or locally), nonsteroidal anti-inflammatory drugs, frequent milking and cold hosing with/without hot-packing applied on the gland. While the frequent monitoring of mares after weaning and reducing food intake should be part of common practices at weaning, cleaning of the udder, control of insect populations and frequent milking of mares with a foal unable to nurse can also aid in preventing mastitis.

Introduction

Mastitis, or infection and inflammation of the udder, is a common condition affecting all domestic mammals, but it appears to be less prevalent in mares than in dairy cows and dairy goats (Jackson 1986; McCue and Wilson 1989). The seemingly reduced incidence of mastitis in mares can be partially explained by the smaller size and relatively concealed location of the mare's udder, coupled with a smaller storage capacity than cows and goats (Jackson 1986). These factors render the equine udder and teats less subjected to trauma and infection than species where the udder is larger and closer to the ground (Jackson 1986). While one report from Germany estimated that as much as 5% of breeding mares are affected by mastitis (Böhm *et al.* 2009) the incidence does not appear to be that high in North America (McCue and Wilson 1989; Perkins and Threlfall 2002;

Brendemuehl 2008). However, the true incidence across breeds and countries remains to be determined.

While mastitis is less prevalent in mares, severe consequences associated with mastitis can occur in horses as well as ruminants. Transmission of the infectious agent to the nursing foal may cause septicaemia, polyarthritis and pneumonia in the foal (Perkins and Threlfall 2002; Knottenbelt 2003). Additionally, agalactia can lead to subsequent foal malnutrition (Kocabiyik *et al.* 2008). Mastitis can also induce abortion if the mare is pregnant and systemically compromised, or less commonly, severe infection can cause permanent loss of function in the affected quarter(s) of the mammary gland due glandular fibrosis or obstruction (Perkins and Threlfall 2002; Knottenbelt 2003). Verminous mastitis (e.g. *Cephalus* sp and *Halicephalobus deletrix*) may potentially disseminate to the mare's systemic circulation and result in lesions to the mare incompatible with life (Wilkins *et al.* 2001; McCue and Sitters 2011).

Mastitis can affect lactating, peripartum, dry mares, mares at dry-off or prepubertal foals (McCue and Wilson 1989; McCue and Sitters 2011). Lactating mares are usually either affected by mastitis within the 2–3 days immediately post-partum or late in lactation (Bostedth *et al.* 1988; McCue and Wilson 1989; Perkins and Threlfall 2002). Peripartum mares affected with mastitis may have a history of galactorrhoea before parturition (Perkins and Threlfall 2002) (Fig 1). A retrospective study from California showed that 42% of mares were affected by mastitis during lactation, another 28% displayed signs within the first 8 weeks post-weaning, and the remaining 30% of mares had not lactated (McCue and Wilson 1989). In the same study, the mean age of affected mares was 13.2 ± 6.2 years, with a range from 3 to 24 years (McCue and Wilson 1989). It is also worth noting that another retrospective study from Ohio involving mostly Standardbred horses had a broader range of age in affected mares, including a 2-month-old foal and three young fillies 2–3 years of age (Perkins and Threlfall 2002).

In the Northern Hemisphere, May to September is the time of the year when most mares in reproduction are lactating or have been weaned. In a report from California, 71% of the mares had signs of mastitis during this time point (McCue and Wilson 1989). Since milk production is dramatically reduced by 4–5 months of lactation (Bostedth *et al.* 1988), while the foal's nutrient requirements are only increasing, it is possible that certain foals become more aggressive while nursing, particularly under food-restricted conditions, thus potentially inflicting trauma to the gland or teat orifice making the mare prone to mastitis. This appears to be especially true for mares raising mule foals (I.F. Canisso, unpublished observations).



Fig 1: *Streptococcus mastitis* in a pony mare on the day of foaling. The mare displayed galactorrhoea prepartum. Note that only the left cranial quarter is affected (*), while the left caudal quarter (x) and both right quarters (+) are not affected.

However, this increase in foal energy requirements cannot be separated from the seasonal effects, as mares are more commonly affected by mastitis during the summer months when insect populations increase (McCue and Wilson 1989), coincidentally also the time when many foals are 4–5 months old. Interestingly, mastitis has also been reported in prepubertal foals due to trauma in the inguinal region (Pugh *et al.* 1985; Perkins and Threlfall 2002; Gilday *et al.* 2015).

Drying-off mares are more likely to suffer from mastitis up to 8 weeks postweaning, which under typical horse industry conditions in the Northern Hemisphere coincides with summer and early fall (May–September), when insect populations are still peaking (McCue and Wilson 1989). In addition, after weaning, mammary gland secretions will accumulate and potentially drip, facilitating the entrance of infectious agents to the teat ('streak') canal (Jackson 1986). Similarly, mares presenting mastitis right after delivery have a history of dripping milk prefoaling, or may have lost a foal at, or immediately after, delivery (Perkins and Threlfall 2002). Other dry mares may present improper idiopathic lactation, particularly in the fall, and inappropriate lactation is also seen in mares with Cushing's disease, probably due to a secondary increase in plasma prolactin (Pugh *et al.* 1985; McCue and Sitters 2011).

The following manuscript describes the diagnosis and treatment of mastitis in mares. Clinical conditions with a somewhat similar presentation will be discussed as part of the differential diagnoses. The presented information herein will be useful for veterinarians facing cases with a similar clinical presentation.

Clinical signs, classification and aetiopathogenesis

Mastitis can occur uni- or bilaterally; 78.6% of cases were unilateral in one report from California (McCue and Wilson 1989), and 59% were unilateral in another report from Ohio

(Perkins and Threlfall 2002). Interestingly, in unilateral mastitis, it is possible for only one lobule or quarter (4/28 clinical cases) to be affected (McCue and Wilson 1989) (**Fig 1**). Typically, each udder half is composed by two lobules and rarely three lobules (Jackson 1986; McCue and Wilson 1989; Knottenbelt 2003); this is particularly relevant if intramammary gland infusions are to be performed as part of the treatment. If the mare has three lobules, three orifices can be seen draining



Fig 2: Ventral view of the mammary gland from a 21-year-old multiparous Quarter Horse mare depicting two orifices in each gland. Scar tissue was present on the right gland (left side of the picture) as a consequence of a mastitis post-weaning. This mare had delivered and weaned 10 foals, and while gland asymmetry is not unexpected, in this case, it was due to fibrosis.

from each teat, rather than two orifices as seen in most mares (Jackson 1986; Knottenbelt 2003) (**Fig 2**).

Clinical signs associated with mastitis include pain, local swelling or heat in the affected gland, gland asymmetry, gland firmness, ventral oedema with or without concomitant lower limb oedema, a congested mammary vein, rejection of the foal (e.g. kicking, biting, walking away and picking up the hindlegs) and grossly abnormal purulent and/or serosanguineous secretions (McCue and Wilson 1989; Perkins and Threlfall 2002; McCue and Sitters 2011) (**Table 1, Figs 1 and 3**). Some mares may become reluctant to move, grumpy or aggressive in response to pain (Roberts 1986; McCue and Wilson 1989). Mares can also show systemic signs such as pyrexia (up to 41°C), anorexia/hyporexia, depression and hindlimb lameness (McCue and Wilson 1989; Perkins and Threlfall 2002). The most common clinical signs are a firm and swollen udder with purulent discharge (Perkins and Threlfall 2002) (**Fig 1**). Bloodwork is often unremarkable in horses without systemic signs but may also show neutrophilia and hyperfibrinogenaemia (McCue and Wilson 1989; Perkins and Threlfall 2002).

Mammary gland abscessation is a potential sequela of mastitis, with *Corynebacterium* spp, *Streptococcus* spp. and *Staphylococcus* spp. appearing to be the predominant agents causing udder abscesses in mares (McCue and Wilson 1989; Knottenbelt 2003; Brendemuehl 2008). True incidence and prevalence of mastitis and subsequent mammary abscesses is unknown. In the authors' experience, cases of mastitis coupled with mammary abscess are more common in horses coming from areas endemic for Pigeon fever (*Corynebacterium pseudotuberculosis*).

Based on the clinical presentation, mastitis can be classified as acute or chronic, and clinical or subclinical. Although specific cut-offs have not been determined for these classifications, in practical terms, mares with acute mastitis present overt clinical signs of less than a week's duration, and clinical signs resolve within 7 days once treatment is initiated. Mares with chronic mastitis fall outside this arbitrary classification. Subclinical mastitis are those cases without overt clinical signs or mares without a fever or painful udder (**Table 1**).

Mastitis is most commonly caused by bacteria, and less commonly by fungi, nematodes or noninfectious agents such as avocado tree poisoning (Greiner *et al.* 1991; McKenzie 1991; McCue and Wilson 1989; Perkins and Threlfall 2002). More than 20 aerobic bacteria have been associated with mastitis in mares. Overall, *Streptococcus* species were the most common isolates reported by various authors (Bostedth *et al.* 1988; McCue and Wilson 1989; Perkins and Threlfall 2002; Böhm *et al.* 2009), although in one report from California, 42% mares suffering from clinical mastitis had



Fig 3: Mammary gland development and unilateral mastitis in a dry 13-year-old Quarter Horse mare. The left udder felt warm and tender on palpation and the mare developed systemic signs. While milk could be expressed from both glands, only the left udder half was affected. The arrow points to a congested 'mammary vein'.

Gram-negative bacterial agents isolated (McCue and Wilson 1989). Most bacteria isolated from mares with mastitis are also found on the skin of the udder and have also been isolated in the milk of healthy post-partum mares (Bostedth *et al.* 1988; Böhm *et al.* 2009), suggesting that occurrence of mastitis may be associated with the breakdown in the innate immune response or disturbance between the host and microbe.

Fungi isolated from mastitis cases include *Rhizoglyphus* *mucilaginosa*, *Coccidioides immitis* and *Blastomyces dermatitidis* (Hajsig and Jacovac 1960; Walker *et al.* 1993; Wilson *et al.* 2006), whereas nematodes diagnosed in mares suffering from verminous mastitis include *Cephalus* sp. and *Halicephalobus deletrix*. In one interesting case, there was evidence of transmission from the dam to the newborn of a soil worm (*H. deletrix*), which resulted in severe neurological signs in both the dam and foal culminating in their euthanasia (Greiner *et al.* 1991; Wilkins *et al.* 2001).

The pathogenesis of mastitis in mares is not completely known. It has been suggested that infectious agents penetrate the gland via the teat canal or that bacteria spread via haematogenous infections, breakdown of the skin or potentially by active penetration of the intact skin by parasites (Jackson 1986; McGladdery 1998). Since the mare's udder is in a relatively protected area compared to ruminants, trauma to the gland is not as common as it is in dairy cows or goats (Jackson 1986; McCue and Sitters 2011). In addition, due to the relatively small udder size and reduced storage capacity (gland cistern), the foal nurses frequently, which is thought to play a role in preventing infection of the gland (Jackson 1986; Knottenbelt 2003). Conversely, after weaning the mare continues to produce milk, the gland becomes engorged, milk drips and insects may feed off the dripping secretions of the mare. This situation can make mares susceptible to developing mastitis, again particularly during the summer (Jackson 1986; Perkins and Threlfall 2002; Knottenbelt 2003).

Diagnosis

Diagnosis of mastitis can be achieved based on inspection of the udder (**Table 2**), which will reveal typical clinical signs. In addition, it is recommended to confirm bacterial presence by

TABLE 1: Common clinical signs of mastitis

- Swollen udder
- Agalactia
- Purulent/serosanguineous secretions
- Pyrexia
- Anorexia
- Depression
- Lameness
- Reluctance to move
- Kicking at, or rejection of, the foal

TABLE 2: Workflow mastitis diagnosis

-
- Mare general physical examination
 - Udder inspection and palpation
 - Expression and inspection of mammary gland secretions
 - Ancillary tests
 - Culture
 - Cytology
 - Complete blood cell count
 - Fibrinogen
 - Ultrasound
-

performing an aerobic culture coupled with cytology of the mammary gland secretions (Freeman *et al.* 1988; Knottenbelt 2003). Mares suffering from bacterial mastitis have a remarkably high number of neutrophils with degenerate changes (Freeman *et al.* 1988; McCue and Wilson 1989). Cytology of the mammary gland secretions can be easily performed; a drop can be placed on a glass slide, smeared with a coverslip or another slide, allowed to dry and then stained with a Romanowsky stain (e.g. Diff-Quick) readily available in most equine practices (Fig 4). The slide can be gently washed with tap water, allowed to dry at room temperature and placed in an incubator at 37°C or a heated stage warmer for 15–20 min and then read in an optical microscope. The slides can be read at 10–40× magnification; however, utilising 100× will increase the chance of detecting bacteria. While only 30% of the samples had bacteria detected on cytological evaluations in one report (McCue and Wilson 1989), the presence and morphology of bacteria can be helpful as a presumptive diagnosis of mastitis. Cytological specimens collected from lactating mares show a proteinaceous material with an occasional squamous cell (Fig 5), whereas drying-off mares present occasional macrophages with a foamy appearance (Freeman *et al.* 1988). The authors use cytology both as a diagnostic aid and to monitor the mare's response to treatment and to determine when to discontinue treatment.

On many occasions, any udder development and enlargement is deemed mastitis by veterinarians, owners and grooms; however, a brief manual examination of the udder and evaluation of the appearance of the mammary secretions is often enough to rule out mastitis (McCue and Sitters 2011) (Figs 1, 6 and 7). It is worth noting that some mares display classic signs of mastitis and secretions may look grossly normal; in this case, a cytological evaluation will reveal mammary gland secretions full of degenerated neutrophils as was seen in the mare's cytology in Fig 4. Other conditions causing mammary gland development and enlargement include idiopathic lactation in dry mares, mammary gland neoplasia, inappropriate lactation in young fillies, galactorrhoea in pregnant mares days before expected due date and conditions affecting the fetoplacental unit (e.g. placentitis, twin pregnancy, imminent abortion and late-term fetal death) (Knottenbelt 2003; Brendemuehl 2008; McCue and Sitters 2011).

Mammary gland secretions should be collected aseptically if intended for aerobic culture (Knottenbelt 2003). The udder should be scrubbed and washed with povidone-iodine scrub, and the teat should be cleaned with 70% rubbing alcohol and allowed to dry for 3–5 min. Then the

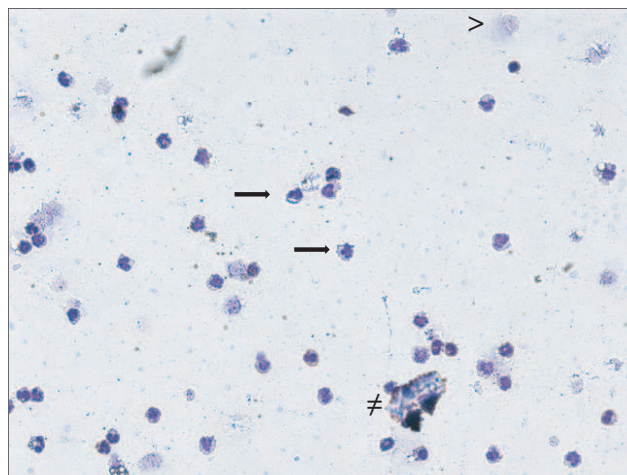


Fig 4: Cytology of mammary gland secretions from a 13-year-old Standardbred mare with clinical mastitis. The mammary gland secretions were grossly normal. Inflammatory change in clinical mastitis on a cytologic smear of the mammary gland secretion showing the presence of polymorphonuclear leukocytes (arrow). Squamous epithelial cells and rare histiocytes (arrows) are present (Romanowsky stain, 20×).

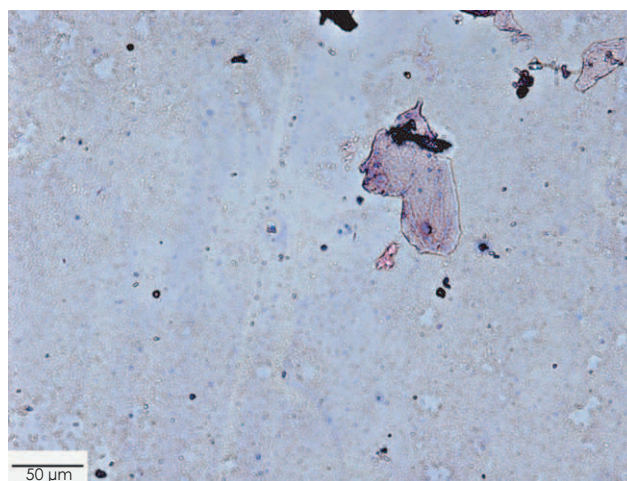


Fig 5: Mammary gland secretion cytology from a mare with normal lactation (Romanowsky stain, 20×).

udder should be milked while wearing sterile gloves, and the first three milk jets discarded to avoid contamination with micro-organisms known to colonise the teat canal. An assistant can then open a plain sterile tube (e.g. a 15-mL falcon tube or vacutainer tube), taking care not to contaminate or touch the top of the tube.

Ultrasonography of the mammary gland can be useful particularly in chronic mastitis, mammary gland neoplasia and unusual mastitis cases (Motta *et al.* 2011). Acute mastitis does not result in remarkable ultrasonographic changes (Waldrige 2011). Obstructive lesions are uncommon and may be better observed with an infusion of saline into the lactiferous sinus or ducts (Motta *et al.* 2011). Mares presented for breeding with obvious signs of bilateral udder fibrosis can have their udder gently distended with saline and assessed



Fig 6: Mammary gland secretions from a mare with unilateral acute mastitis caused by *Streptococcus zooepidemicus*. The mare had moderate mammary gland development. The left udder had normal consistency and yielded secretions with normal appearance (left tube), whereas the right udder was hot, painful and firmer than normal and secretions were grossly abnormal (right tube) with purulent appearance.

this way as a proxy for potential milk production. Before infusion, the udder needs to be aseptically prepared and then completely drained after the procedure is finished to avoid iatrogenic infection. As this procedure may carry a risk of infection and inflammation, prophylactic antimicrobial therapy with sulfamethoxazole and trimethoprim (30 mg/kg bwt per os for 3 days) can be carried out at the clinician's discretion. Clients may elect to not breed mares with extensive udder fibrosis, or alternatively assisted reproductive techniques or nurse mare can help circumvent this problem.

Some diagnostic tools widely used in the dairy cattle industry have conflicting results when used in horses. The detection of gross abnormalities in milk is routinely performed with the first jets collected in a cup with a filter and a dark contrast to diagnose clinical mastitis. While this seems to be useful, the tool used in cattle is not commonly available in the equine practitioners' clinic or truck, thus making this technique less useful. The California mastitis test (CMT) is based on somatic cells reacting to a detergent solution and producing an agglutination that can be graded according to the degree of gel-like formation (0, +, ++ and +++). Studies assessing this technique concluded that there was no association between the CMT results and the presence of clinical or subclinical mastitis and aerobic culture in mares

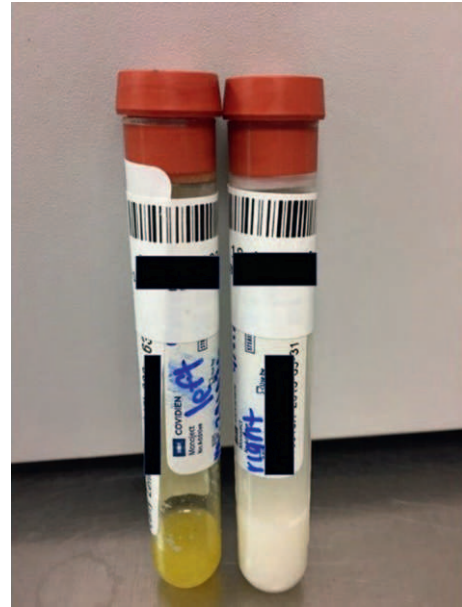


Fig 7: Mammary gland secretions from acute *Streptococcus mastitis*. Left tube shows a remarkably yellow secretion, while the right udder had normal milk secretions. Cytological examination revealed large numbers of degenerate neutrophils and bacteria. The udder was hot, firm and painful on palpation.

(Waldridge 2011). Similar findings were obtained with mares assessed via total somatic cell counts (Böhm *et al.* 2009). Typically, CMT is not commonly available in the equine practitioners' clinic or truck. In cows, a somatic cell count of fewer than 100,000 cells/mL is considered ideal and counts greater than 200–250,000 are considered to indicate infection. In contrast, in a study assessing CMT, somatic cell count and aerobic culture in horses, there was no association between somatic cell count and clinical disease (Böhm *et al.* 2009; Motta *et al.* 2011). Collectively, the authors concluded that these tests are not currently optimised for horses, therefore not useful screening or diagnostic tools.

Treatment

Treatment of mastitis involves systemic antibiotics, intramammary antibiotic infusion or antiseptics solution (e.g. povidone-iodine solution), nonsteroid anti-inflammatories, frequent milking, cold water hosing or hot packs (McCue and Wilson 1989; Motta *et al.* 2011) (**Table 3**). Frequent milking is utilised to remove bacteria, debris and inflammatory cells from the gland, and intravenous or intramuscular administration of oxytocin (10–20 units) can aid with milk let-down and clearance. During the first 5–7 days of treatment, the mare should be milked two to three times a day. At the onset of treatment, some mares may become difficult and violent while having their udder touched and milked. Physical restraining methods such as lip-chain, nose-twitch and/or skin-twitch can be used in combination with sedatives such as alpha-two agonists. Tranquilisers such as acepromazine are also effective to chemically restrain the mare but can stimulate prolactin production and potentially aggravate clinical mastitis in dry or drying-off mares.

Hot packs have also been recommended as an ancillary method to treat mastitis in mares; however, the authors' preference is to cold hose with water for 15 min right after the mare has been milked out. After the mare's udder is cold-hosed, the udder is dried, and petroleum jelly applied to the udder and teat to prevent skin cracks caused by mastitis and the frequent milking.

Nonsteroidal anti-inflammatory drugs (e.g. flunixin meglumine 1.1 mg/kg q. 12–24 h or phenylbutazone 2.2 mg/kg q. 12 h) can be used to treat pyrexia, to reduce inflammation and promote analgesia. Febrile mares will go off-feed, stop drinking water and become depressed and dehydrated if not treated adequately. We recommend treating the mare initially twice a day with nonsteroidal anti-inflammatory drugs. Normally, the mare will restore appetite and become afebrile within 12–24 h. Mares left untreated for a long period of time may need fluid therapy to restore normal hydration.

Antimicrobial therapy should be performed according to culture and sensitivity. Interestingly, micro-organisms cultured from affected glands were resistant to many of the commonly used antimicrobials in horses (McCue and Wilson 1989). Given that approximately 75% of bacterial agents cultured from mastitis mares in a study from California were susceptible to sulfamethoxazole and trimethoprim (McCue and Wilson 1989), it seems reasonable to collect milk samples from affected mares, submit for culture and sensitivity, and while waiting for the results to come back, start treating the mare with sulfamethoxazole and trimethoprim (30 mg/kg bwt per os q. 12 h). Alternatively, some clinicians have advocated administering systemic long-acting cephalosporin (i.e. Excede Zoetis, ceftiofur crystalline free acid) at recommended manufacturer's doses to empirically treat mastitis in mares, although its effectiveness has not been critically tested. This antimicrobial is the dairy cattle producer's favourite to treat uterine and respiratory infections, and since it does not diffuse to milk, it requires no discard of milk when administered systemically. It remains to be determined whether this antimicrobial diffuses to mammary gland secretions in mares; if it does not, its usage to treat mastitis should be questionable. In addition, in view of the critical importance of this antimicrobial drug in human medicine, its use in the horse should be restricted to cases where culture results indicate an absolute need.

Other authors proposed to use intramammary antimicrobial infusion of the affected gland(s) with bovine intramammary products, particularly in cases not responding to initial treatment (Jackson 1986; McCue and Wilson 1989; Perkins and Threlfall 2002). It is worth noting that quarter(s)

unaffected by mastitis should not be infused. This route can be used alone or in combination with systemic antibiotics (McCue and Wilson 1989; Perkins and Threlfall 2002). If the clinician elects to use such products, short-life (lactating cow) formulations should be used to allow for frequent milking, and each affected lobule (i.e. teat orifice) should be infused. Cow mastitis long-life (dry off cow) products are less soluble and have a slower release of drugs and are more expensive. In addition, since the teat canal is shorter, and the cistern of the gland is smaller in mares than cows, the clinician should be careful to not cause further trauma to the gland while performing intramammary gland infusions (McCue and Wilson 1989).

The authors use the gross appearance and cytological findings (e.g. scant or absent presence of neutrophils and lack of hypersegmented neutrophils) of the milk to decide whether to discontinue or reduce milking frequency. Once the mammary gland secretions are grossly and cytologically normal, the authors reduce the milking frequency to once a day and continue to observe the mare. A complete blood count and measurement of plasma fibrinogen can be useful for determining when to discontinue treatment. Fortunately, most mares respond in 2–3 days to treatment for bacterial mastitis and most are normal within a week after diagnosis. Some mares may fail to respond to treatment, particularly mares with fungal or verminous mastitis. Unfortunately, the treatment for fungal or verminous mastitis in horses is poorly defined.

Surgical removal of the udder has been advised for mares suffering from recurrent chronic mastitis, mammary gland neoplasia, extensive laceration and for convenience of the owner in mares from owner's disturbed by the occurrence of idiopathic lactation. The surgery is not trivial; post-surgical complications include haemorrhage, improper healing, surgical infection and dehiscence. It has fewer complications if performed when the mare is not lactating, as there is an increase in blood flow to the udder during lactation (Knottenbelt 2003). For the procedure, the mare needs to be under general anaesthesia, and placed in dorsal recumbency, and then the major vessels irrigating the mammary gland ligated (Knottenbelt 2003). Except for select cases, surgical removal of the mammary gland should be discouraged due to inherent surgical and general anaesthesia risks and welfare concerns.

Prevention

Most mares developing mastitis after weaning were up to 8 weeks after weaning (McCue and Wilson 1989). Milk production is highly linked with feed intake, and reduction or complete removal of grains from the mare's diet at drying-off can be helpful in preventing mastitis. For mares losing foals at, or immediately after, parturition, the authors' preference is to collect all colostrum for storage in a colostrum bank and then start drying off the mare by reducing grain and hay. Such mares are also at high risk of metritis and are often maintained on frequent doses of oxytocin (e.g. 10 units, 2–3×/day for 7 days) to help with uterine involution. Mares with down foals (e.g. critically ill) or mares with a history of neonatal isoerythrolysis should be milked regularly every 2–6 h until the foal is recovered or able to suckle on its dam, respectively.

It is also helpful to suggest to clients to wash the udder and hindlegs of mares to clean off dripping milk. This ensures

TABLE 3: Treatment of mastitis

- Milk the mare frequently (2–3×/day)
- Nonsteroidal anti-inflammatory drugs (e.g. flunixin meglumine, phenylbutazone)
- Oxytocin for milk-let-down pre milking (optional and not recommended in mid to late pregnant mares due to risk of premature labour)
- Antimicrobials (start with sulfamethoxazole and trimethoprim and switch if needed based on sensitivity)
- Cold hose with water
- Hot pack compress
- Feed restriction

TABLE 4: Prevention of mastitis

- Monitor and keep the udder clean for 8 weeks post-weaning
- Control insect population on farm
- Reduce dry matter intake, particularly grains
- Provide creep feed for foals
- Keep stable groups of mares to avoid fights and accidents

that clients are paying attention to mares accumulating and dripping milk (e.g. weaned-off or mares with dead foals). Mares dripping milk will present 'oily' hindlegs and will attract more flies that could potentially increase the odds for mastitis. Since gland distension is important for discontinuation of milk production, the practitioner should instruct clients not to milk the mare after weaning, but also to watch for signs of mastitis in the 4–8 weeks post-weaning. Providing good nutrition support for the nursing foals will allow them to be less dependent on maternal milk, which will potentially lead to a gradual decrease in milk production towards the end of lactation (Table 4).

Conclusion

Mastitis is a disease affecting mares of all categories (nursing, dry and drying-off) and also fillies. While mastitis is less prevalent in mares, severe consequences associated with mastitis can occur in horses as well as ruminants. Transmission of the infectious agent to the nursing foal causes septicaemia, polyarthritis and pneumonia in the foal. Additionally, agalactia can lead to subsequent foal malnutrition. Mastitis can also induce abortion if the mare is pregnant and systemically compromised, or less commonly, severe infection can cause permanent loss of function in the mammary gland due to glandular fibrosis or obstruction. Diagnosis of mastitis can be achieved based on inspection of the udder, which will reveal typical clinical signs. In addition, it is recommended to confirm bacterial presence by performing an aerobic culture coupled with cytology of the mammary gland secretions. Mares suffering from bacterial mastitis have a remarkably high number of neutrophils with degenerate changes. Treatment for mastitis involves systemic antibiotics, intramammary infusion of antibiotics or antiseptics solution, nonsteroid anti-inflammatories, frequent milking, cold hosing or hot packs. Prevention including mainly monitoring mares after weaning or loss of a foal, potential reduction of feeding post-weaning, provide appropriate nutrition for the nursing foals to be less dependent on mare's milk, control insect populations on the stud farm.

Authors' declaration of interests

No conflict of interests have been declared.

Ethical animal research

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Authorship

All authors contributed to the preparation of this manuscript.

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Image Article

Visual evidence of progression and eventual resolution of nasofrontal suture exostosis over 27 months in a gelding

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Keywords: horse; nasofrontal suture exostosis

Summary

A 22-year-old Thoroughbred gelding presented with a noticeable external firm and nonpainful swelling over the location of the frontal sinuses. Further radiographic investigation of the swelling identified soft tissue facial swelling, new bone formation and a radiolucent line between two areas of bone remodelling. The horse was diagnosed with a nasofrontal suture exostosis. This is a relatively rare disease of the head but is one of the more common reasons for facial swelling. It is reported that these horses are not painful and that the swelling and bony reaction will resolve over 12–18 months with no treatment needed. It is well described in the current literature what the initial presentation should look like; however, there is a void when it comes to demonstration of the clinical course of the disease. This report provides veterinarians and owners with a visual reference to a relatively typical course of disease, where swelling can enlarge over time and still resolve within 2 years.

Introduction

The equine skull is made up of many bones that are connected via 'sutures' (Fig 1a,b). Appositional bone growth occurs at these sutures with most becoming fused once the skull matures (Klein *et al.* 2014). Exostosis of the nasofrontal suture (highlighted in Fig 1a,b) is a relatively rare disease of the head but is one of the more common reasons for facial swelling (Lane *et al.* 1987). The aetiology is unknown, even though trauma has been suspected to be one of the main causes (Dixon 2014). Radiographs will often confirm the diagnosis, but the location of the swelling is often diagnostic in its own right (Lane *et al.* 1987; Dixon 2014). There are only a few reports of this disease, with most focusing on the initial appearance of the swelling (Lane *et al.* 1987; Dixon 2014) or on the complicated cases (Carslake 2009; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014). It is reported that these horses are not uncomfortable and that the swelling and bony reaction will resolve over 12–18 months (Dixon 2014), therefore, no treatment is necessary. This lesion is mainly a cosmetic issue (Dixon 2014) unless the swelling does not dissipate over approximately one year, or if epiphora occurs and persists (Carslake 2009; Dixon 2014; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014). Dixon reports that '...these lesions just need to be correctly identified and their owners reassured about their innocuous nature and that complete

self-resolution will spontaneously occur in nearly all cases' (Dixon 2014). The trouble with this statement is that since it is uncommon, many practitioners will not have the experience to 1) identify it and 2) assure the client that it will dissipate with no treatment, especially if the owner is concerned about cosmetics. It is well described in the current literature what the initial presentation should look like (Lane *et al.* 1987; Dixon 2014). However, there is a void when it comes to demonstration of the clinical course of the disease. In fact, many of the references can make the clinician more nervous since they discuss complicated cases that need surgery to help resolve issues associated with the exostosis (Carslake 2009; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014). The purpose of this report is to visually demonstrate via photographs and radiographs the clinical course of the disease in one horse over 27 months, where the only treatment administered was anti-inflammatories.

Case history

A 22-year-old Thoroughbred gelding presented for a wellness examination and a noticeable external firm and nonpainful swelling was noted over the location of the frontal sinuses, predominantly on the right side (Figs 2–4). There was no knowledge of previous trauma or irritation to the area of interest.

Clinical findings

At initial presentation, the horse was bright, alert and responsive, in good physical body condition and overall health. The horse had an asymmetric facial swelling that was present between and slightly rostral to the eyes (Figs 2–4). The swelling was most prominent on the right side of midline, extending further caudally and abaxially than the swelling on the left side (Fig 4). The horse had evidence of slight bilateral epiphora. To further characterise the lesion, standing skull radiographs were obtained. Lateral, dorsoventral, left ventral-right dorsal oblique and right ventral-left dorsal oblique views were taken. On initial radiographs (Fig 5), a focal soft tissue swelling and underlying moderately smooth margined new bone proliferation was present in the region of the nasofrontal suture. There was an irregular radiolucent defect in the bone contour at the centre of the lesion. The side of the most

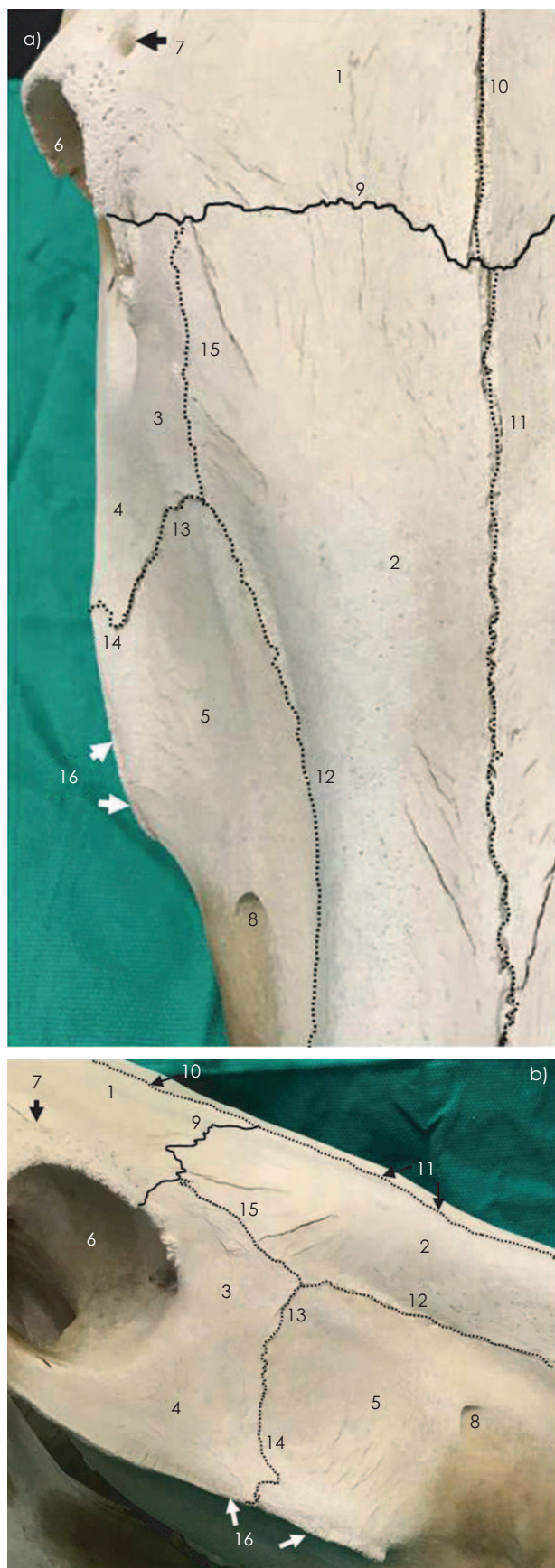


Fig 1: a) Dorsal and b) lateral view of the right side of an equine skull. 1 = frontal bone; 2 = nasal bone; 3 = lacrimal bone; 4 = zygomatic bone; 5 = maxilla; 6 = orbit; 7 = supraorbital foramen; 8 = infraorbital foramen; 9 = nasofrontal suture (solid black line); 10 = interfrontal suture (dashed line); 11 = internasal suture (dashed line); 12 = nasomaxillary suture (dashed line); 13 = lacrimomaxillary suture (dashed line); 14 = zygomaticomaxillary suture (dashed line); 15 = nasolacrimal suture (dashed line); 16 = facial crest.

affected oblique (right) suggested that the new bone formation was more apparent internally within the frontal sinus as compared to the external growth, which likely meant that the bone growth spanned from midline to the orbit.

Diagnosis

Nasofrontal suture exostosis was diagnosed based on the location of the swelling and the radiographic findings.

Treatment

After initial radiographs were taken, a 10-day treatment course of 1–2 g of oral phenylbutazone tablets was prescribed. No other treatment was instituted at the time of initial presentation. The owner was instructed to closely monitor the swelling and epiphora.

Outcome

At one month, the swelling appeared to be enlarged and there was a partial-thickness skin laceration just rostral and abaxial to the swelling, on the right side of the face (**Fig 2**). Upon palpation of the swelling, the horse withdrew his head more than at the initial presentation. It was not possible to determine if the increased resentment to palpation was due to the wound or the ongoing swelling. No epiphora was present. The laceration was cleaned, but not sutured, and it was recommended to obtain radiographs of the head again after a few weeks if the swelling continued to enlarge or suffered repeated trauma.

At 2 months, the swelling had further enlarged, with the most pronounced increase on the right side of the head (**Figs 2 and 3**). The laceration noted at one month was present but was healing without complications. The swelling was nonpainful upon palpation, and the horse was no longer resentful to palpation as he was at one month. No epiphora was present. Repeat standing skull radiographs were taken (**Fig 6**). Compared to radiographs taken upon initial presentation (**Fig 5**), radiographs showed moderate enlargement of the soft tissue swelling and underlying bony reaction. The bony reaction was more nodular, with extension into the dorsal soft tissues, and greater opacity on either side of the irregular radiolucent defect in the centre of the lesion. It was decided to continue observation of the swelling and if the bony swelling increased or additional problems arose, further diagnostics such as computed tomography would be considered.

At 4 months, the owner sent a picture (**Fig 3**) demonstrating that the degree of swelling appeared to have plateaued on the right side and decreased on the left. The owner stated that the horse was not painful to palpation, and no epiphora was present. As before, the owner agreed to continue observation.



Fig 2: Photographs of the horse's head as taken from the right side. Images were taken at presentation, as well as 1, 2, 14 and 27 months after presentation. The white arrow on each figure highlights the location of the swelling on the right side. The black arrow on the photograph at one month points to a new partial-thickness laceration and its presence at 2 months. Note that the swelling enlarged over 1–2 months, but then slowly regressed over time. Most of the lesion regressed by 14 months, but additional improvement was achieved over the next year.

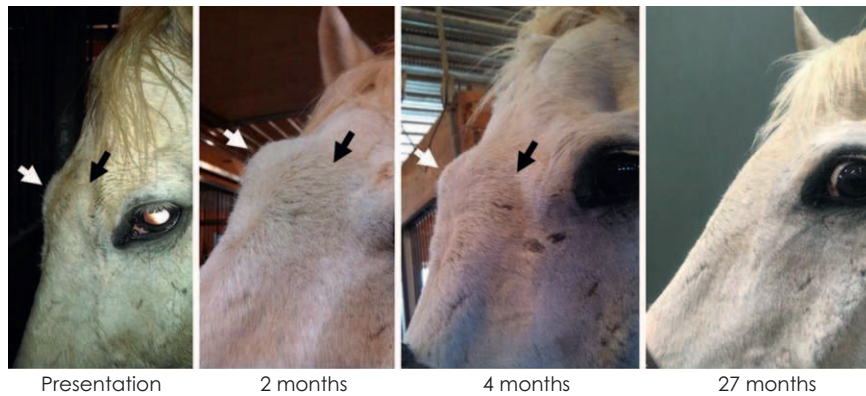


Fig 3: Photographs of the horse's head as taken from the left side. Images were taken at presentation, as well as 2, 4 and 27 months after presentation. The white arrow highlights the location of the swelling on the right side. The black arrow highlights the swelling present on the left side. Note that the swelling on the left side was always smaller than the right side. In addition, it appeared that the right side enlarged at 2 months and plateaued by 4 months while the left side regressed over that same period of time. By 27 months, no swelling was present on either side when looking at the left side of the head.

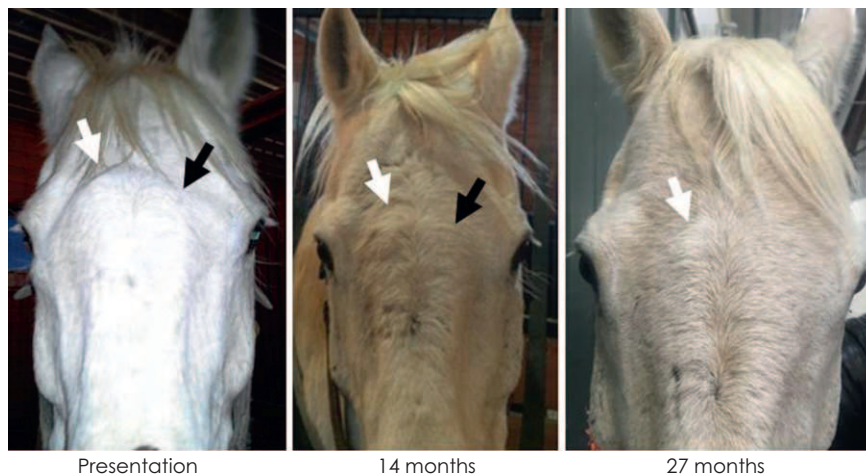


Fig 4: Photographs of the horse's head as taken from the front of the horse. Images were taken at presentation, as well as 14 and 27 months after presentation. The white arrow highlights the location of the swelling on the right side. The black arrow highlights the swelling present on the left side. Note that the swelling on the left side was always smaller than the right side. By 14 months, most of the swelling regressed on both the right and left sides of the head, but by 27 months, only a slight protuberance could be identified on the right side of the head. This was the best view to see this protuberance at this time.



Fig 5: Standing lateral radiograph and photograph of the horse at the time of presentation to provide context on the location and appearance of the swelling (white arrows) externally and internally. A focal soft tissue swelling and underlying moderately smooth margined new bone proliferation was present in the region of the nasofrontal suture that spanned from midline to the orbit. There was an irregular radiolucent defect in the bone contour at the centre of the lesion.

Over the next 10 months, the swelling decreased substantially in size. The horse was photographed at 14 months demonstrating a much smaller swelling on the right side of the head, with only a slight swelling present on the left (Figs 2 and 4). The horse remained nonpainful to palpation and with no epiphora present. It was agreed that the horse should be radiographed again within 12 months.

When the horse presented to the hospital for an unrelated reason at 27 months, his head was examined (Figs 2–4) and radiographed (Fig 7). The swelling had almost completely resolved. In fact, the swelling was only visible when looking at the horse head on. A slight protuberance was present on the right side (Fig 4). The horse was nonpainful to palpation, and no epiphora was present. Radiographically, the previous swelling and proliferative lesions could no longer be identified (Fig 7). The bone appeared to have completely remodelled. The horse continued his normal daily routine throughout the entire course of the disease process.

Discussion

A suture exostosis clinically presents as a nonpainful facial swelling at the junction of skull bones, with most occurring over the nasofrontal suture (Lane *et al.* 1987; Carslake 2009; Manso-Díaz and Taeymans 2012; Dixon 2014; Klein *et al.* 2014). Nasofrontal suture exostosis is a poorly understood disease with few known aetiologies and complications. Potential aetiologies include: head trauma, sinus surgery and unstable suture lines, but a history of trauma rarely is verified (Lane *et al.* 1987; Carslake 2009; Manso-Díaz and Taeymans 2012; Dixon 2014; Klein *et al.* 2014). The location of the swelling between the eyes, on the dorsum of the skull, can

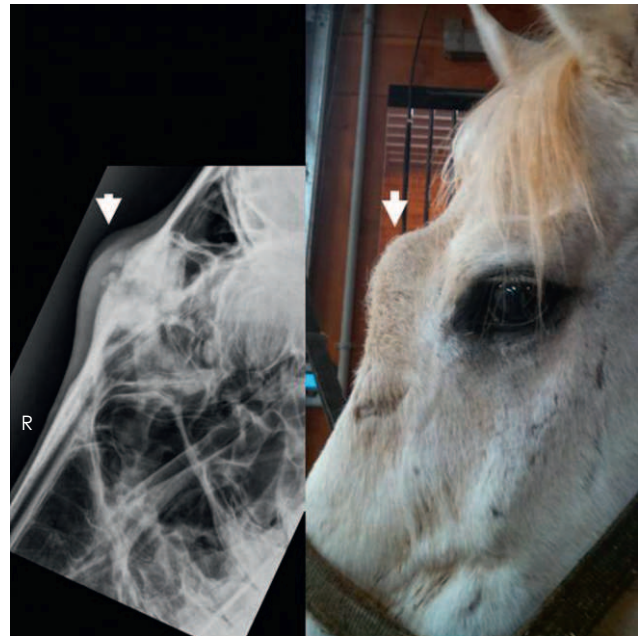


Fig 6: Standing lateral radiograph and photograph of the horse at 2 months after initial presentation to provide context on the location and appearance of the swelling (white arrows) externally and internally. Radiographs showed moderate enlargement of the soft tissue swelling and underlying bone reaction. The bone reaction was more nodular with extension into the dorsal soft tissues and greater opacity on either side of the irregular radiolucent defect in the centre of the lesion.

be considered diagnostic for nasofrontal suture exostosis (Lane *et al.* 1987). The nasofrontal suture is the only suture that spans between the eyes (Fig 1a,b) but the exact rostral to caudal location relative to the eye can be variable (Evans and McGreevy 2006). Ultrasound or radiographs can be obtained to confirm bony remodelling over the suture. Radiographs typically demonstrate a radiolucent line between two areas of sclerotic bone with cortical thickening (Figs 5 and 6), but the extent of the lesion is difficult to interpret due to overlap (Lane *et al.* 1987; Carslake 2009; Manso-Díaz and Taeymans 2012; Dixon 2014; Klein *et al.* 2014). The horse in this report was diagnosed with a nasofrontal suture exostosis based on the location of the swelling and the radiographic changes present. The only thing slightly different in this case was that the swelling was more irregular, with the right side being more prominent than the left (Figs 2–4). Even though ultrasound was not used in this case, it would have been helpful to examine this irregularity since it could be used to evaluate the entire suture, providing comparisons between the left and right sides that radiographs could not.

Similar to other reports, the horse in this report was a mature Thoroughbred with no known history of trauma (Carslake 2009; Dixon 2014). A potential side effect of a nasofrontal suture exostosis is an obstruction of the nasolacrimal duct, most commonly characterised by epiphora; contrast studies of the nasolacrimal duct can be used to confirm this finding (Carslake 2009; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014). At presentation, the horse had mild epiphora. As some of the initial swelling decreased,

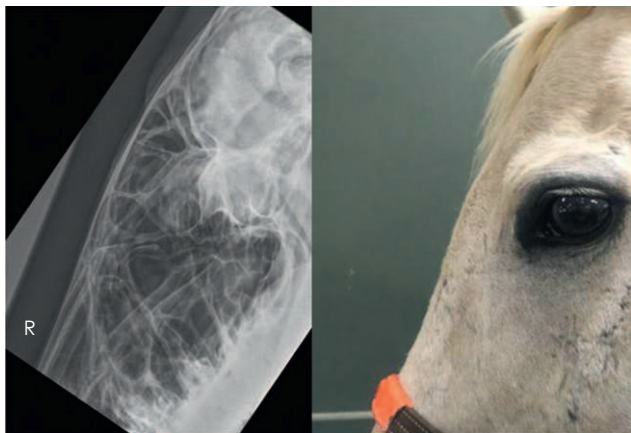


Fig 7: Standing lateral radiograph and photograph of the horse at 27 months after initial presentation to demonstrate the amount of remodelling that has occurred both externally and internally. Radiographs demonstrated that the bone completely remodelled.

the epiphora was no longer present, likely indicating that it was due to soft tissue swelling and not bony remodelling at the junction of the maxillary bones, nasolacrimal and lacrimalomaxillary sutures (**Fig 1a,b**) (Carslake 2009; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014).

Horses are described as having no discomfort throughout the course of the exostosis (Lane *et al.* 1987; Carslake 2009; Manso-Díaz and Taeymans 2012; Dixon 2014; Klein *et al.* 2014). At one month, the horse in this report sustained a laceration on the right side of its head just rostral and abaxial to the swelling (**Fig 2**). At this same time, the swelling had enlarged and the horse was resentful to palpation. This could suggest that the swelling made the horse uncomfortable, causing him to rub his head on objects or that he was resentful to palpation because of his newly sustained laceration. By 2 months, the horse was no longer reactive to palpation even though the swelling had continued to enlarge slightly (**Figs 2 and 3**). This continued enlargement may have been due to the trauma sustained at one month. Nonetheless, this horse demonstrated that the swelling associated with nasofrontal exostosis can increase after the initial presentation and still regress over time without further treatment (**Figs 2 and 3**). This is important for owners to understand, especially if the cosmetic appearance is of high concern. It has been reported that nasofrontal exostosis usually resolves in 12–18 months (Dixon 2014). For the most part, the horse in this report followed that progression of improvement. The swelling was substantially reduced in size at 14 months, with continued resolution out to 27 months (**Figs 2 and 4**).

Further diagnostics such as computed tomography should be pursued if there is persistent epiphora present, or if the facial swelling either enlarges on the abaxial margins or does not substantially decrease after 12–18 months. Additional treatment may be required to either stabilise the sutures or debulk them to decrease the occlusion of the nasolacrimal ducts (Carslake 2009; Manso-Díaz and Taeymans 2012; Klein *et al.* 2014).

A limitation of this report is that it only documents the course of the disease in a single case. Nonetheless, this report provides veterinarians and owners with a visual reference to a relatively typical course of disease, where swelling can enlarge over time and still resolve within two years when no further treatment is chosen except for anti-inflammatories.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This is an image case report on a single clinical case. The owner consented to all procedures that were performed. No ethical review was needed.

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None.

Authorship

All authors participated in the conception, design, acquisition and interpretation of data. All authors contributed to the intellectual content and approved the final version.

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Critically Appraised Topic

The retrobulbar block: A review of techniques used and reported complications**R. A. McKinney** 

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Introduction

The ocular examination in horses with painful eyes is limited by their physicality and powerful orbicularis oculi muscles. Ocular examination is normally facilitated by a combination of chemical restraint (sedation), topical local anaesthesia and periocular nerve blocks. For the majority of horses, blocking the auriculopalpebral nerve (CN VII) to immobilise the orbicularis oculi muscle, and supraorbital nerve (frontal n., CN V – ophthalmic branch) to desensitise the upper eyelid, will facilitate ocular examination, collection of samples from the ocular surface and placement of subpalpebral lavage systems (Labelle and Clark-Price 2013).

The retrobulbar nerve block (RBNB) involves injecting local anaesthetic directly within the periorbital, (**Fig 1**), and in general practice, can be utilised for standing enucleations. In the referral setting, the RBNB is used in numerous procedures including standing corneal surgeries (keratectomies and grafting), eyelid surgeries, laser ablation of granula iridica cysts and cytophotocoagulation for management of glaucoma. The RBNB has the advantage

of adding safety to a procedure by removing the requirement for general anaesthetic by facilitating standing procedures (Pollock *et al.* 2008), as well as impeding the cardiac changes of the oculocardiac reflex (OCR) (Raffe *et al.* 1986).

The periorbital is a conically-shaped fibrous membrane that encloses the 'intraconal' muscles, fat, nerves and blood vessels behind the eye. It extends from the globe obliquely to the apex of the orbit. Structures enclosed by the periorbital include the extraocular muscles and their motor nerve branches (CN III, IV and VI) and the optic nerve (CN II). Sensory nerves (including branches of the ophthalmic nerve (CN V), lacrimal n., supraorbital and infratrochlear n., and maxillary nerve (CN V; zygomatic n.)) which provide sensation to the eyelids and periocular skin, are not consistently blocked by the RBNB. The branches of the ophthalmic nerve which provide innervation to the eyeball (long and short ciliary nerves) are consistently blocked by the RBNB. As a result of this inconsistent anaesthesia of the sensory branches of CN V supplying the eyelids, additional nerve blocks are required for desensitisation of the eyelids,

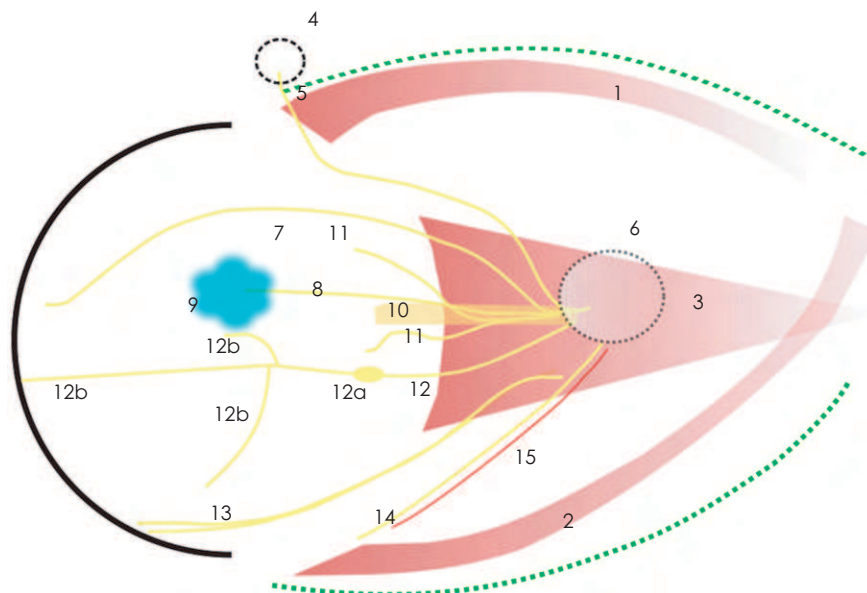


Fig 1: Schematic of the retrobulbar structures. 1. Dorsal rectus muscle; 2. ventral rectus muscle; 3. retractor bulbi muscle; 4. supraorbital foramen; 5. infratrochlear nerve; 6. orbital apex (including orbital foramen, orbital fissure and foramen rotundum); 7. ophthalmic nerve (CN V); 8. lacrimal nerve; 9. lacrimal gland; 10. optic nerve (CN II); 11. long ciliary nerves (branch of the nasociliary nerve, CN V1); 12. sensory root; 12. A) ciliary ganglion; 12. B) short ciliary nerve branches (innervating cornea, iris and ciliary muscles, not depicted); 13. zygomatic nerve; 14. maxillary nerve; 15. maxillary artery. Green dashed lines denote the periorbital, dorsally and ventrally.

commonly the supraorbital nerve for the upper eyelid and a line block for the lower eyelid and canthi.

Complications of the retrobulbar block have been described as intra-meningeal injection from caudal placement of the needle, haematoma formation from placement of the needle too ventrally, globe trauma, optic neuritis and nerve penetration, prolapse of the globe secondary to extraocular muscle blockade, orbital cellulitis and abscessation, and orbital oedema (Gilger and Davidson, 2002; Tremaine 2007). Although a wide variety of complications are reported, with some being devastating, involving morbidity to the eye or mortality of the patient (Labelle and Clark-Price 2013), these are very dependent upon the technique utilised. For this reason, this review will consider the three commonly utilised techniques separately: the four-point block (RBNB-FP), Peterson or modified Peterson block (RBNB-P/MP) and blockade via the supraorbital fossa (RBNB-SOF). This paper seeks to critically appraise the literature on recognised complications reported with the various types of RBNB used in equine practice, according to the relevant literature identified.

Preparation for the retrobulbar block

Complications are recognised with the RBNB; however, the practitioner can take a number of steps to limit these risks in their preparation.

- 1 *Manual restraint.* Manual restraint and head positioning are essential for comfort and stabilisation of the patient and good visualisation for the practitioner; many practitioners elect to use stocks, a head-stand or hay bales and an assistant who is experienced in horse handling.
- 2 *Chemical restraint.* This facilitates accurate and safe administration of the block. Often, the patient's anxiety, ocular pain and movement require sedation, additional to the local anaesthesia (Labelle and Clark-Price 2013). Alpha-2 agonists are the most commonly used sedative for equine standing procedures (Labelle and Clark-Price 2013). Of this class, xylazine, detomidine and romifidine have been described in literature. Some authors cite detomidine HCl (0.01–0.02 mg/kg i.v.) as the best means of sedation for minimal head movement, and xylazine and an adjunct of butorphanol are the worst (Gilger and Davidson, 2002). However, butorphanol as an adjunct to an alpha-2 is widely used by other practitioners (Labelle and Clark-Price 2013), who acknowledge that there is an association with systemic opioid use and muzzle tremors and head movements (Robertson 2004), but that the benefits of anti-nociception out-weigh this potential effect. These tremors are often not seen at the doses administered for standing sedation (Townsend 2013). Detomidine CRIs are also described for longer procedure (Labelle and Clark-Price 2013).
- 3 *Site preparation.* Sterile site preparation can reduce the risk of bacterial inoculation from a needle, thereby reducing the risk of cellulitis and orbital abscesses (Gilger and Davidson, 2002). The area prepared will depend on the type of RBNB being used. In the case of the RBNB-SOF, it is necessary to clip and aseptically prepare the orbital fossa, above the dorsal bony rim of the orbit, and the zygomatic arch (Stoppini and Gilger, 2017). For the RBNB-

FP and RBNB-P/MP, the periorbital is surgically prepared (Hewes *et al.* 2007). Iodine should be used for aseptic preparation at a concentration of 1:50 (Roberts *et al.* 1986), as chlorhexidine or alcohol can cause corneal irritation and ulceration (Gilger and Davidson, 2002).

Literature review

Search strategy

CAB Abstracts on OVID platform, and Web of Science database searches with the following criteria:

- 1 "equine" OR "equid" OR "equids" OR "horse" OR "horses" OR "pony" OR "ponies"
- 2 "eye" OR "eyes" OR "orbit" OR "orbital" OR "ophthalmic" OR "ophthalmology"
- 3 "local anaesthesia" OR "local anesthesia" OR "local anaesthetic" OR "retrobulbar" OR "retrobulbar block"
- 4 1 AND 2 AND 3

An additional search using the specific complications of the retrobulbar block yielded no further results (Search terms "1" AND "2" AND: "subarachnoid anaesthesia" or "intra-meningeal anaesthesia", "ocular perforation" or "globe perforation" or "ocular penetration" or "globe penetration", "retrobulbar haemorrhage" or "retrobulbar bleeding", "globe ischaemia" or "eye ischaemia", "optic nerve atrophy" or "optic nerve neuritis", "extra-ocular muscle damage", "optic nerve perforation" or "optic nerve penetration").

Quantity of evidence

Results were filtered by whether they discussed the use of the RBNB in equids. This yielded seven relevant results looking at the clinical use of the retrobulbar block; one of these was a tutorial article (Tremaine 2007) and hence has been referenced but not included in the analysis of reported complications. Six articles, which are retrospective or prospective experimental studies, reporting on complications from the retrobulbar block itself, or associated complications from enucleations, were analysed. With the exclusion of one paper, Morath *et al.* 2013, due to concerns regarding the methodology. (The authors' *ex vivo* study replicated the RBNB-SOF under ultrasound guidance to the cone formed by the retractor bulbi muscle (RBM), which they equated with the intraconal space. The intraconal space is encompassed by the periorbital (**Fig 1**). Injection into the space enclosed by the RBM which closely envelopes CN II would be associated with significantly higher risks such as damage to CN II, which was noted within this study with a case of CN II nerve sheath laceration.) Five papers have been evaluated in this critically appraised topic.

Quality of evidence

Four papers were from peer-reviewed journals and one from the American Association of Equine Practitioners Proceedings, from a peer-reviewed convention. All papers found are of high reputability, providing a good quality of evidence. A summary table (**Table 1**) highlights different impact factors of these journals.

A larger sample size can affect confidence intervals in the data analysis, and validity of conclusions. The papers

TABLE 1: Summary of quality of evidence

Paper	Reputability of journal	Number of cases	Type of study
Raffe <i>et al.</i> (1986)	Veterinary Surgery; impact factor 1.044	37	Retrospective
Gilger and Davidson (2002)	AEEP Proceedings	189	Retrospective
Hewes <i>et al.</i> (2007)	Canadian Veterinary Journal, impact factor 0.523	5	Retrospective
Pollock <i>et al.</i> (2008)	Veterinary Surgery, impact factor 1.044	40	Retrospective
Oel <i>et al.</i> (2014)	Veterinary Ophthalmology, impact factor 0.59	16	Prospective

reported on different numbers of cases, as summarised in **Table 1**.

Therefore, Hewes *et al.* (2007) provided the lowest quality of evidence with the smallest sample size and being from the lowest impact journal. Conversely, Pollock *et al.* (2008) had the second largest sample size and was from the journal with the highest impact factor. However, one must consider that Gilger and Davidson (2002) had the largest review of cases, and although not from a peer-reviewed journal, it did arise from the proceedings of a national conference.

There is variability in the quality of evidence; however, all papers were considered to be of acceptable quality to contribute to the conclusions of this literature review.

Conclusions of the evidence

The evidence from each paper is summarised in **Table 2**.

Results discussion

Discussion of techniques

The RBNB for use in general practice should ideally be relatively straightforward to perform following a well-defined protocol, provide predictable anaesthesia to the globe and orbit, and have a low risk of complications. The ease with which a RBNB protocol can be performed relies on having well-defined and identifiable landmarks for needle placement and reliable indicators for when the needle has reached an appropriate position for anaesthetic injection. The latter will ensure that anaesthetic is delivered to a location which will block the sensory and motor nerves within the periorbital. Of the techniques visited in this literature review, the RBNB-SOF has the technique whereby accurate needle placement can most easily be identified and involves placement in a location with the fewest vulnerable structures.

The RBNB-4P and RBNB-MP/P techniques involve injection in the region of the orbital apex. This region consists of a high density of cranial nerves, arteries, veins and extraocular muscle insertions passing from the optic canal, orbital fissure and rostral alar foramen (**Fig 1**, 'orbital apex'). Furthermore, just ventral to the periorbital lies the maxillary artery which is a direct branch of the internal carotid artery and associated maxillary nerve (CN V).

In the summary of the RBNB-4P technique by Pollock *et al.* (2008), a prebent, 20 gauge, 9-cm needle is inserted at the 12, 3, 6 and 9-o'clock positions around the orbit, and the needle is advanced along the curve of the bony orbit until the most caudal aspect of the orbit is met. However, using the orbital bone as a guide is only possible dorsally and medially, as the orbit of the horse is open. Although the orbital 'rim' is complete and ventrally and laterally and this may provide an initial guide, beyond the rim there is no bony orbital wall to follow; therefore needle passage through the soft tissue is not facilitated by any specific landmarks. This is of particular importance ventrally due to the proximity of the maxillary artery and nerve which lie just ventral to the orbital cone, making the technique a risk for haematoma formation and neuritis (Tremaine 2007). The RBNB-4P technique described by Hewes *et al.* (2007) involves advancing the needle until it is approximately two-thirds of the way around the globe and as such avoids the risks associated with injecting in the region of the orbital apex; despite this, there is still no reliable way of establishing if the periorbital has been penetrated prior to injection of local anaesthetic.

The RBNB-MP/P technique utilises a long, curved needle, injected 1cm lateral to the lateral canthus of the eye (Raffe *et al.* 1986), while Tremaine (2007) described a 8-cm needle over zygomatic arch, and then advanced in a ventromedial path. The injection point is defined as when the medial orbital bone is reached (Tremaine 2007); this is not specified by Raffe *et al.* (1986). From these descriptions, there are no reliable indicators to determine when the needle has reached an appropriate position with respect to the periorbital or orbital apex, and as such, it is impossible to be certain as to the exact location of the local anaesthetic injection.

In contrast, however, the RBNB-FOS needle placement is just caudal to the globe, thereby avoiding the risks associated with injections into the region of the orbital apex. Furthermore, the sigmoid flexure in the optic nerve in which it courses ventrolaterally before entering the globe leaves it less vulnerable to damage from a needle placed through the dorsal periorbital. The landmarks for needle placement are well defined and easily identified, and accurate needle positioning for anaesthetic injection can be identified by the initial dorsal globe movement (when the needle impinges in the periorbital), the tactile 'pop' as this fascial plane is penetrated, and the return of the globe to a central position once the periorbital is penetrated.

Discussion of complications

The published complications associated with all types of RBNBs are low:

- Raffe *et al.* (1986) 1/12 (RBNB-MP);
- Hewes *et al.* (2007) 0/5 (RBNB-4P);
- Pollock *et al.* (2008) 5/40 (RBNB-4P 36/40 & RBNB-FOS 4/40);
- Oel *et al.* (2014) 0/5 (RBNB-FOS);
- Gilger and Davidson (2002) 2/189 (RBNB-FOS)

The greatest limitation on interpreting these data is that in most studies, the globes have been enucleated, and as such, there is no way of determining whether significant trauma to the neurovascular structures of the globe or orbit was damaged. In the study by Raffe *et al.* (1986), 50% of horses had procedures not involving enucleation, and in the papers of Hewes, Pollock and Oel, all eyes were enucleated.

TABLE 2: Summary of retrobulbar block complications

Reference and study type	Patient group	Theoretical complications described	Key results; complications experienced	Study weaknesses
Raffe <i>et al.</i> 1986 •Retrospective •RBNB-MP	12 enucleation cases with retrobulbar nerve blocks, and a control group of 25 enucleations without retrobulbar nerve blocks.	Optic neuritis, trauma to retrobulbar structures, stimulation of the oculocardiac reflex.	Bradycardia (4/25 of the control group, 1/12 of the retrobulbar group). No other complications described.	Small sample size. 6/12 nerve block cases were enucleated; unable to determine neurovascular damage to orbit/globe postsurgery, or if the eye was visual. The authors state that there was 'no signs of tissue injury', such as optic neuritis from gross evaluation, but does not exclude potential for neurovascular damage without histopathology. Unsure if bradycardia was due to traction or an incomplete block.
Gilger and Davidson 2002 •Retrospective •RBNB-SOF	189 retrobulbar blocks performed between 1996–2001; the author estimated 80–85% of these were for non-enucleation procedures (personal communication).	Orbital abscesses and cellulitis, trauma to the extraocular muscles, optic nerve, sclera and ophthalmic arteries.	2/189 complications; one lidocaine hypersensitivity causing generalised hives and retrobulbar swelling, and one post-operative ulceration. No complications associated with block administration.	
Hewes <i>et al.</i> 2007 •Retrospective •RBNB-FP	Standing enucleation in 5 adult horses.	Not discussed.	No complications reported. Minimal haemorrhage, no contralateral blindness.	Small sample size. All retrobulbar nerve block cases enucleated so unable to determine neurovascular damage to orbit/globe postsurgery, unable to assess if eye was visual.
Pollock <i>et al.</i> 2008 •Retrospective •RBNB-FP, and RBNB-SOF	Standing transpalpebral enucleation in 40 horses between 2003–2007. 36/40 with a four-point retrobulbar nerve block and 4/40 with a retrobulbar nerve block via the supraorbital fossa.	Vagal nerve stimulation causing cardiac dysrhythmias.	Complications referred to the surgery itself rather than the block; mild oedema around the surgical site (5), facial nerve paralysis (1) which resolved 3 h post-operatively, 1 serosanguinous discharge which was treated with 20 mg/kg metronidazole orally, twice daily.	All retrobulbar nerve block cases enucleated so unable to determine neurovascular damage to orbit/globe postsurgery, unable to assess if eye was visual.
Oel <i>et al.</i> 2014 •Prospective •RBNB-SOF	16 horses undergoing enucleation under inhalation anaesthesia only (10), or retrobulbar nerve block and inhalation anaesthesia (6).	Not discussed.	No complications of the block discussed. 1 transitory bradyarrhythmia which didn't require treatment; 2 in the nonretrobulbar group, 1 of which required atropine.	Small sample size. All RBNB cases enucleated so unable to determine neurovascular damage to orbit/globe postsurgery, or if eye was visual.

Therefore, for these techniques we may have false negatives for 'no complications'. By contrast, Gilger and Davidson were the largest study involving 189 horses (RBNB-FOS) of which 80–85% were procedures other than enucleation (personal communication). Therefore, we can have a higher confidence that this paper is reflective of the complication rates associated with this technique.

Only one case experienced a suspected post-operative infection (Pollock *et al.* 2008). The RBNB itself often does not merit use of antimicrobials; however, for enucleations, there is a risk of surgical site infection due to the indication itself for enucleation (corneal perforation, infected ulcers), potential implant placement, opening of the conjunctival sac, increased difficulty maintaining asepsis in a standing surgery

as opposed to in a theatre, the duration of the procedure itself and prolonged use of antimicrobials predisposing to resistant bacteria (Huppes *et al.* 2017). Therefore, there may be some bias towards a low-rate of infection following the RBNB, as practitioners elected to use antibiotics for the enucleation procedure.

All of the above studies were performed within a referral hospital environment. One must therefore bear in mind that the experience of the practitioner and their familiarity with the technique influences the rate of complication.

Other complications reported in equine practice (such as the aforementioned haematoma formation, intra-meningeal injection and trauma to the globe and/or optic nerve) were not reported in any study.

Clinical message

This article seeks to clarify whether clinicians should be concerned for the complications of a retrobulbar block in clinical practice. There are only a small number of reported studies on complications of the retrobulbar block in horses, but these indicated a low incidence of complications. The retrobulbar block can be utilised for standing ophthalmic procedures or to increase physiological stability within a general anaesthetic, with few reported complications. The practitioner must be aware that potential complications may be reported as low in incidence, however, they are of high morbidity, including vision loss, seizure or death of the patient. In all of these studies, the practitioners performing these blocks are in specialist institutions; the indications for the RBNB are predominantly for procedures within a referral institution, and therefore, the first-opinion practitioner must be cognisant that it has potential for a high risk of complications outside of this setting. With the exception of a standing enucleation, the first-opinion veterinarian may never need to use this block. As previously stated, the RBNB-SOF has the best defined and most easily identifiable indications of successfully reaching the desired site for injection and has a low reported complication incidence in nonenucleated eyes, which is a better indicator of true morbidity to the globe caused by a

RBNB than in enucleated studies. Hence, it would be the author's recommendation that experienced practitioners who are familiar with the procedure utilise this block for cases where local analgesia and sedation do not suffice.

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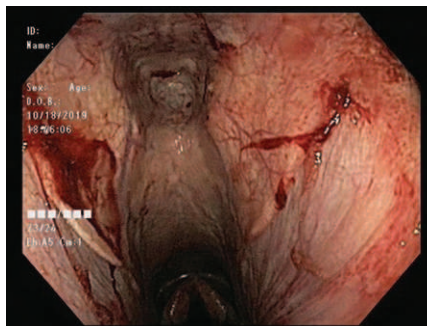
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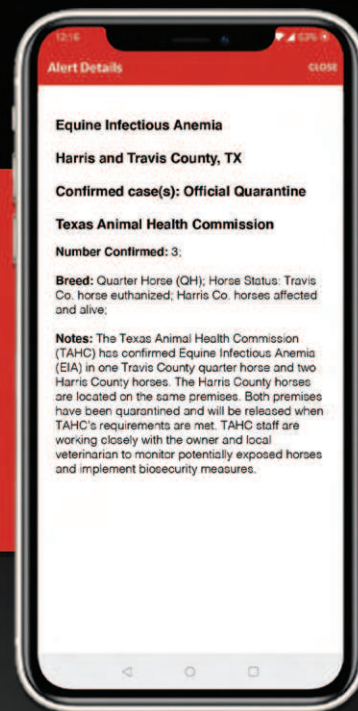
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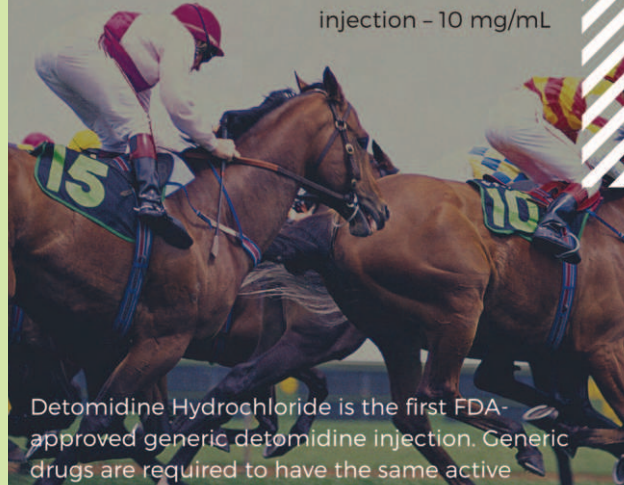
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