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American Edition | September 2020

EQUINE VETERINARY EDUCATION/AMERICAN EDITION

VOLUME 32 NUMBER 9

SEPTEMBER 2020



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

IN THIS ISSUE:

- From the president: Winds of change
- Dental bridging as a treatment for large oral fistulae in two horses
- Suspected hepatic amyloidosis in a horse

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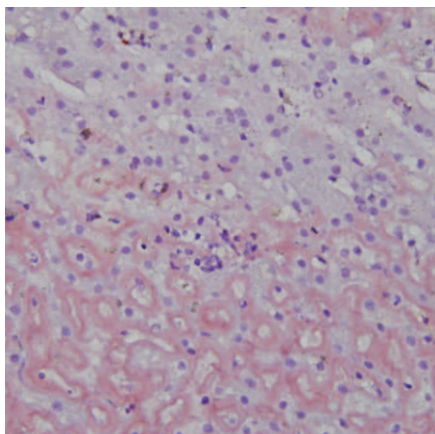
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Published monthly. Deadlines are the seventh of the preceding month.

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

EQUINE VETERINARY EDUCATION

AMERICAN EDITION

SEPTEMBER 2020 • VOLUME 32 • NUMBER 9

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Equine Veterinary Education (American Edition ISSN 1525-8769) is published monthly by the American Association of Equine Practitioners, an international membership organization of equine veterinarians. Office of publication is 4033 Iron Works Parkway, Lexington, KY 40511. Periodicals Postage paid at Lexington, KY and additional mailing office. POSTMASTER: Send address changes to: *Equine Veterinary Education*, 4033 Iron Works Parkway, Lexington, KY 40511.

Communications regarding editorial matters should be addressed to: The Editor, *Equine Veterinary Education*, Mulberry House, 31 Market Street, Fordham, Ely, Cambridgeshire CB7 5LQ, UK. Telephone: 44 (0) 1638 720250, Fax: 44 (0) 1638 721868, Email: sue@evj.co.uk.

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All subscription inquiries should be addressed to: Subscriptions Department, AAEP, 4033 Iron Works Parkway, Lexington, KY 40511, Telephone: (859) 233-0147, Email: jcooney@aaep.org. Subscription rates: AAEP annual membership dues include \$40 for a subscription to *Equine Veterinary Education*. Other subscriptions at \$151.80. Single copies \$37.50.

Canadian Subscriptions: Canada Post Corporation Number 40965005. Send change address information and blocks of undeliverable copies to IBC, 7485 Bath Road, Mississauga, ON L4T 4C1, Canada.

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Printed by: Cenveo Publisher Services, Lancaster Division, Lancaster, PA.

From the president: Winds of change

By David Frisbie, DVM, Ph.D., DACVS, DACVSMR



Dr. David Frisbie

Autumn is coming, bringing with it the changing of leaves and seasons. Change seems to be the ongoing theme, and, through it, I hope you and your loved ones are safe and well. In my June president's letter, I was grappling with uncharted territories in everyday life, as were most of you. Although each day brings fresh challenges, and stability or a clear under-

standing of the future have not yet materialized, we are adapting and creating new routines.

Happily, one thing that has not changed is that we continue to see fellow members doing great things. This summer, the AAEP invited horse owners to nominate their equine veterinarian for the My Vet Rocks contest, and the heartfelt stories received truly showcase our clients' admiration for our profession. More than 130 AAEP members were nominated for recognition, and the June and July honorees are featured on page IX in this issue. Congratulations to each of you for serving your communities and creating bonds that benefit the horse.

In July, your board of directors met remotely. On the agenda were recommendations from the Nominating Committee; financial review; discussion about CE offerings, including the annual convention; diversity and inclusion initiatives; and committee updates. Some highlights of these topics include the approval of Drs. Rob Franklin and Amy Grice for vice president and treasurer, respectively, as well as approval of board candidates and award recipients, for which more information is forthcoming. Our financial update indicated that the year to date was comparable to that of 2019; with general reductions in expenses, we are still in a favorable cash position. While our cash reserves remain intact, this rainy day fund stands ready if needed and may be dependent on the annual convention financial picture.

Our two biggest sources of income are membership dues and the annual convention. Membership renewal is also on par with 2019 with renewals occurring earlier than past years. Many thanks to all of you for your support.

We have worked diligently this summer to gather information and opinion around the annual convention, including input from our educational partners, trade show attendees and, importantly, our membership. Again, a shout-out to our membership for your engagement by providing over 1,000 responses within the first 24 hours

to our late-July convention survey. The board has continued to monitor the re-opening of Las Vegas as well as compile all the data currently available from our membership and stakeholders. After careful consideration of all the data as well as the potential safety risks to our members, staff, exhibitors and other attendees from the ongoing COVID-19 pandemic, the board voted unanimously in mid-August to hold this year's annual convention and trade show as a virtual event. While disappointed to not be able to gather in person this year, we are excited about the opportunities for education and connection presented by a virtual convention and trade show. The educational program will offer a blend of live and on-demand sessions, ensuring that you can conveniently earn CE hours based on your personal schedule. Exact dates and the schedule of sessions and events will be announced in September.

Looking outward, our nation, and the world, are in a state unlike any other time in history. In an age where fear, social unrest and anxiety fuel mistrust and a divided nation, our profession is a source of light. While we come from many backgrounds, creeds and beliefs, we are brought together by a common goal. The horse, a creature that is almost mythical in its public perception, holds the ties that bind us. I see people who would

otherwise not be friends or even acquaintances drawn together in friendship and respect due to their common love and service to the horse. This is the type of bond that allows us to see the best in each other, to find the light at the end of the tunnel and to help lead a movement of better understanding and respect to our fellow human beings. To help augment what the horse already does for us, the AAEP board at our recent meeting approved a task force to evaluate our current and future efforts in diversity and inclusion.

Although it is undeniable that the future holds a changing landscape, there are some things we can always count on. For this organization and our membership, it is the commitment to the horse and the people who love the horse. The AAEP will continue working to provide the best continuing education and support to its members in fulfilling the goals of advancing the welfare of horses everywhere.

This is the type of bond that allows us to see the best in each other, to find the light at the end of the tunnel and to help lead a movement of better understanding and respect to our fellow human beings.

Directors meet virtually to chart the months ahead

By David Foley, AAEP Executive Director



David Foley

With proliferation of COVID-19 causing cancellation or postponement of many in-person gatherings, the AAEP board of directors met July 20 by videoconference to conduct its summer meeting. Much of the half-day meeting involved updates from our various committees, councils and task forces. There was also discussion of the status of our annual

convention scheduled for early December in Las Vegas, Nev. Following is a synopsis of the meeting:

The Nominating Committee reviewed and recommended candidates for our board of directors' ballots, 2021 vice president and treasurer positions, and annual awards. Ballots for the three open board positions have been established and voting will occur in late August through early September. The committee comprehensively reviews candidates to ensure the board maintains an appropriate balance of skills and perspectives. Dr. Rob Franklin was selected as the next vice president and will assume the presidency in 2023. Dr. Amy Grice was selected for a three-year term as the next treasurer. Meanwhile, award recipients will be announced during the annual convention.

Board deliberations then shifted to a variety of discussion items, beginning with a review of the budget, which showed a consistent year-to-date comparison with 2019. Reduced general office, travel and committee meeting expenses have boosted AAEP's cash position; however, our cash position would be significantly reduced if unable to conduct an in-person convention.

The board was informed that AAEP staff had been conducting convention scenario planning, which included discussions with educational partners and a survey of exhibitors. Members were to be surveyed in late July. The exhibitor and member surveys may be repeated in late August to discern any trends that, when coupled with ongoing financial scenario planning, potential travel bans and exploration of a virtual option, would help the board decide by early-September whether to proceed with an in-person meeting. While Mandalay Bay, the AAEP convention hotel, is open for business, current regulations in Nevada preclude gatherings of over 50 people, so governmental regulations may dictate any decision about an in-person convention in 2020.

Following convention discussions, the board focused on potential correlations between current societal events and equine veterinary practice. Specifically, the board approved a motion to form a task force to examine

diversity and inclusion issues within both the profession and the association. The task force will be formed in August and will audit the association's activities and programs to ensure that the AAEP is providing opportunities for all members to participate and creating a welcoming environment at its events. Until more formal action could be taken, the following interim statement was approved: "The AAEP's mission is to champion the health and welfare of the horse and we welcome and encourage anyone of any ethnicity, identity, and background who shares this mission to join us. Recent events have again reminded us to be vigilant in this area, a mission the board has recently discussed and is taking action to ensure."

The discussion items portion of the meeting concluded with review of the feasibility of the Leadership Development Workshop planned for this fall in Lexington, Ky. Considering COVID-19 disruption, the board approved a motion to postpone the workshop until 2021 to allow for an in-person event.

The meeting's focus then turned to work group recommendations. Specific actions taken included:

- Approval of a recommendation from the Finance Committee to change its charge and composition. This motion requires a Bylaws change, so it will need to be presented for a vote at the General Membership Meeting for approval.
- Referral to the Nominating Committee of a President's Advisory Council recommendation to add an additional board position; and approval of a recommendation to remove the 15-year restriction on eligible officer candidates.
- Approval of a Professional Conduct and Ethics Committee recommendation to change the policies and procedures surrounding disciplinary action to be better harmonized with the Bylaws. The board also provided input on ethical scenarios the committee has proposed to run in *EVE* and/or *Spur*.
- Approval of a revised motion regarding Student Task Force recommendations to table action on chapter activities (receptions) and chapter grant programs; send chapter activities (wet labs) and scholarships to the Foundation Advisory Council for funding consideration; and approve various communications-related items.

Additional topics discussed that did not require board action included the prospect of a New Graduate program, digital education, mentorship and the current state of practice.

The next scheduled meeting of the board will be held in December in conjunction with the annual convention.

Acquire telemedicine guidance during new Practice Life podcast



“Don’t think of telemedicine as substituting for, but as enhancing what we are doing,” according to the University of Pennsylvania School of Veterinary Medicine’s Dr. Cris Navas on the most recent episode of the AAEP Practice Life podcast.

The 36-minute episode, entitled “Equine Telemedicine,” is hosted by Dr. Mike Pownall and explores the experiences and recommendations of three equine practitioners: Dr. Navas; Dr. Elizabeth Herbert, owner of Adelaide Plains Equine Clinic in Gawler, South Australia; and Dr. Erica Lacher, owner of Springhill Equine Veterinary Clinic in Newberry, Fla.

Discussion included fees and how to charge, ideally suited cases, potential pitfalls and onboarding clients. To facilitate her clients’ adoption and use of telemedicine, for instance, Dr. Lacher at routine calls distributes a card containing relevant information on installing and using the practice’s telemedicine app so that clients can get set up in advance should they ever need or want to use the service. In addition, she created a “Telemedicine How-To Video” that shows clients how to take proper photos and videos of eye injuries, lacerations and lamenesses. The video is available on the practice’s Youtube channel at youtube.com/user/SpringhillEquineVet.

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

Practitioners from Texas and Montana named AAEP officers

Drs. Rob Franklin and Amy Grice have been named officers of the AAEP and will assume their respective positions when installed at the end of 2020. Dr. Franklin has been named 2021 vice president and will assume the role of AAEP president in 2023; Dr. Grice has been named treasurer and will serve a three-year term.



Dr. Rob Franklin

Rob Franklin, DVM, DACVIM

Dr. Franklin is a partner in Fredericksburg Equine Veterinary Services in Fredericksburg, Texas, and a strong advocate for equine-humanitarian efforts through his support of working equid welfare.

Dr. Franklin, who earned his veterinary degree from Texas A&M University, is a founding director of the Equitarian Initiative and has led

more than 15 veterinary medical trips to Central America since 2012 to administer care to the region’s working equids and education to caretakers. He is also co-founder of the animal nutritional supplement company Animal Stewards International, whose pay-it-forward model helps animals in need in underdeveloped countries.

An AAEP member since 1998, Dr. Franklin serves as chair of the Wellness Committee and previously served on the board of directors from 2015-2017. In addition, he has volunteered as a member of the Educational Programs and Nominating committees. He is co-founder and past president of the Texas Equine Veterinary Association, past president of the Marion (County, Fla.) Veterinary Medical Association and a former director of the Florida Association of Equine Practitioners. He has published numerous book chapters and peer-reviewed journal articles, and he has presented at national and international veterinary conferences.



Dr. Amy Grice

Amy Grice, VMD, MBA

After 25 years as an ambulatory equine practitioner with Rhinebeck Equine in Rhinebeck, N.Y., Dr. Grice resigned as managing partner of the large referral practice in 2015 to launch a veterinary business consulting practice in Virginia City, Mont. She established Amy Grice VMD, MBA, LLC to help veterinarians navigate challenging practice environments to lead more successful and satisfying lives.

Dr. Grice received her veterinary degree from the University of Pennsylvania and her MBA from Marist College School of Management. She frequently speaks at educational seminars for veterinarians and contributes veterinary business articles to AAEP Media Partner *EquiManagement*. In addition, she facilitates regional Decade One networking groups for early-career veterinarians and serves on the AVMA Veterinary Economics Strategy Committee.

An AAEP member since 1990, Dr. Grice currently serves on the Wellness Committee. She previously served on the board of directors from 2016-2018, the Foundation Advisory Council, and the Educational Programs, Leadership Development, Nominating and Owner Education committees. She received the 2017 AAEP President’s Award for her central role in the development of the AAEP-AVMA Economic Survey.

5 things to know about AAEP this month

1. If you are now in a COVID-19 hotspot, acquire health and safety tips for you and your practice at aaep.org/resources/covid-19-resources-veterinarians.
2. Racetrack practitioners: Read the newly expanded AAEP Guidelines for the Necropsy of Racehorses at <https://tinyurl.com/aaepnecrh>.
3. International members: AAEP's reinstated document retrieval service is available to you. Request copies of articles, book chapters and conference papers at membership@aaep.org.
4. View the AAEP's new African Horse Sickness Guidelines or save them as a PDF to your mobile device at <https://tinyurl.com/aaepahsg>.
5. Access an online special issue of EVE containing 16 original articles on "equine medicine" at wileyonlinelibrary.com/journal/eve. The issue is free access until Nov. 1.

African Horse Sickness Guidelines published

The AAEP has published comprehensive guidelines to assist practitioners and regulatory agencies with identification, diagnosis and control of African horse sickness (AHS), a highly fatal, internationally reportable disease of equids.

Although AHS does not occur in horses in the United States, a recent outbreak in Thailand, with a 94% mortality rate, illustrates the devastation possible when the non-contagious, insect-borne infectious disease affects a naive horse population.

"The potential risk of introducing endemic or transboundary diseases into the country's equine population cannot be over emphasized, either at the level of the practicing veterinarian or the horse-owning public," said guidelines author Dr. Peter Timoney, the Frederick Van Lennep Chair in Equine Veterinary Science at the University of Kentucky's Gluck Equine Research Center. "Failure to suspect the occurrence of such a disease could have major consequences, especially when dealing with a contagious disease or a vector-borne disease like African horse sickness."

"We must remain vigilant through the USDA's strict testing of horses at points of entry into the U.S. and expand awareness among equine practitioners to prevent the potential detrimental effects of AHS and other endemic or



A horse affected with the cardiac form of AHS presenting with significant swelling of the supraorbital fossa and a bilateral conjunctival discharge.

transboundary diseases," added Timoney. "The risk applies not only to horses but also to other equid species, specifically zebra, that are sought after for zoos and privately owned wildlife or safari parks."

The African Horse Sickness Guidelines were edited and reviewed by Dr. Abby Sage along with the AAEP's Infectious Disease Committee. View the guidelines or save them as a PDF file to your mobile device at <https://tinyurl.com/aaepahsg>.

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The Hawthorne Effect and racetrack practice

By Kevin Dunlavy, DVM



Dr. Kevin Dunlavy

In the last two years, virtually every aspect of the horse racing industry has been under increased scrutiny, with much of that increased scrutiny specifically directed at racetrack veterinary practice. As a result, the practice of veterinary medicine on the racetrack has been called to a new standard of accountability.

The Hawthorne Effect is a type of reactivity in which

individuals modify an aspect of their behavior in response to their awareness of being observed. As racetrack veterinary practitioners, we are being observed and the resultant reactivity is a good thing. It is causing the practitioner to reassess medical treatments and the medical ethics of those treatments.

A good case in point has been the practice of dispensing supplements like Thyro-L (levothyroxine). Although the literature is clear that hypothyroidism in the horse is rare, an all-too-common practice has been wholesale treatment of entire stables. We can all agree that thyroxine supplementation may be beneficial in individual cases, and those cases are based on lab work, exam and clinical signs such as horses with poor hair coats, lethargy or juvenile obesity. But is it an ethical practice to dispense a prescription medication to an entire stable? The concept of herd treatment is simply not medically justifiable and modifying this type of behavior will not only serve the racing industry but, more importantly, the horse.

Medical records are another area of increased accountability. Traditionally, the medical records of most racetrack practices have consisted of an invoice of billed procedures. The medical records would rarely reflect any detailed patient information or any of the thought process behind the treatments. The lack of a detailed medical record is a substandard practice.

As state racing commissions and racetracks have requested and enforced transparency of medical treatment, the need for more detailed medical records is an ever-increasing necessity. The ethical and legal question of confidentiality of medical records is typically addressed in the Veterinary Practice Act of each state, and it is incumbent upon the practitioner to know who is entitled to that information. In some states, the Veterinary Practice Act has been

amended to allow for veterinary reporting requirements to regulatory authorities. Racetracks have also instituted Conditions of Racing whereby veterinarians, trainers and owners agree to transparency of medical records. Needless to say, the accountability of complete medical records is an ethical goal we should all strive for.

The scrutiny of horse racing has also caused the practitioner to consider the concept of risk aversion or, more accurately, the evolution of risk aversion. Although risk aversion is typically used in economics and finance, the concept for the veterinarian is to minimize as many health risk factors as possible for the horse. Hopefully, the evolution of risk aversion is the selection of the opposite, advantageous selection; what that means is an opportunity to truly represent the horse. There is inherent risk in horse racing, and there is also the opportunity to minimize as many health risk factors as possible. Numerous racetracks have instituted guidelines for the express purpose of evaluating a horse's fitness to race and work. These guidelines require the trainer's attending veterinarian to perform these exams prior to the scheduled race or work. These exams present an opportunity for the practitioner to not only be risk averse but advantageous selecting.

Regardless of discipline of equine practice, the Hawthorne Effect can call us all to a new standard of accountability. Protecting the health and wellbeing of the horse is our moral obligation as equine practitioners, and the racetrack veterinary practitioner is being called more than ever before to intercede on behalf of the horse.



"The accountability of complete medical records is an ethical goal we should all strive for."



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Every Day-Every Time

Dr. Dunlavy is managing partner of Kentucky Equine Medical Associates, PLLC in Louisville, Ky. He is a member of both the AAEP's Racing Committee and Professional Conduct and Ethics Committee.

More than 250 crack the code during AAEP's first virtual CE event

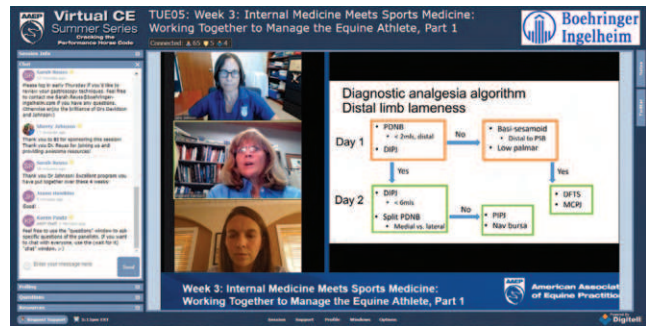
Much as COVID-19 has influenced the practice of veterinary medicine in 2020, the global pandemic has similarly altered how practitioners acquire their necessary CE hours.

Following postponement of AAEP's traditional summer meetings until 2021, the association's inaugural venture into live online CE crossed the finish line Aug. 27 as 254 practitioners and veterinary students tuned into the monthlong Virtual CE Summer Series, "Cracking the Performance Horse Code: Interdisciplinary Strategies to Maximize Clinical Outcome."

Featuring a pair of live two-hour sessions each week in August with on-demand options for those unable to attend any of the live sessions, the series provided 16 hours of RACE-approved CE on interdisciplinary diagnostic, therapeutic and rehabilitative strategies for performance horses.

"I was at a loss as to how I was going to get CE this year and this has really saved me," said Dr. Kathleen Paasch, ambulatory practitioner and partner in Rood & Riddle Equine Hospital in Lexington, Ky., after Week 1 of the series. "Just as importantly, I'm getting a lot out of it!"

2020 has been a transformational year for AAEP's educational offerings. In addition to hosting its first live virtual



event, in April the association launched the AAEP Anywhere online learning platform (at aaepanywhere.org) through which members can pick up an hour or two of complimentary CE toward license renewal.

"While in-person learning remains an important component of our educational offerings, ramping up our digital education presence is essential to providing members with as much flexibility and choice to acquire relevant CE in multiple formats and on their schedule," said AAEP Director of Education Karen Pautz.

The AAEP thanks Boehringer Ingelheim, Equithrive, Hallmarq and PulseVet for their sponsorship of the Virtual CE Summer Series.

SHINE

2020 VIRTUAL CONVENTION & TRADE SHOW

Complete your CE needs for 2020 during the AAEP Virtual Convention & Trade Show! The educational program and event schedule, featuring both live and on-demand sessions, will be announced in September.

Visit aaep.org/meetings for updates!

Coming this December

My Vet Rocks honors members' practice excellence



Six AAEP members providing exemplary care to clients and their horses have been announced as the June and July honorees in the AAEP's My Vet Rocks Contest, which celebrates the important relationship between veterinarian, owner and horse. Veterinarians are nominated by their horse-owning clients, and each month's overall winner receives a prize package from the AAEP and contest sponsor American Regent Animal Health. In addition, the monthly winners are eligible to win the contest's grand prize, which will be announced later this year in conjunction with the AAEP's 66th Annual Convention.

June Honorees



Dr. Jonathan Yardley



Dr. Kate Hodson



Dr. Bob Meyer

Win: Dr. Jonathan Yardley, associate professor-clinical in Equine Community Practice, The Ohio State University College of Veterinary Medicine, Columbus, Ohio

Place: Dr. Kate Hodson, owner, Hodson Veterinary Services LLC, Hebron, Ind.

Show: Dr. Bob Meyer, co-owner, Neuse River Equine Hospital, Wendell, N.C.

Patience, stall-side manner and commitment to client education were common themes among the nomination letters received in support of Dr. Yardley. According to nominator Mindy Ridgeway, "Not only is he a compassionate and talented veterinarian, he is also a brilliant educator. ... As an owner, it is such a valuable learning experience and he never misses an opportunity to educate as he rounds in the hospital and in the field. He is realistic, yet optimistic as he helps me achieve optimal health and long-term soundness for my horse."

Dr. Yardley manages the university's general equine veterinary practice, where he provides a broad range of clinical care while also educating fourth-year veterinary students and interns.

"Sometimes, veterinary medicine can be a thankless job but it's a great feeling to know that what you're doing for clients and their animals is being received positively," said Dr. Yardley, who received his veterinary degree from Tufts University in 2006. "It gives me motivation to keep doing what I'm doing and to continue to practice the way I'm practicing. It's pretty cool."

July Honorees



Dr. Aimee Eggleston



Dr. Kim Abernathy Young



Dr. Emilie Setlakwe

Win: Dr. Aimee Eggleston, owner, Eggleston Equine LLC, Woodstock, Conn.

Place: Dr. Kim Abernathy Young, owner, Kentucky Lake Equine Hospital, Benton, Ky.

Show: Dr. Emilie Setlakwe, associate, Tryon Equine Hospital, Columbus, N.C.

Her nominators lauded Dr. Eggleston's responsiveness, attentiveness and compassion. According to nominator Rachael Maginess, "Her ability to explain a situation to an owner is perhaps one of her greatest strengths. ... She has spent hours on the phone with me over the years discussing treatment options, the side effects of surgeries, medications and has never rushed me off the phone or dismissed a question or concern that I had about either of my horses."

Dr. Eggleston received her veterinary degree in 2000 from Tufts University. In 2005, she and husband Tim established her solo ambulatory practice, which serves horse owners throughout Connecticut, Massachusetts and Rhode Island.

"We've definitely tailored the practice to the idea that our patients and clients are family to us," she said. "It's very meaningful to help influence the health and care of our clients' horses, and their awareness and appreciation of the business model I've worked 20 years for provides a sense of accomplishment."

Benefit: Keep up with AAEP and The Foundation with the Publications App

Like its name suggests, the AAEP Publications App is your digital source for the association's catalog of publications, including *Equine Veterinary Education*, Annual Convention *Proceedings*, annual report, Spur, white papers and guidelines. You'll also find COVID-19 resources as well as The Foundation for the Horse annual report and newsletter on the free app.

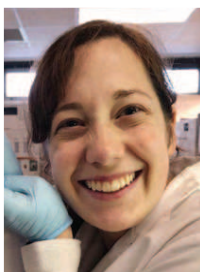
Digital editions of AAEP's publications are generally available on the app prior to their print counterparts dropping in the mail.

Besides the library of publications, the app also features a "Member Lookup" button through which you can acquire contact information via a quick and simple search by name of the membership database. What previously required thumbing through 250+ pages of member listings in the discontinued membership directory can be accomplished in seconds from anywhere with Internet access.

Download the app at no charge by searching "AAEP Publications" at the App Store or Google Play.



Members in the news



Dr. Ashley Steuer

Dr. Ashley Steuer named outstanding graduate student

Dr. Ashley Steuer, Zoetis Resident in Veterinary Parasitology at the University of Kentucky Gluck Equine Research Center, was named the 2020 AAEP/Merck Animal Health Outstanding Graduate Student during the American Association of Veterinary Parasitologists yearly scientific conference in June.

Dr. Steuer received her veterinary degree in 2016 from the University of Tennessee. Watch her virtual conference presentation, entitled "Cyathostomins: Their Interaction with the Equine Host and with My Life," at <https://tinyurl.com/aavpmah>.



Megan Fahey

Student member Megan Fahey recognized for research

Megan Fahey, a DVM and Ph.D. degree student at Cornell University College of Veterinary Medicine, received the 2020 Boehringer Ingelheim Veterinary Research Scholar Award during the virtual Veterinary Summer Scholars Program in early August.

Fahey's work in the scholars' program has explored use of mesenchymal stem cells to prevent or reduce degeneration in intervertebral disc disease. She is committed to a career as a veterinary clinician scientist, and her research interests focus on zoonotic disease, virology and immunology.

Drs. Mienaltowski, Whitfield-Cargile appointed to Morris Animal Foundation board

Dr. Michael Mienaltowski and Dr. Canaan Whitfield-Cargile have been appointed to the Morris Animal Foundation's Large Animal Scientific Advisory Board, which provides objective review from experts in the field to ensure the Foundation supports the highest quality research.



Dr. Michael
Mienaltowski



Dr. Canaan
Whitfield-Cargile

Dr. Mienaltowski is an associate professor of applied physiology at the University of California, Davis Department of Animal Science. He received his veterinary degree from Michigan State University in 2004.

Dr. Whitfield-Cargile, who received his veterinary degree from the University of Georgia in 2006, is an assistant professor of large animal surgery at Texas A&M University and the 2016 recipient of the AAEP Foundation Past Presidents' Research Fellow.

A Community that Cares *For Horses*



Established to unite everyone who is dedicated to improving the health and well-being of horses, The Foundation for the Horse provides support for horses in need, relevant research and continued education for future equine veterinarians.

JOIN US TODAY! Your gift will ensure horses in need get the care they deserve.



Equine Welfare Data Collective releases second report

Following release last fall of its inaugural report that analyzed equine welfare data for the first half of 2018, the Equine Welfare Data Collective (EWDC), whose funding partners include The Foundation for the Horse, has released its second report analyzing similar data for July–December 2018.

Data collected across the two reports captures 32.86% of the total population of 501(c)(3) and municipal organizations within the United States and Puerto Rico that take custody of at-risk equines. The data analysis is reported on a national and regional level. Respondents varied widely, from small capacity organizations capable of caring for fewer than 10 equines at any one time, to larger organizations with capacity for over 100 equines.

The robust sample size of the second report allowed for national estimates of the maximum number of at-risk equines the total population of equine welfare organizations is able to care for at any one point in time. The estimated total maximum capacity of the entire population of organizations that take custody of equines in the United States and Puerto Rico at any one time is 47,194 equines (95% CI, Std. Err. 4,664, lower 95% 38,017, upper 56,370, accounting for outliers).

“With the coming of this second report, we can truly start to have a better understanding of where we stand as a nation when it comes to the welfare of the equines in our care by supplying factual data and analysis—not just anecdotal opinions. This report is the continuation of a baseline of incredibly crucial information that we can build upon and expand as more data is contributed to the survey,” said Ashley Harkins, program director of the United Horse Coalition.

View EWDC reports or contribute data for the current collection period at unitedhorsecoalition.org/ewdc. It is critical to continue tracking data related to at-risk equines and identify trends, especially so during the current extraordinary times.



INDUSTRY

AAEP Media Partner Profile: *The Horse*: Your Guide to Equine Health Care



The Horse provides hands-on participants in the horse industry with accurate, up-to-date horse health information. AAEP members, both on our editorial advisory board and beyond, are trusted sources and respected reviewers of our world-class content. We consistently reinforce the value of working with equine practitioners to provide optimal care.

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¹ West Nile Virus Challenge Vaccine Efficacy, BI study number: V9 2009 WNV 12mo DOI

² Equine Influenza Challenge, BI study number: 01 V9 6mo DOI OH/03

³ Lack of Interference - Influenza Challenge, BI study number: 2012-001 Inf. Data on file at Boehringer Ingelheim.

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Highlights of recent clinically relevant papers

Strangles

This retrospective study by Andy Durham and Jeremy Kemp-Symonds investigated the sensitivity of serological testing for antibodies against Streptococcus equi subspecies equi antigens A and C to detect guttural pouch carriers.

Retrospective data from 287 horses arriving at a welfare charity quarantine unit that underwent microbiological sampling of guttural pouches and serological testing were reviewed. In total, nine (3.1%) horses were found to be guttural pouch carriers on microbiology and 35 (12.2%) horses were seropositive (had at least one ELISA OD value ≥ 0.5). Of the 35 seropositive horses, one (2.9%) had evidence of *S. equi* in a guttural pouch lavage. Of the 252 horses with OD values < 0.5 , eight (3.2%) had evidence of *S. equi* in guttural pouch samples. One (11%) of the nine horses found to be guttural pouch carriers was seropositive at a cut-off of OD ≥ 0.5 , but lowering the cut-off to OD ≥ 0.3 identified two additional guttural pouch carriers.

There was no association between serological status and guttural pouch carriage of *S. equi*. Therefore seronegativity to antigens A and C should not be relied upon when determining if a horse is a chronic carrier of *S. equi*.

Facial nerve paralysis

In this study Sophie Boorman and colleagues in the USA investigated the causes of facial nerve paralysis (FNP) and associations among clinical variables, diagnosis and outcome.

Medical records were retrospectively reviewed and 64 equids presenting with FNP were identified. Cases of post-anaesthetic FNP were excluded. Variables were evaluated for associations with outcomes (diagnosis and case outcome) using logistic regression.

The most common cause of FNP was trauma ($n = 20$). Additional diagnoses included central nervous system (CNS) disease ($n = 16$), idiopathic ($n = 12$, 4 of which had adequate diagnostic investigation and were considered 'true' idiopathic, and 8 were considered 'not investigated' idiopathic), temporohyoid osteoarthropathy ($n = 10$), otitis media-interna ($n = 3$), lymphoma ($n = 1$), iatrogenic as a consequence of infiltration of local anaesthetic ($n = 1$), and clostridial myositis ($n = 1$). Follow-up was available for 55 (86%) cases. Twenty-nine (53%) equids had full resolution of FNP, 14 (25%) were euthanised, 6 (11%) partially improved, and 6 (11%) were unchanged or worse.

The authors concluded that if FNP is the consequence of CNS disease, successful treatment of the primary disease likely leads to resolution of FNP. Most cases of FNP in equids are traumatic in origin. True idiopathic cases are uncommon.

Subchondral lucencies of the proximal tibia

In this retrospective study Elizabeth Santschi and colleagues in the USA and Australia described subchondral lucencies (SCL) in the equine proximal tibia, several treatment options, and clinical outcomes.

Seventeen horses with proximal tibial SCL were identified from a review of medical records and radiographs. Follow-up

was obtained via examination and radiography when possible and by telephone and race records when required. The median duration of follow-up was 20 months (range, 0–48). Proximal tibial SCL were associated with lameness in 14 of 17 horses. Subchondral lucencies were primary in 11 horses and secondary to an ipsilateral medial femoral condyle SCL in six horses. One foal with a primary SCL was euthanised due to osteomyelitis. Six horses ≤ 1 year old with primary SCL were managed with exercise restrictions only; SCL in three horses without lameness decreased in size, whereas three horses with lameness did not improve. One young horse treated with surgical debridement did not improve and was euthanised. Lameness resolved in three horses with primary tibial SCL treated with screw fixation. Screw fixation of secondary SCL in five horses led to a reduction in SCL size and degree of lameness.

Primary tibial SCL healed with rest in three non-lame young horses with small SCL, but was not successful in lame horses with larger SCL. Radiographic size and associated lameness improved or resolved with screw fixation in primary and secondary proximal tibial SCL.

Health of competition horses

This study by Marie Dittmann and colleagues in Switzerland assessed husbandry, use, and orthopaedic health in Swiss riding horses and compared these aspects between horses owned by self-identified competitive riders (CR) and leisure riders (LR) in Switzerland.

An online survey was completed by 237 owners providing information on their athletic ambitions, their horse's husbandry, health, training, and tack. Two experienced veterinarians assessed gait irregularities, muscular development, and back pain in the horses and evaluated saddle fit. Compared with horses owned by competitive riders (CH), a higher proportion of horses kept by leisure riders (LH) were kept unshod, under more natural conditions, and turned out with other horses. LH were exercised less frequently, and LR trained less frequently with instructors. CR reported less time since the last saddle check and the use of more training aids during riding. No differences between the two groups could be found in orthopaedic health, muscular development, or back pain, but LH had higher body condition scores and a slightly higher proportion of saddles with at least one fit problem. The data from this study revealed no increased prevalence of the assessed health problems in competition horses compared with leisure horses in Switzerland. However, suboptimal saddle fit and muscular development, back pain, and gait irregularity are frequent in both groups and deserve more attention.

Bisphosphonate treatment for lameness

In this knowledge summary, Hannah Greene from Washington State University, USA, considered the PICO question "In horses that are lame due to osteoarthritis of the distal tarsal joints (bone spavin), is intra-articular medication with corticosteroids compared to systemic bisphosphonate treatment more effective in long-term lameness reduction?"

Three papers were critically reviewed; two were randomised controlled trials, and one was a retrospective study. Insufficient evidence was found to support the use of systemic bisphosphonates over intra-articular corticosteroids to treat distal hock osteoarthritis in horses.

The author concluded that horses with distal hock osteoarthritis should not be treated with systemic bisphosphonates until further blinded randomised controlled trials are completed. Supportive evidence for the use of intra-articular corticosteroids as a treatment for degenerative hock osteoarthritis was limited to a retrospective study where modest, short-term improvements were reported: 58% of horses improved after an average of 56 days. In the randomised controlled trials evidence did not support significant improvement in long-term outcomes: 50% of horses improved after 4 months in one study and only 38% of horses improved after a mean follow-up period of 787 days in the other study.

The application of evidence into practice should take into account multiple factors, including individual clinical expertise, patient's circumstances and owners' values, country, location or clinic, the individual case, and the availability of therapies and resources.

Arthroscopy of the stifle

This cadaver and clinical study by Henry O'Neill and Bruce Bladon described and evaluated a novel arthroscopic approach to the caudal pouches of the lateral femorotibial joint as current approaches are considered challenging and risk iatrogenic nerve and cartilage damage.

The surgical technique was developed initially using 19 cadaver limbs positioned to simulate dorsal recumbency and with the stifle held in 90-degree flexion. A portal was made immediately cranial to the lateral collateral ligament and the arthroscope advanced along the popliteal tunnel of the femorotibial joint in a cranial to caudal direction.

Following the cadaver study, 33 horses underwent inspection of 38 caudal lateral femorotibial joints using the alternative technique as part of routine joint inspection. Entry and examination of both pouches of the caudal lateral femorotibial joint were consistently achieved in both the cadaver and clinical limbs, with no intra- or post-operative complications in the latter.

Foot pain in Warmblood horses

In this study, Santiago Gutierrez-Nibeyro and colleagues in the USA and Argentina determined the spectrum of foot lesions detected by magnetic resonance imaging (MRI) in Warmblood horses used for dressage, jumping and eventing.

Data including signalment, occupation, lameness, diagnostic analgesia, imaging results, treatments, and follow-up assessments were obtained from the medical records of 550 Warmblood horses with foot pain that had been scanned using standing MRI. Associations between standing MRI lesions and chronic lameness following treatment were tested. Abnormalities of the navicular bone (409 horses, 74%), distal interphalangeal joint (362 horses, 65%), and deep digital flexor (DDF) tendon (260 horses, 47%) occurred most frequently. Abnormalities significantly associated with chronic lameness following conservative therapy were moderate to severe MRI lesions in the trabecular bone of the navicular bone, mild or severe erosions of the flexor surface of the navicular bone,

moderate sagittal/parasagittal DDF tendinopathies, and moderate collateral sesamoidean desmopathies. Also, identification of concurrent lesions of the DDF tendon, navicular bone, navicular bursa, and distal sesamoidean impar ligament was associated with chronic lameness after conservative therapy. The authors concluded that development of effective treatment options for foot lesions that respond poorly to conservative therapy is necessary.

Equine proliferative enteropathy

This study by Nicola Pusterla and colleagues in the USA aimed to determine whether serum amyloid A (SAA), a major acute-phase protein, could help support the diagnosis of equine proliferative enteropathy (EPE) caused by Lawsonia intracellularis infection in foals.

Archived serum samples from 101 foals with enteric signs and hypoproteinaemia were available for SAA testing. The foals were divided into EPE-suspect ($n = 67$) and non-EPE-suspect cases ($n = 34$) based on immunodiagnostics for *L. intracellularis*. Serum amyloid A values ranged from 0 to 2761 $\mu\text{g/mL}$ (median 466 $\mu\text{g/mL}$) for the EPE-suspect cases and 0–2555 $\mu\text{g/mL}$ (median 192 $\mu\text{g/mL}$) for the non-EPE-suspect cases. Although SAA can be measured patient-side and help determine the severity of the underlying inflammatory condition, SAA was unable to consistently support the diagnosis of EPE in hypoproteinaemic foals with enteric signs.

S. WRIGHT

EVE Editorial Office

References

- Boorman, S., Scherrer, N.M., Stefanovski, D. and Johnson, A.L. (2020) Facial nerve paralysis in 64 equids: clinical variables, diagnosis, and outcome. *J. Vet. Intern. Med.* **34**, 1308–1320.
- Dittman, M.T., Latif, S.N., Hefti, R., Hartnack, S., Hungerbühler, V. and Weishaupt, M.A. (2020) Husbandry, use, and orthopedic health of horses owned by competitive and leisure riders in Switzerland. *J. Equine Vet. Sci.* **91**, 103107. <https://doi.org/10.1016/j.jevs.2020.103107>
- Durham, A.E. and Kemp-Symonds, J. (2020) Failure of serological testing for antigens A and C of *Streptococcus equi* subspecies *equi* to identify guttural pouch carriers. *Equine Vet. J.* Epub ahead of print <https://beva.onlinelibrary.wiley.com/doi/10.1111/evj.13276>
- Greene, H. (2020) Are bisphosphonates a more effective treatment than intra-articular steroids in horses with distal hock osteoarthritis? *Veterinary Evidence* **5**, 1. <https://doi.org/10.18849/ve.v5i1.235>
- Gutierrez-Nibeyro, S.D., Werpy, N.M., Gold, S.J., Olguin, S. and Schaeffer, D.J. (2020) Standing MRI lesions of the distal interphalangeal joint and podotrochlear apparatus occur with a high frequency in Warmblood horses. *Vet. Radiol. Ultrasound* **61**, 336–345.
- O'Neill, H.D. and Bladon, B.M. (2020) An alternative arthroscopic approach to the caudal pouches of the equine lateral femorotibial joint. *Equine Vet. J.* Epub ahead of print; <https://beva.onlinelibrary.wiley.com/doi/10.1111/evj.13274>
- Pusterla, N., Barnum, A., Hall, J.A., Marshall-Lund, L. and Gebhart, C. (2020) Investigation of the usefulness of serum amyloid A in supporting the diagnosis of equine proliferative enteropathy. *J. Equine Vet. Sci.* **92**, 103151.
- Santschi, E.M., Whitman, J.L., Prichard, M.A., Lopes, M.A.F., Pigott, J.H., Brokken, M.T., Jenson, P.W., Johnson, C.R., Morrow, C., Brusie, R.W., Juzwiak, J.S. and Morehead, J.P. (2020) Subchondral lucencies of the proximal tibia in 17 horses. *Vet. Surg.* **49**, 778–786.

Editorial

Equine medicine special issue

This month we are publishing another online collection of Original Articles focussing on equine medicine. The collection covers a diverse range of important and clinically relevant topics, including oncology, gastroenterology, neurology and behaviour. The series adds to the previously published collection of articles on orthopaedics and lameness.

Sarcoids are the commonest neoplasm seen in horses, but have unique problems in terms of their treatment. Numerous different 'home remedies' are used by horse owners, often perpetuated by social media. Herbal preparations containing extracts of bloodroot (*Sanguinaria canadensis*) are easy and convenient to use, and there have been many anecdotal claims of success of using such preparations for treating sarcoids. However, most preparations contain other components, including caustic zinc salts. The concentration of zinc chloride in three commercially available bloodroot preparations was evaluated in the study by Ramey and Poppenga (2020). The studied products contained between 11.6% and 25% ZnCl₂. Radiotherapy is considered by many to be the 'gold standard' treatment for sarcoids, and strontium plesiotherapy can be particularly useful in cases where sarcoids are located in areas that are difficult to access using other therapies. The outcome of this type of radiotherapy for the treatment of sarcoids in eight horses was reviewed by Hollis (2020). Complete resolution occurred in all eight cases, with no significant short or long-term adverse effects, apart from local leucotrichia, leukoderma and hair loss.

Gastroscopic examination of the stomach is commonly performed in equine practice to diagnose equine gastric ulcer syndrome (EGUS). Although it is a routine procedure, it is invasive and carries a small risk of complications. The two studies by Spanton *et al.* (2020a and b) addressed these issues through a clinical audit of colic in the 48 h following gastroscopy and a study of serum amyloid A concentrations in horses with gastroscopy-confirmed EGUS. In short, colic occurred in 2.9% of 573 gastroscopies, most commonly in horses affected by gastric impaction. No association was found between SAA concentrations and the presence or degree of squamous or glandular EGUS.

A number of studies have been published in recent years on the topic of pain assessment in horses, including the development of pain scales for use in horses with colic. A modified equine composite pain scale (CPS) is described by Lawson *et al.* (2020). A significant correlation was identified between the CPS score and serum concentration of cortisol in medical and surgical colic cases ($n = 49$), thereby providing physiological validation of pain scores as a marker of underlying stress in horses with colic. Of course, colic can have numerous different causes, and diet is often considered to be one of the risk factors that may play a role in the pathophysiology of intestinal pain. Troya *et al.* (2020) performed a prospective observational study to determine whether the inclusion of germinated barley as a supplement decreased the incidence of colic in a population of horses. Sprouted cereals have improved digestibility and contain oligosaccharides that may act as prebiotics improving and stabilising the intestinal flora. It was concluded that

supplementation with germinated barley might decrease the appearance of colic in stabled horses; however, further studies are required to substantiate these findings and to identify the potentially beneficial substances in the supplement.

Equine coronavirus (ECoV) is an emerging enteric virus with reported morbidity rates ranging from 10 to 83% and fatality rates ranging from 7 to 27% in adult horses. The study by Prutton *et al.* (2020) investigated the safety, humoral response and viral shedding in horses inoculated with a commercially available modified-live bovine coronavirus (BCoV) vaccine. The results showed that the modified-live BCoV vaccine was safe to administer, caused minimal virus shedding and resulted in detectable antibodies to BCoV in 27% of the vaccinates.

With the widespread development of anthelmintic resistance in several parasite species in many horse populations around the world, the selective and targeted use of anthelmintics is ever more important in order to reduce the selection pressure leading to the development of resistance. The study by Ramey and Nielsen (2020) aimed to document the strongylid infection status of stabled horses residing in an arid environment with limited access to pasture. They concluded that in horses living in dry, arid conditions, with little or no access to pasture, frequent deworming for strongylid parasites is less necessary than in other environments.

Equine multinodular pulmonary fibrosis (EMPF) is an uncommon, but well-recognised pulmonary disease, for which there is currently limited information about long-term outcomes. Easton-Jones *et al.* (2020) describe the signalment, clinicopathological data, radiographic and ultrasonographic findings, clinical outcomes and pathological lesions associated with EMPF in 14 horses. The disease had a poor prognosis for survival, with horses frequently displaying severe radiographic and histopathological changes at the time of diagnosis. Treatment with systemic corticosteroids reduced the odds of short-term mortality. Cytological evaluation of bronchoalveolar lavage (BAL) samples can be valuable in the diagnosis of lower respiratory tract diseases. The objectives of the study by Hansen *et al.* (2020) were to evaluate the reliability of two different staining methods for the evaluation of mast cells in BAL fluid samples from 78 horses and the reliability of differential cell count using both staining methods. The results suggest that staining with both the May-Grünwald-Giemsa (MGG) and toluidine blue (TB) methods is appropriate and that toluidine blue should be used for the enumeration of mast cells.

Sedation facilitates the ocular examination in horses. Alpha₂-adrenoceptor agonists are commonly used in equine practice; however, little is known about the effects of α_2 -adrenoceptor agonists on equine Schirmer tear test I (STT I) values. The aim of the study by Leonardi *et al.* (2020) was to assess the effects of α_2 -adrenoceptor agonists on the STT I values in horses. They found that the administration of xylazine or detomidine alone or combined with butorphanol is associated with significant changes in aqueous tear

production, whereas romifidine does not affect the STT I values.

Head-shaking can be a difficult and frustrating condition to investigate and treat. Thomson *et al.* (2020) report the clinical findings of six horses referred for investigation of head-shaking associated with musculoskeletal pain and compared these to those of trigeminal-mediated head-shaking. None of them displayed excessive sneezing or snorting, or rubbing and/or striking at the nose with the forelimbs. It was concluded that headtossing during ridden exercise can be associated with musculoskeletal pain, and it is important to recognise this and to differentiate it from trigeminal-mediated head-shaking.

The infraorbital nerve block is most commonly used to desensitise the maxillary teeth for dental procedures. Weber *et al.* (2020) investigated the distribution pattern of two different volumes of a mepivacaine 2%/iopromide mixture along the infraorbital nerve using a controlled injection pressure. They found that blocks using 10 and 15 mL result in complete filling of the infraorbital canal in the majority of horses and may therefore result in sufficient analgesia of Triadans 06 to 11 and offer a suitable safe alternative to maxillary nerve blocks.

Carroll *et al.* (2020) report the results of a survey of the prevalence and treatment options for stereotypic behaviours and undesirable behaviours associated with handling and riding. An online survey was completed by 943 horse industry participants from 31 countries. The results suggest that undesirable behaviours are common. Agents with a nonspecific sedating effect were the most common agents suggested by veterinarians and used by horse owners for attempted management.

Reed *et al.* (2020) carried out a survey to collect information regarding the use and perceived health of Thoroughbreds retired from racing. A 31-question survey on use, health and behaviour was made available to owners of Thoroughbred horses who had retired from racing. Thoroughbreds retired from racing were more likely to suffer from musculoskeletal injuries, gastrointestinal, behavioural and foot/hof issues than controls. Horses with >51 lifetime starts were more likely to experience gastrointestinal disease in the first year after retirement from racing.

'Herbal' preparations for equine dermal neoplasms contain large amounts of zinc chloride

Ramey and Poppenga (2020)

This original study was performed to investigate the levels of zinc chloride (ZnCl₂) in 'herbal black salve' preparations, purportedly containing an active ingredient of bloodroot, sometimes used to treat equine dermal neoplasms. Three samples of different 'bloodroot' preparations were tested. Zinc and other elements were measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The chloride in the samples was partitioned into an aqueous solution and measured by ion chromatography (IC). The studied products contained between 11.6% and 25% ZnCl₂. Veterinarians should be aware that 'herbal' or 'black salve' preparations intended for the treatment of equine cutaneous neoplasms may contain significant amounts of zinc chloride (ZnCl₂), a caustic, corrosive chemical. Equine practitioners should also be aware that various international government

agencies have warned against the use of black salve products in human cancer therapy.

Strontium plesiotherapy for the treatment of sarcoids in the horse

Hollis (2020)

Sarcoids are a common condition in the horse. They are often difficult to treat, and there is no universally effective treatment method. Radiotherapy is the most consistently successful treatment, and plesiotherapy may be effective for carefully selected sarcoid lesions. The objective of this retrospective clinical case series was to describe the response rate and safety of strontium plesiotherapy for the treatment of equine sarcoids. Horses and ponies referred for strontium treatment of sarcoids were eligible for inclusion in the study, and diagnosis was based solely on the clinical features. Horses were given a total tumour dose of 100 Gy under either standing sedation or general anaesthesia, depending on the accessibility of the lesion. Eight horses with 10 sarcoids were treated with strontium plesiotherapy. Follow-up was available for between 6 and 30 months after treatment. Complete resolution occurred in all cases. No significant short- or long-term adverse effects were noted apart from local leucotrichia, leukoderma and hair loss. The major limitations of this study are the lack of long-term follow-up and the small number of horses. It was concluded that strontium plesiotherapy appears to be an effective and safe method of treating selected equine sarcoids. This is a useful alternative for lesions in areas difficult to treat with other methods or where other methods have been unsuccessful. Longer term follow-up is required to determine the risk of recurrence of treated lesions.

A clinical audit of the prevalence of colic in the 48 h after gastroscopy in 436 horses

Spanton *et al.* (2020a)

Gastroscopy is a routine technique performed in equine practice to evaluate the stomach and is the gold standard diagnostic test for equine gastric ulcer syndrome (EGUS). There are few publications on the safety of the technique and any associated complications, in particular colic. The objective of the study was to review all gastroscopic examinations performed at two equine clinics over a 5-year period and to describe any colic episodes in the 48 h post gastroscopy. In this clinical audit, hospital databases were searched for animals that had a gastroscopic examination in the 5-year study period. Signalment, sedative drugs, stomach insufflation/deflation, gastroscopic findings, occurrence of colic in the 48 h post examination and any medication administered during that time were recorded. A total of 436 horses underwent 573 gastroscopic examinations during the study period. Post gastroscopy colic was recorded in 17/573 examinations (2.9%); 16 were mild, but one (0.2%) required exploratory laparotomy. Cases of gastric impaction were more commonly associated with colic post gastroscopy. When examinations of horses with gastric impaction were excluded, the prevalence of colic post gastroscopy was 5/561 (0.9%). A limitation of the study was that variability in technique was likely, due to multiple different clinicians performing gastroscopic examinations. A study with a larger sample size is required to confirm the findings of this audit. Gastroscopy is a relatively safe procedure but there is a small risk of colic afterwards.

Is Serum Amyloid A elevated in horses with equine gastric ulcer syndrome?

Spanton *et al.* (2020b)

Serum amyloid A (SAA) is an acute-phase protein. Increased concentrations are seen in response to inflammatory stimuli. Equine gastric ulcer syndrome (EGUS) is a common condition in the horse and has an inflammatory component, but there are few studies assessing SAA concentrations in horses with EGUS. The objective of this prospective cohort study was to assay SAA in horses presented for gastroscopy with suspected EGUS over a 2-year period and to establish whether significant elevations in SAA concentration occur with any form of EGUS. Horses presented for gastroscopy for suspected EGUS had blood collected for SAA evaluation at the time of i.v. sedative administration. Two experienced clinicians reviewed the gastroscopic examinations and classified lesions according to the ECEIM EGUS consensus statement (2015). A total of 94 horses had 114 gastroscopic examinations. Twenty-three horses were negative for EGUS, 25 had glandular EGUS, 38 had squamous EGUS, and 28 had both squamous and glandular EGUS. Four horses had SAA concentration >10 mg/L (range 11.4–104.7); one had mild multifocal pyloric ulceration, one had mild multifocal pyloric ulceration and grade 2 squamous ulceration, one had moderate multifocal pyloric ulceration and grade 1 squamous ulceration, and one had no ulceration. A limitation was that low sample numbers compromised the power of the study. It was concluded that no association was found between SAA concentrations and the presence or degree of squamous or glandular EGUS.

Application of an equine composite pain scale and its association with plasma adrenocorticotrophic hormone concentrations and serum cortisol concentrations in horses with colic

Lawson *et al.* (2020)

This study assessed the application of a modified equine composite pain scale (CPS) and identified the interobserver reliability. Associations between CPS scores and the measured concentrations of serum cortisol ([cortisol]) and plasma adrenocorticotrophic hormone ([ACTH]) in horses presenting with colic were determined. The study design was prospective, uni-centred and observational. The interobserver reliability of the adapted CPS was determined for 59 horses hospitalised for a variety of conditions. The associations between CPS, ACTH and cortisol were assessed in a further 49 horses admitted for medical or surgical colic. During hospitalisation, blood samples were obtained each morning and analysed for serum [cortisol] and plasma [ACTH]. Horses were pain scored using the adapted CPS score. Data from the most painful time point ($n = 48$ horses; $n = 48$ [cortisol]; $n = 44$ [ACTH]) and all data time points ($n = 49$ horses and $n = 133$ time points) were used for analysis of association between [cortisol], [ACTH] and CPS score. The CPS score interobserver reliability was excellent ($n = 59$ horses; $n = 102$ pain scores; weighted kappa 0.863). CPS score and [cortisol] were positively associated at the most painful time point ($P < 0.001$) and at all data time points ($P < 0.001$). No significant association was found between CPS score and [ACTH]. [ACTH] was associated with [cortisol] ($P = 0.034$)

when all time points were analysed but not when only the most painful point was analysed. The significant correlation identified between CPS score and [cortisol] in medical and surgical colic cases provides physiological validation of pain scores as a marker of underlying stress in horses with colic.

Comparison of the colic incidence in a horse population with or without inclusion of germinated barley in the diet

Troya *et al.* (2020)

Sprouted cereals have a better digestibility and contain oligosaccharides that act as prebiotics improving and stabilising the intestinal flora. Supplementation with germinated malted barley could help to prevent the occurrence of colic in horses. The objective of this study was to determine whether the inclusion of germinated barley as a supplement decreased the incidence of colic in a population of horses. An observational prospective study was designed to record the colic incidence of an equestrian centre horse population in Madrid (Spain). Data were collected during two 21-month periods, only including horses that were maintained at the centre for the whole time. Age, sex, housing and colic events were recorded during Period 1 (control period) and Period 2 (with germinated barley supplementation, Equinocol®). Sixty-three horses were included in the study of which 43 were stabled 12 h/day (Group A) and 20 that lived at pasture all-day long (Group B). Colic incidence of the total population, Group A and group B during Period 1 was 18.1, 23.9 and 5.7 cases/100 horses at risk-year, respectively. With the inclusion of germinated barley, there was a significant decrease in the colic events in the total population (5.4 cases/100 horses at risk-year) and group A (5.3 cases/100 horses at risk-year). It was concluded that supplementation with germinated barley might decrease the appearance of colic in stabled horses. Further investigation is warranted to identify the potentially beneficial substances and the repeatability of the results.

Evaluation of safety, humoral immune response and faecal shedding in horses inoculated with a modified-live bovine coronavirus vaccination

Putton *et al.* (2020)

Equine coronavirus (ECoV) is considered an emerging enteric virus with reported morbidity rates ranging from 10 to 83% and fatality rates ranging from 7 to 27% in adult horses; a vaccine for ECoV is currently not available. This study investigated the safety, humoral response and viral shedding in horses inoculated with a commercially available modified-live bovine coronavirus (BCoV) vaccine. Twelve healthy adult horses were vaccinated twice, 3 weeks apart, either orally, intranasally or intrarectally. Two healthy unvaccinated horses served as sentinel controls. Following each vaccine administration, horses were monitored daily for physical abnormalities, whilst the onset and duration of BCoV shedding were determined by quantitative PCR (qPCR) in nasal secretions and faeces. Whole blood was collected every 3 weeks to determine BCoV-specific antibody response. With the exception of transient and self-limiting changes in faecal character observed in seven vaccinated and one control horse, no additional abnormal clinical findings were found in the study horses. Following the first and second vaccine administration, two and one horse,

respectively, tested qPCR-positive for BCoV in nasal secretions 1 day post intranasal vaccination. No vaccinated horses tested qPCR-positive for BCoV in faeces following each vaccine administration. One of the two horses that shed BCoV seroconverted to BCoV after the first vaccine administration and an additional two vaccinated horses (oral and intrarectal) seroconverted to BCoV after the second vaccine administration. In conclusion, the results show that the modified-live BCoV is safe to administer to horses via various routes, causes minimal virus shedding and results in detectable antibodies to BCoV in 27% of the vaccinates.

Limited strongyle parasite occurrence in horses kept in an arid environment

Ramey and Nielsen (2020)

The objective of this study was to document the strongylid infection status of stabled horses residing in an arid environment with limited access to pasture. Faecal parasite examinations were conducted in a private equine practice in Southern California over a period of 7 years, from 2012 to 2018, from a variety of horses in seven different locations; not all horses living at these locations were studied. Results of all faecal examinations were obtained and tabulated, as to both total number of horses examined, as well as individual animals followed with at least four consecutive bi-annual faecal examinations over a 2-year period. A total of 851 faecal tests on 79 individual horses were performed during the 7-year study period, and 78 (9%) were strongyle positive. By the end of the study period, during which horses were monitored and treated according to faecal flotation tests, 97% of 117 faecal flotation tests were negative for strongyle parasites. In conclusion, in a population of 79 adult horses living in dry, arid conditions, with little or no access to pasture, frequent deworming for strongylid parasites would appear to be less necessary than in other environments. Regular faecal monitoring of horses in such conditions is appropriate for determining the necessary level of anthelmintic intervention.

Prognostic indicators and long-term survival in 14 horses with equine multinodular pulmonary fibrosis

Easton-Jones *et al.* (2020)

There is limited information on long-term follow-up and prognostic indicators for horses diagnosed with equine multinodular pulmonary fibrosis (EMPF). The objectives of this study were to describe the signalment, clinicopathological data, radiographic and ultrasonographic findings, equine herpesvirus-5 viral loads, clinical outcomes and pathologic lesions associated with EMPF. Medical records from 2008 to 2016 were reviewed for this retrospective case series of 14 horses diagnosed with equine multinodular pulmonary fibrosis on lung histopathology. Independent variables associated with survival to hospital discharge (short-term survival) were determined using chi-square or Fisher's exact test. Odds ratios and 95% confidence intervals were calculated when applicable. Short-term survival was 57%, with only 14% of cases surviving longer than 6 months after discharge. The odds of short-term survival were higher in horses administered corticosteroids (OR = 0.029, 95% CI 0.002-0.615; P = 0.026). Severity of thoracic radiographic changes and equine herpesvirus-5 viral loads measured by quantitative PCR in the

lung on presentation was not associated with survival time. Severity of thoracic radiographic changes was also not correlated with equine herpesvirus-5 viral loads in the lung ante-mortem. Equine multinodular pulmonary fibrosis has a poor prognosis for survival, with horses frequently displaying severe radiographic and histopathological changes at the time of diagnosis. Treatment with systemic corticosteroids reduced the odds of short-term mortality.

Reliability of cytological evaluation of mast cells from bronchoalveolar lavage fluid in horses: Intraobserver agreement and mast cell identification

Hansen *et al.* (2020)

Endoscopy, including bronchoalveolar lavage (BAL) fluid cytology, is invaluable tools for equine lower airway diagnostics. Objectives of the study were to evaluate the reliability of two staining methods, May-Grünwald-Giemsa (MGG) and toluidine blue (TB), for the evaluation of mast cells in cytopsin smears from BAL fluid samples and the reliability of a 500-cell differential cell count using both staining methods. Endoscopies and BAL fluid sampling were performed, and BAL cytology was evaluated from cytopsin smears. BAL cytology slides from 78 horses were evaluated. Three experienced observers evaluated the BAL cytology cytopsin smears for the mast cell comparison study. The intra- and interobserver agreements were calculated using intraclass correlation coefficients (ICC). BAL cytology mast cell counts were significantly higher with the TB staining method compared with the MGG staining method. Observer agreements showed below acceptable agreement between observers for mast cell counts for both staining methods, even with fixed coordinates. Based on results from this study, recommendation for BAL cytology staining would be to use both the MGG and the TB staining method, relying on the TB for the enumeration of mast cells.

Effects of intravenous romifidine, detomidine, detomidine combined with butorphanol and xylazine on tear production in horses

Leonardi *et al.* (2020)

Sedation facilitates the ocular examination in horses. Alpha₂-adrenoceptor agonists are commonly used in equine practice. If the eye is painful, the combination of an α_2 -adrenoceptor agonist and butorphanol provides a greater analgesic effect. Unfortunately, little is known about the effects of α_2 -adrenoceptor agonists on equine Schirmer tear test I (STT I) values. The aim of the study was to assess the effects of intravenous romifidine, detomidine, detomidine combined with butorphanol and xylazine on the STT I values in horses. Forty healthy client-owned Italian saddle horses were enrolled. Horses received 0.04 mg/kg bwt of romifidine or 15 µg/kg bwt of detomidine or 10 µg/kg bwt of detomidine combined with 10 µg/kg bwt of butorphanol or 0.7 mg/kg bwt of xylazine intravenously. The Schirmer tear test strip was inserted into the lateral third side of the inferior conjunctival fornix for 1 min in each eye. The STT I measurements were performed before sedation and at 5, 15, 30, 60, 120 and 180 min after the administration of sedation. The data were analysed by ANOVA. Romifidine did not affect the STT I values. Detomidine significantly reduced the

STT I values at 15 min (18.17 ± 0.97 mm/min). The combination of detomidine and butorphanol significantly reduced the STT I values at 30 and 60 min (17.44 ± 0.99 , 15.81 ± 0.99 mm/min). Xylazine significantly increased the STT I values at 5, 15 and 30 min (25.17 ± 0.99 , 26.72 ± 0.99 , 28.07 ± 0.99 mm/min). The STT I values at 180 min were similar to those before sedation. These results suggest that the administration of xylazine or detomidine alone or combined with butorphanol is associated with significant changes in aqueous tear production, whereas romifidine does not affect the STT I values. Romifidine is therefore suitable for chemical restraint to measure tear production in horses.

Head tossing behaviour in six horses: Trigeminal-mediated head-shaking or musculoskeletal pain?

Thomson *et al.* (2020)

The objective of this study was to report the clinical findings of six horses referred for investigation of head-shaking and to compare and contrast the findings to those of trigeminal-mediated head-shaking. The case records of six horses showing head tossing behaviour (vertical up and down movement of the head during ridden exercise) that were referred to the Animal Health Trust were reviewed and a summary of the clinical findings reported. The history was appraised, including video footage when available. A comprehensive clinical examination at rest and exercise, including ridden assessment, was performed on several occasions over at least 2 days; diagnostic analgesia and imaging were carried out. A thorough review of the literature on trigeminal-mediated (idiopathic) head-shaking was performed. All horses showed headtossing behaviour when ridden, and two horses also tossed their heads on the lunge. All horses had various sources of musculoskeletal pain. Five horses had abolition of headtossing behaviour after diagnostic analgesia resolved musculoskeletal pain. The remaining horse had significant improvement in this behaviour. This horse also displayed clinical signs at rest, and it is likely that there was a component of trigeminal-mediated head-shaking. Many horses with trigeminal-mediated head-shaking show clinical signs both at rest and when ridden, often with worsening of clinical signs when ridden. However, all horses in this series showed additional signs of musculoskeletal pain when ridden compared with in hand and on the lunge. None of these horses displayed excessive sneezing or snorting, acting like an insect was flying up the nostril and rubbing and/or striking at the nose with the forelimbs which can often be seen in horses with trigeminal-mediated head-shaking. No horse had a history of seasonality of clinical signs. It was concluded that it is important for veterinarians to recognise behavioural signs of pain, such as headtossing during ridden exercise and to be able to differentiate this behaviour from trigeminal-mediated head-shaking.

Ex vivo evaluation of the distribution of a mixture of mepivacaine 2% and iopromide following local infiltration of the infraorbital nerve via the infraorbital foramen

Weber *et al.* (2020)

The objective of this study was to investigate the distribution pattern of two different volumes of a

mepivacaine 2%/iopromide mixture along the infraorbital nerve using a controlled injection pressure. Infraorbital nerve blocks were performed at the infraorbital foramen with two different volumes (group 10: 10 mL or group 15: 15 mL) using a 22 gauge, 3 cm long needle and a standardised injection pressure in 10 cadaver skulls. Ten minutes after injection, computed tomography was performed in all skulls. Images were analysed for needle position, length of the iopromide column, filling percentage of the infraorbital canal, presence of iopromide at the maxillary foramen, volume of leakage, length and angle of the infraorbital canal and pathological changes. Percentage of infraorbital canal filling ranged from $74\% \pm 0.23$ to $86.9\% \pm 0.24$ and iopromide was present at the maxillary foramen in 70–90% of the blocks of groups 15 and 10, respectively; neither variables differed significantly between groups 15 and 10 ($P = 0.582$ and $P = 0.244$ respectively). Mean leakage retrograde into the rostrally surrounding tissue and into the maxillary sinus was significantly greater in group 15 ($7.9 \text{ cm}^3 \pm 4.2$) than group 10 ($3.02 \text{ cm}^3 \pm 3.13$), $P = 0.008$. Older horses were significantly associated with higher filling percentages ($P = 0.049$), whereas filling percentages or whether the mixture reached the maxillary foramen were not associated with any of the other variables. Infraorbital nerve blocks using 10 and 15 mL result in complete filling of the infraorbital canal in the majority of horses. This block may result in sufficient analgesia of Triadans 06 to 11 and offer a suitable safe alternative to maxillary nerve blocks.

An online survey investigating perceived prevalence and treatment options for stereotypic behaviours in horses and undesirable behaviours associated with handling and riding

Carroll *et al.* (2020)

In the horse, inappropriate management and training, as well as pain, frustration, fear and anxiety can result in undesirable behaviours. Common undesirable behaviours include pawing, striking, rearing, kicking, bolting, bucking, shying, napping, freezing, biting and bite threats, as well as a range of oral and locomotive stereotypic behaviours. Many of these behaviours are dangerous for the human handlers and can be unhealthy and harmful for the horse; for safety and welfare reasons, they must be rapidly addressed. An online survey was completed by 943 horse industry participants from 31 countries. The survey was conducted to gain greater insight into the perceived prevalence of undesirable behaviours in horses; options considered in the management of horses displaying undesirable behaviours; attitudes towards the use of prescription and over-the-counter (OTC) behaviour-modifying agents; and owner attitudes towards the role of veterinarians and equine behaviourists. The results of this survey suggest that undesirable behaviours are common. Agents with a nonspecific sedating effect were the most common agents suggested by veterinarians and used by horse owners. Horse owners indicated a greater use of α_2 agonists for the management of undesirable behaviours associated with riding horses. Many owners in this survey indicated they would consider seeking advice from veterinarians (83.2%) and behaviourists (58.0%) if they had a horse that was 'consistently difficult or uncooperative to handle or ride'. The majority (97.3%) of nonveterinarian equine behaviourists

would seek the input of a veterinarian to investigate physical causes for undesirable horse behaviour. Twenty-two per cent of veterinarians would refer a case to a behaviour expert to address the behavioural component, whilst most veterinarians (77.6%) would devise a behaviour modification and retraining programme themselves. It is hoped that information from this survey can be used to improve existing horse management practices and has a positive impact on animal welfare.

Survey on Thoroughbred use, health and owner satisfaction following retirement from racing

Reed *et al.* (2020)

Thousands of Thoroughbred horses retire from racing each year and go on to second careers unrelated to racing. Although there are many publications regarding health concerns for Thoroughbreds whilst racing, evidence-based information regarding what happens after retirement from racing is scarce. Veterinarians are relegated to use anecdotal information to guide owners and potential owners. The study objective was to collect and evaluate extensive information regarding the use and perceived health of Thoroughbreds retired from racing, as well as owner satisfaction. A 31-question survey on use, health and behaviour was made available to owners of Thoroughbred horses who had retired from racing. A similar survey was available to owners of non-Thoroughbred horses for a control population. Racing data were obtained from a publicly available database for Thoroughbreds. Statistical analysis was performed to compare incidence of health and behaviour issues between Thoroughbreds and controls and between different racing experiences for Thoroughbreds. Thoroughbreds retired from racing were more likely to suffer from musculoskeletal injuries, gastrointestinal, behavioural and foot/hof issues than controls. Age at first start, age at last start, number of starts and breaks of 6 months or more during racing career did not affect incidence of musculoskeletal disease, behavioural issues, hoof/hof issues, respiratory disease and neurologic disease. Horses with >51 lifetime starts were more likely to experience gastrointestinal disease in the first year after retirement from racing. Thoroughbreds were as likely as controls to have eventual resolution of issues present at acquisition. Veterinarians can use this information to guide pre-purchase evaluations, provide ongoing care and counsel owners/prospective owners on the possible needs of Thoroughbred horses retired from racing. Knowing the common issues faced by the population will increase the success of transition from racing by creating informed veterinarians and owner expectations.

T. S. MAIR 

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References

- Carroll, S.L., Sykes, B.W. and Mills, P.C. (2020) An online survey investigating perceived prevalence and treatment options for stereotypic behaviours in horses and undesirable behaviours associated with handling and riding. *Equine Vet. Educ.* **32**, Suppl. **11**, 71-81.
- Easton-Jones, C.A., Cissell, D.D., Mohr, F.C., Chigerwe, M. and Pusterla, N. (2020) Prognostic indicators and long-term survival in 14 horses with equine multinodular pulmonary fibrosis. *Equine Vet. Educ.* **32**, Suppl. **11**, 41-46.
- Hansen, S., Fjeldborg, J., Hansen, A.J. and Baptiste, K.E. (2020) Reliability of cytological evaluation of mast cells from bronchoalveolar lavage fluid in horses: Intraobserver agreement and mast cell identification. *Equine Vet. Educ.* **32**, Suppl. **11**, 47-52.
- Hollis, A.R. (2020) Strontium plesiotherapy for the treatment of sarcoids in the horse. *Equine Vet. Educ.* **32**, Suppl. **11**, 7-11.
- Lawson, A.L., Opie, R.R., Stevens, K.B., Knowles, E.J. and Mair, T.S. (2020) Application of an equine composite pain scale and its association with plasma adrenocorticotrophic hormone concentrations and serum cortisol concentrations in horses with colic. *Equine Vet. Educ.* **32**, Suppl. **11**, 20-27.
- Leonardi, F., Costa, G.L., Dubau, M., Sabbioni, A., Simonazzi, B. and Angelone, M. (2020) Effects of intravenous romifidine, detomidine, detomidine combined with butorphanol, and xylazine on tear production in horses. *Equine Vet. Educ.* **32**, Suppl. **11**, 53-57.
- Putton, J.S.W., Barnum, S. and Pusterla, N. (2020) Evaluation of safety, humoral immune response and faecal shedding in horses inoculated with a modified-live bovine coronavirus vaccination. *Equine Vet. Educ.* **32**, Suppl. **11**, 33-36.
- Ramey, D.W. and Nielsen, M.K. (2020) Limited strongyle parasite occurrence in horses kept in an arid environment. *Equine Vet. Educ.* **32**, Suppl. **11**, 37-40.
- Ramey, D.W. and Poppenga, R. (2020) 'Herbal' preparations for equine dermal neoplasms contain large amounts of zinc chloride. *Equine Vet. Educ.* **32**, Suppl. **11**, 3-6.
- Reed, S.K., Vander Ley, B.B., Bell, R.P., Wilson, D.A., Wilborn, E. and Keegan, K.G. (2020) Survey on Thoroughbred use, health, and owner satisfaction following retirement from racing. *Equine Vet. Educ.* **32**, Suppl. **11**, 82-87.
- Spanton, J.A., Smith, L. and Mair, T.S. (2020a) A clinical audit of the prevalence of colic in the 48 hours after gastroscopy in 436 horses. *Equine Vet. Educ.* **32**, Suppl. **11**, 12-15.
- Spanton, J.A., Smith, L. and Mair, T.S. (2020b) Is Serum Amyloid A elevated in horses with equine gastric ulcer syndrome? *Equine Vet. Educ.* **32**, Suppl. **11**, 16-19.
- Thomson, K., Chan, C. and Dyson, S. (2020) Head tossing behaviour in six horses: Trigeminal-mediated head-shaking or musculoskeletal pain? *Equine Vet. Educ.* **32**, Suppl. **11**, 58-64.
- Troya, L., Blanco, J., Romero, I. and Re, M. (2020) Comparison of the colic incidence in a horse population with or without inclusion of germinated barley in the diet. *Equine Vet. Educ.* **32**, Suppl. **11**, 28-32.
- Weber, S., Ohlerth, S., Mosing, M., Torgerson, P.R., Fürst, A. and Bischofberger, A.S. (2020) Ex vivo evaluation of the distribution of a mixture of mepivacaine 2% and iopromide following local infiltration of the infraorbital nerve via the infraorbital foramen. *Equine Vet. Educ.* **32**, Suppl. **11**, 65-70.

Case Report

Suspected hepatic amyloidosis in a horse

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Keywords: horse; amyloidosis; liver; haemoabdomen; serum amyloid A

Summary

A 9-year-old Saddlebred gelding was referred to the University of Wisconsin Veterinary Care for decreased energy levels, weight loss, persistently elevated liver enzymes, hyperglobulinaemia and leucocytosis. On presentation, the gelding was bright and physical examination findings were unremarkable. A biochemistry profile evidenced hyperproteinaemia (90 g/L, rr 47–75 g/L) due to hyperglobulinaemia (58 g/L, rr 22–38 g/L), a moderately elevated GGT (176 U/L, rr 12–46 U/L) and normal bile acids. Haematology showed a mild normocytic, normochromic anaemia (6.4×10^{12} /L, rr $6.8\text{--}12.9 \times 10^{12}$ /L), a normal leukogram with the exception of a mild increase in band neutrophils (0.3×10^9 /L; rr $0\text{--}0.1 \times 10^9$ /L) and hyperfibrinogenemia (8.0 g/L, rr 1.0–4.0 g/L). Abdominal ultrasonography showed a large volume of peritoneal fluid of mixed echogenicity, and the presence of focally distributed, circular to oval (approximately 1–2 cm), hyperechoic areas within the parenchyma of an enlarged liver (**Fig 1**). Cytological analysis of the peritoneal fluid revealed sterile neutrophilic/macrophagic inflammation, with haemosiderophages. A liver biopsy revealed the presence of hepatic amyloidosis and focal fibrosis (**Fig 2**). Positive Congo red staining and immunohistochemical results confirmed the presence of hepatic amyloidosis, most likely associated with accumulation of serum amyloid A.

Medical therapy had included trimethoprim-sulfamethoxazole, as previously prescribed by the referring veterinarian, for a total of 28 days. Once the histopathology results became available and amyloidosis was suspected, long-term treatment with oral dexamethasone was recommended. Dexamethasone was associated with both a clinical and

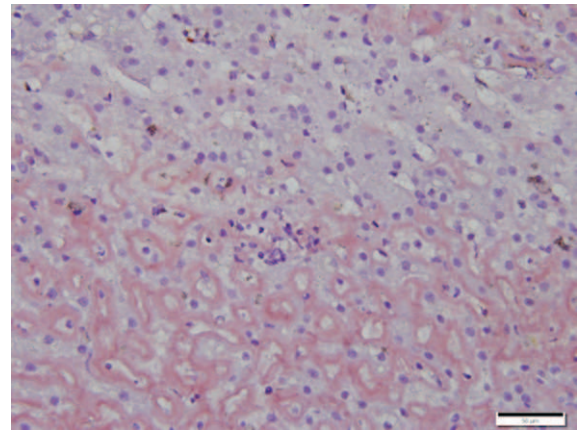


Fig 2: Photomicrograph of liver biopsy. The eosinophilic amorphous material seen in photomicrograph a stains positive with the Congo-red reaction consistent with amyloid. 400× magnification.

biochemical response for 7 months. On the last recheck appointment (day 189), the gelding was reported to be back to his normal attitude and energy levels. Physical examination at that time was unremarkable, and his body weight had increased from 505 kg on initial presentation to 528 kg. Ultrasonographic examination showed a subjectively enlarged liver, similar to before, but the formerly visualised hyperechoic areas within the hepatic parenchyma were no longer apparent, and GGT activity had decreased to 57 U/L (normal range 2–36 U/L). Given the lack of information regarding this condition in horses, a repeat liver biopsy was recommended but declined by the owner and oral dexamethasone treatment was then discontinued. Unfortunately, an acute colic episode approximately 1 month later subsequently led to euthanasia, regrettably without any further significant ante-mortem and pathologic diagnostic work-up.

To the authors' knowledge, this is the first case report describing the medical management and successful medium-term survival (7 months) of a horse with hepatic amyloidosis.

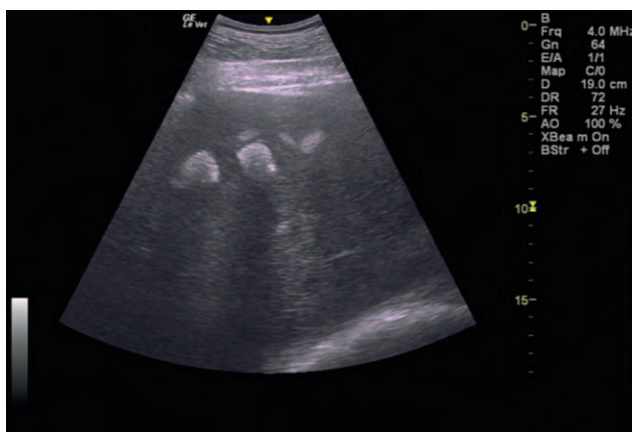


Fig 1: Ultrasonographic image of the liver over the right hepatic window. Left is dorsal and right is ventral. Note the presence of five focally distributed, circular to oval (approximately 1–2 cm), hyperechoic areas within the parenchyma of the liver.

Key points

- Abdominal ultrasonography can be helpful in diagnosing hepatic amyloidosis.
- Long-term corticosteroids may be a possible therapy for successful medium-term management of hepatic amyloidosis.
- Hepatic amyloidosis and subsequent hepatic rupture should be considered as a differential diagnosis for haemoabdomen in horses



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Case Report

Right to left patent ductus arteriosus, acute bronchointerstitial pneumonia, pulmonary hypertension and cor pulmonale in a foal

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Keywords: horse; patent ductus arteriosus; bronchointerstitial pneumonia; pulmonary hypertension; cor pulmonale; foal

Summary

A 20-day-old colt was examined with a history of respiratory distress. Thoracic auscultation revealed loud wheezes and crackles on both sides and a holosystolic plateau-type murmur over the tricuspid valve area. Thoracic radiographs demonstrated caudodorsally scattered bronchointerstitial pattern. A tentative diagnosis of acute bronchointerstitial pneumonia was made. The foal was administered dexamethasone and ceftriaxone sodium. The case was poorly responsive to treatment and 4 days after initial presentation, the severity of clinical signs was markedly increased. On echocardiography, right atrial and ventricular dilatations with paradoxical ventricular septal motion, increased ratio of pulmonary artery internal diameter to the aorta, tricuspid valve regurgitation and right ventricular outflow tract dilation were detected. Five days after initial presentation, the foal was found dead. The major post-mortem (Fig 1) and histopathological findings were: dark red and diffusely enlarged lungs with granular and rubbery texture, marked enlargement of right atrium and ventricle, pulmonary artery thickening and enlargement, patency of the ductus arteriosus, alveolar walls thickening and hyaline membrane formation, hypertrophy and thickening of the

medial layers of the pulmonary arteries and right ventricular myocardial cell distortion and hypertrophy. The diagnosis was established as an acute bronchointerstitial pneumonia and pulmonary hypertension, right heart failure (cor pulmonale) and PDA with right to left shunting.

Key points

- Pulmonary hypertension associated with bronchointerstitial pneumonia can result in a PDA with reversed shunting (Eisenmenger's physiology) in foals.
- The typical clinical and echocardiographic findings of usual forms of PDA are not usually present in right-to-left shunting PDA and sophisticated diagnostic techniques are required to establish the diagnosis.
- A reverse PDA should be considered in the differential diagnosis of any foal suffering from respiratory distress and cyanosis; in particular, when the pulmonary artery is dilated or the ratio of pulmonary artery to the aorta diameter is evident on echocardiographic examination.

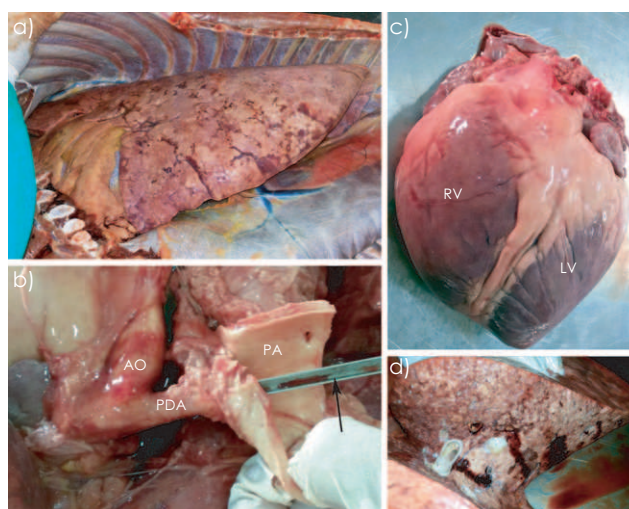


Fig 1: Bronchointerstitial pneumonia, PDA and right ventricular dilation in a 20-day-old foal. a) Diffusely enlarged right lung with rubbery texture and interspersed dark red areas. b) Groove director (black arrow) passed into the PDA from pulmonary artery towards the aorta. c) Right ventricle enlargement. d) Well demarcated areas of pulmonary consolidation with frothy fluid and pus in the airways.



Clinical Commentary

Equine congenital heart disease and respiratory disease interactions

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Summary

The interactions between the respiratory and cardiovascular system in neonates with severe illness are relevant to the equine clinician. There is little information available regarding the treatment of congenital heart disease or pulmonary hypertension in foals, thus a team approach with experts in these fields may help our equine cases.

Equine congenital heart disease

Congenital cardiac disease is uncommon in foals and has been reported to occur in 0.1–0.5% of births in some

populations (Marr 2015). A ventricular septal defect (VSD) is by far the most commonly recognised congenital cardiac defect in horses. Complex defects such as tetralogy of Fallot (TOF) are less common and other solitary congenital defects such as patent ductus arteriosus (PDA) are rare. Careful physical examination followed by cardiac imaging is crucial for determining the diagnosis and prognosis of congenital cardiac disease in foals.

Cardiac murmurs are common in equine neonates and careful auscultation is often capable of differentiating the concerning from the clinically irrelevant. Systolic murmurs over the aortic or pulmonic valve areas are the most common

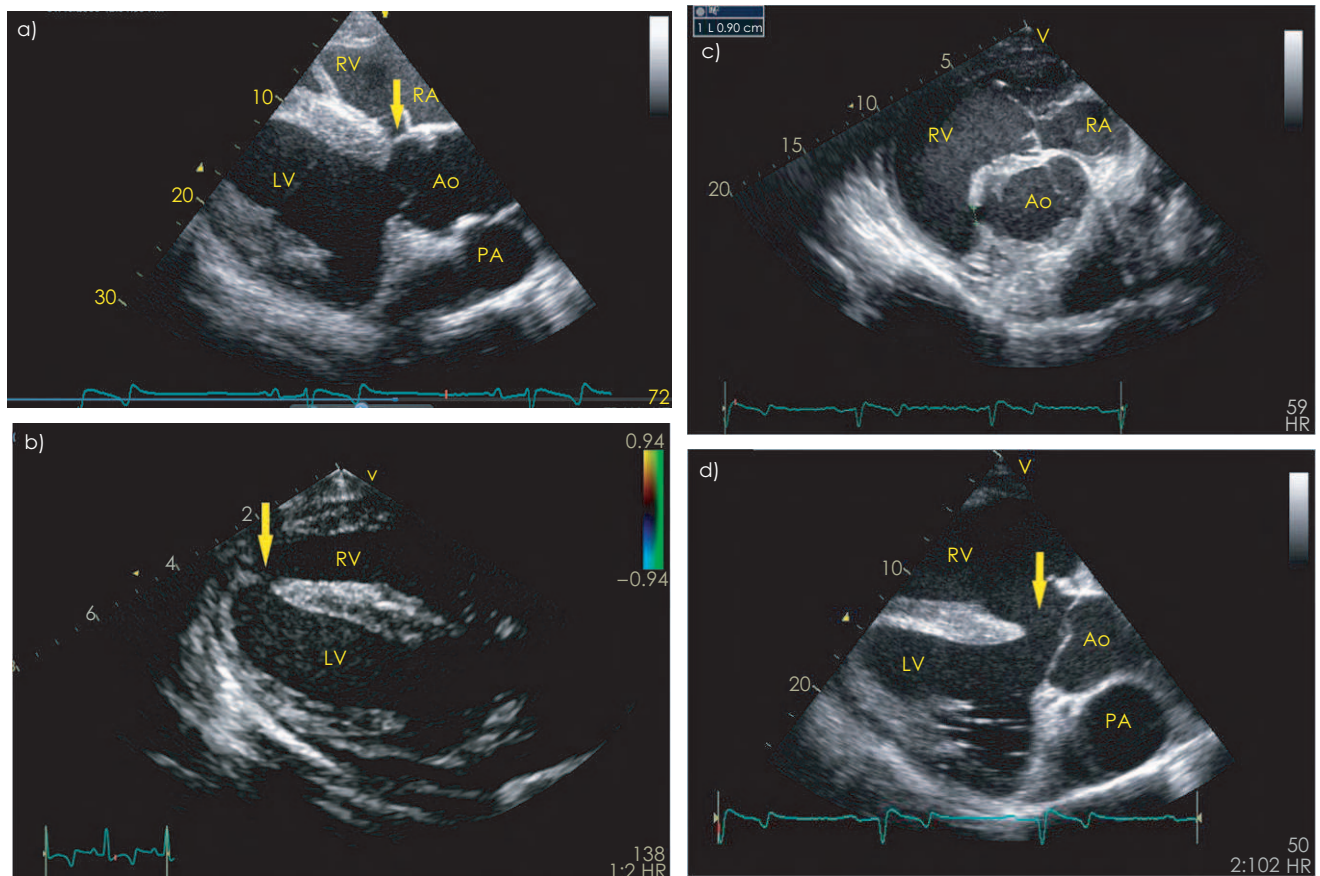


Fig 1: The common presentations of ventricular septal defects (VSD) in horses are shown. a) Perimembranous VSD, b) Muscular VSD, c) Subpulmonic VSD, d) VSD associated with tetralogy of Fallot. Ao = aorta, LV = left ventricle, RV = right ventricle, PA = pulmonary artery, RA = right atrium. Arrows point VSDs.

murmurs appreciated in neonates and are frequently associated with normal ejection of blood (i.e. physiologic). Pulmonic stenosis without other concomitant defects is rare and aortic stenosis is almost unheard of in the foal, though either of these conditions would be expected to result in a systolic murmur over the respective valve area (Hall *et al.* 2010). Continuous murmurs are rare in horses with the exception of neonates. Aortocardiac fistulas or aorta to pulmonary artery (PA) fistulas in the case of Friesians are the most common cause for continuous murmurs in adults. The ductus arteriosus (DA) is a fetal connection between the aorta and the main PA that remains patent in newborn foals, making continuous murmurs common during the first days of life. Functional closure occurs 2–3 days after birth and anatomical closure at approximately 4 days of age. A continuous murmur in horses older than 5 days or in the younger foal with clinical signs of cardiovascular disease, or potentially respiratory or systemic disease, warrants investigation. Reversal (left-to-right reversing to right-to-left) of the ductal flow (rPDA) causes the continuous murmur to disappear or to become systolic and can predispose to louder tricuspid or pulmonic regurgitation murmurs. In the case reported by Saadi *et al.* (2020), only a right-sided systolic murmur was auscultated. A right-sided systolic murmur in a horse suggests tricuspid regurgitation. If the right-sided murmur is accompanied by a left-sided murmur over the pulmonic valve area, congenital heart disease is the most likely differential diagnosis. Ventricular septal defects often lead to a characteristic combination of murmurs. These are: (1) a 4–6/6 pansystolic, band shaped and coarse murmur with the point of maximal intensity over the tricuspid valve area (due to the shunt) and (2) a softer murmur that is holosystolic or pansystolic, crescendo-decrescendo and blowing or coarse, with the point of maximal intensity over the pulmonic valve area. This second murmur is due to an increased volume of blood being ejected through a normal pulmonic valve and often described as a 'relative pulmonic stenosis' murmur. The characteristics of the murmurs can differ from this classic combination when the VSD is subpulmonic or muscular instead of the most common perimembranous location. If the murmur over the pulmonic valve area is louder than the murmur over the tricuspid valve area, TOF or subpulmonic VSD can be suspected (Fig 1).

Patent ductus arteriosus

Clinically relevant PDAs in horses are rare. When appreciated, they are often diagnosed in conjunction with concurrent respiratory disease or additional congenital cardiac defects. Published reports are sparse and definitive treatment attempts have not been reported. Saadi *et al.* (2020) report an interesting case of a suspected rPDA. Cases of confirmed or suspected reversed ductal flow in foals have been previously reported (Reimer *et al.* 1993; Dufourni *et al.* 2018). There are no peer reviewed reports of adult horses with PDA and the authors only know of one adult horse with this clinical problem.

Patent ductus arteriosus are relatively common in humans and other domestic animals. Experience in these species may provide useful insight when the rare PDA is appreciated in the horse. Increased oxygen tension and decreased prostaglandins after birth normally promote contraction and closure of the DA. If the DA fails to close, in an otherwise normal cardiovascular system, left-to-right continuous shunting occurs,

as aortic pressure is higher than pulmonic pressure throughout the entire cardiac cycle. Patients with untreated PDA can present asymptotically, or have clinical signs related to atrial fibrillation or left-sided congestive heart failure.

In a small subset of patients with severe pulmonary overcirculation due to a PDA or other intracardiac shunting lesion, vascular remodelling of the pulmonary circulation develops due to high pulmonary blood flow and subsequent endothelial damage, which leads to pulmonary hypertension (PH) and shunt reversal. This phenomenon is known as Eisenmenger's syndrome. Reversed PDAs lead to poor oxygenation, differential cyanosis and polycythaemia.

Diagnosis

The diagnosis of PDA in most species is made echocardiographically. In small animals, the PDA itself can be visualised as it enters into the main PA typically just above the left main PA branch. Continuous, turbulent blood flow can be appreciated in the main PA with colour Doppler imaging.

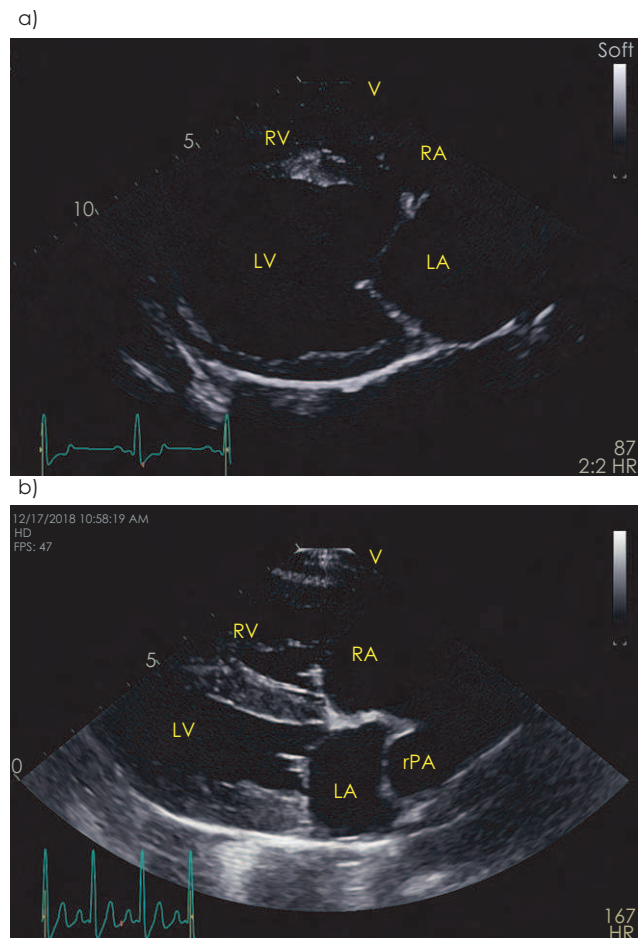


Fig 2: a) Echocardiogram of a dog with a left-to-right shunting PDA. Note the left ventricular and left atrial dilation. b) Echocardiogram of a dog with a rPDA. Note the flattened interventricular septum, right ventricular concentric hypertrophy and dilated right pulmonary artery branch above the left atrium. LV = left ventricle, RV = right ventricle, rPA = right pulmonary artery branch, RA = right atrium, LA = left atrium.

Spectral Doppler interrogation of the PDA flow allows for measurement of the peak PDA flow velocity (4.5–5 m/s with normal aorta and PA pressures), which can be used to estimate the pressure gradient between the aorta and the main PA. Low-velocity left-to-right PDA flow suggests that pulmonary hypertension may be present. Expected secondary chamber remodelling that develops with standard left-to-right shunting PDAs includes left ventricular and atrial enlargement (**Fig 2**). Secondary mitral regurgitation may develop as a result of annular dilation and distortion of the mitral valve apparatus that accompanies the left-sided cardiac enlargement. Mild aortic valve regurgitation is also commonly appreciated, as is dilation of the main PA (Schneider and Moore 2006).

In patients with rPDA, severe right-sided cardiac remodelling develops as a result of severe PH and is characterised by right ventricular concentric hypertrophy, flattening of the interventricular septum and severe dilation of the main PA and its branches (**Fig 2**). If tricuspid regurgitation or pulmonic insufficiency is present, the velocity of these valvular insufficiencies is expected to be abnormally high as a result of the on-going PH. Left-sided cardiac chambers are expected to be normal or even decreased in size due to poor venous return to the left heart. Visualisation of rPDA flow can

sometimes be difficult, with contrast echocardiography (intravenous injection of agitated saline) typically needed for confirmation of the diagnosis. In the case of an rPDA, the right-to-left shunt is extracardiac, thus imaging of microbubbles in the abdominal aorta is expected.

The anatomy of a PDA varies substantially from individual to individual (Krichenko *et al.* 1989). Size and shape of both the PDA ampulla (tube portion) and the ostium where the PDA inserts on the PA side (minimal ductal diameter) are crucial for determining the feasibility of different definitive treatment options. Additional imaging modalities such as angiography or transoesophageal echocardiography are often needed prior to definitive treatment to better define PDA anatomy.

Therapy

The therapy of choice for a left-to-right PDA in humans and small animals is early closure. Minimally invasive procedures to deliver intravascular devices or direct surgical ligation via a thoracotomy are performed in these species. Patient size and some PDA anatomic phenotypes, mainly insufficient ductal tapering to allow for adequate device stability, are limitations for device placement. Whether or not a catheter-based

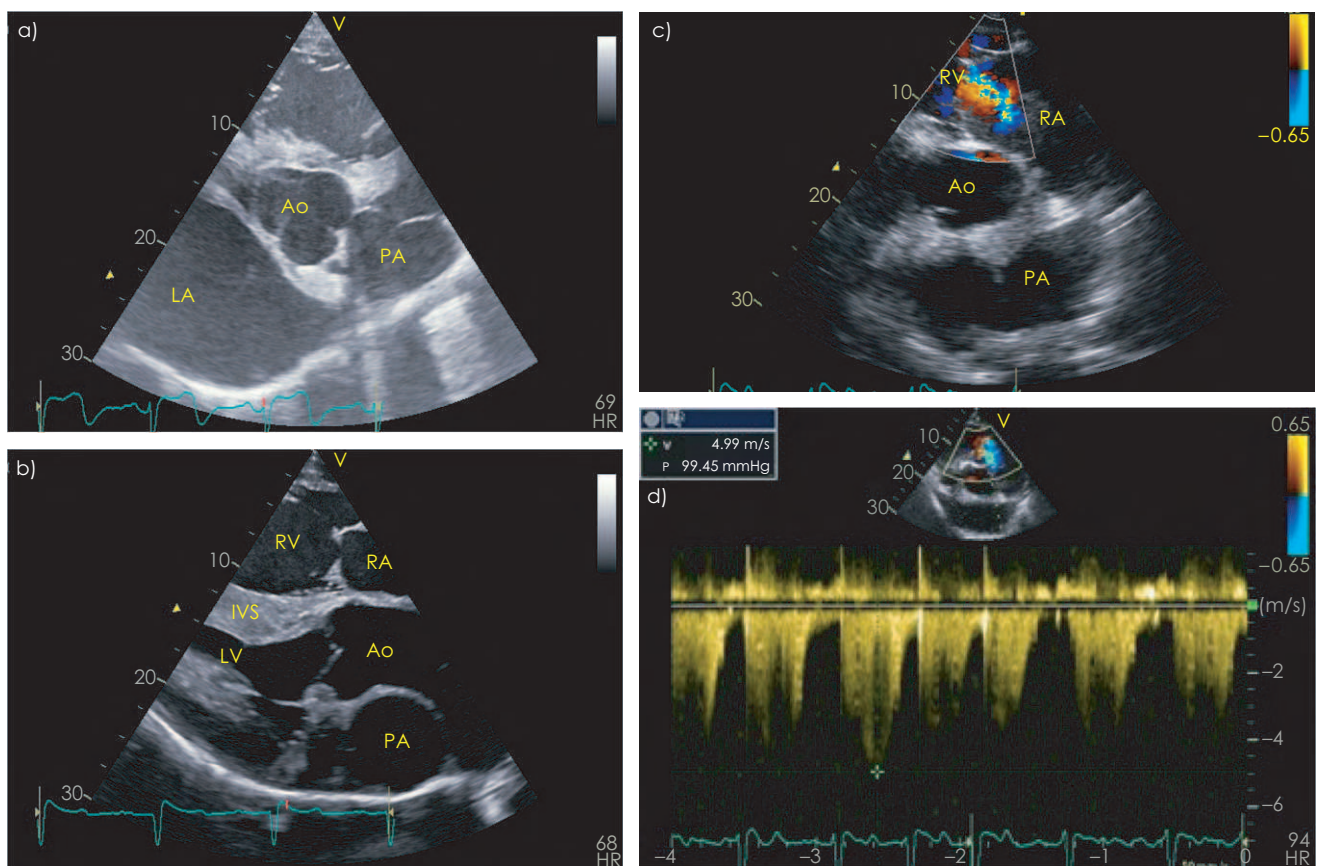


Fig 3: Echocardiograms of horses with pulmonary hypertension. a) Echocardiogram of a horse with PH secondary to left-sided heart disease. Note the enlargement of the PA, left atrium and left atrial appendage. b) Echocardiogram of a horse with PH secondary to pulmonary disease. Note the PA enlargement and the flattened interventricular septum. c and d) Colour flow Doppler and spectral Doppler of a jet of tricuspid regurgitation. Note the tricuspid regurgitation maximal velocity of approximately 5 m/s, suggesting a systolic PA pressure of approximately 100 mmHg. Ao = aorta, LV = left ventricle, RV = right ventricle, PA = pulmonary artery, LA = left atrium, RA = right atrium, IVS = interventricular septum. Arrows point to jet of tricuspid regurgitation.

occlusion could be considered in foals would largely depend upon the size of the foal and the size and shape of the PDA. Normally growing foals would quickly become too large for a catheter-based occlusion, though ligation could be considered in a horse or other large animal species. Haemodynamically significant PDAs that are not closed typically lead to the development of left-sided congestive heart failure and drugs such as diuretics, angiotensin-converting enzyme inhibitors, pimobendan or digoxin can be used.

Closure of rPDAs is contraindicated as it can precipitate life-threatening PH. These patients can be treated for the underlying PH and monitored for secondary polycythaemia. Pulmonary vasodilators such as oxygen, nitric oxide or phosphodiesterase-5 inhibitors have been used in foals with PH. Sildenafil has been shown to improve clinical signs and reduce secondary erythrocytosis in dogs with rPDAs (Nakamura *et al.* 2011). If primary lung disease is present, successful treatment of that pathology would be a primary goal. There is minimal clinical experience in the use of the majority of these therapies in horses.

Pulmonary hypertension

In addition to PH that develops as a result of a large shunting lesion and Eisenmenger's syndrome, a multitude of other causes of PH are possible including left-sided cardiac disease, chronic lung diseases and/or hypoxia, thromboembolic disease or multifactorial mechanisms (Simonneau *et al.* 2013). Pulmonary hypertension associated with hypoxia and lung disease may be the most commonly described causes of PH in horses, followed by left-sided cardiac disease (Fig 3). Echocardiographic changes associated with increased PA pressures in horses with acute exacerbation of asthma have been reported. In these horses increased PA diameter, abnormal septal motion, thickening of the right ventricular wall, decreased left ventricular diameter and estimated stroke volume and changes in tissue doppler and speckle tracking have been described (Johansson *et al.* 2007; Decloedt *et al.* 2017). Persistent PH of the newborn is also described, and is attributed to a failure of the cardiovascular system to transition to neonatal life after birth (Cottrill *et al.* 1987; Drummond 1987). In the case reported by Saadi *et al.* (2020), PH may have been caused primarily by respiratory disease and persistent PH of the newborn or Eisenmenger's syndrome could have played a role.

Interstitial pneumonia

Acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) are syndromes arising from an uncontrolled inflammatory response in the lungs. Infection is often the suspected original insult for cause, and damage to vascular and alveolar epithelium causing pulmonary interstitial oedema, alveolar fluid accumulation, decreased surfactant, hyaline membrane formation, atelectasis, early fibrosis, collapse of the alveoli and sudden respiratory distress the result. Inefficient gas exchange is part of the definition of ALI/ARDS and the consequence of ventilation-perfusion mismatch with both areas of low and high ventilation-perfusion ratios (Dunkel *et al.* 2005).

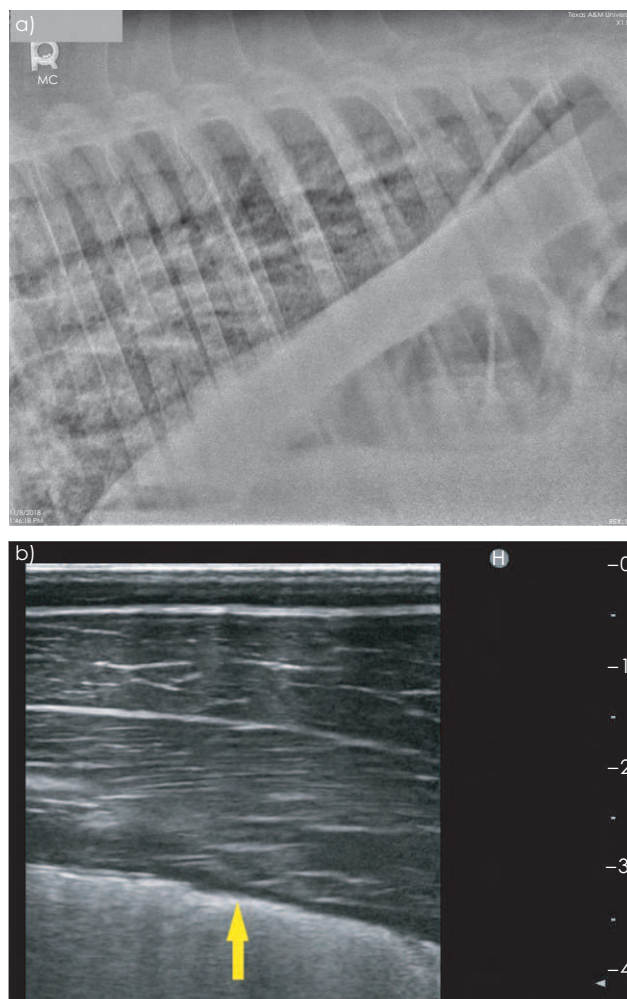


Fig 4: Thoracic radiograph and sonogram of a horse with severe interstitial pneumonia. **a)** the radiograph shows severe, diffuse, interstitial and bronchial patterns, **b)** the sonogram shows coalescing or broad-based comet tail artefacts (arrow) often seen in foals (diffuse 'ground glass appearance').

The bronchointerstitial pneumonia and acute respiratory distress described in 1 to 7-month-old foals (Lakritz *et al.* 1993) resembles the clinical presentation of the foal described by Saadi *et al.* Respiratory distress, tachypnea, initial large bronchial sounds followed by crackles and wheezes, fever, cyanosis, sudden death, leukocytosis, hyperfibrinogenaemia, hypoxaemia, hypercapnia and disseminated intravascular coagulation are common clinical and clinicopathological features in these cases Wilkins (2003). Pulmonary imaging (Fig 4) in conjunction with the above described signs of PH help define the severity of the disease, and can guide therapy in conjunction with the clinical and the clinicopathological (mainly arterial blood gases) progression. Chronic interstitial pneumonia and ALI/ARDS (Cottrill *et al.* 1987; Nout *et al.* 2002) may reflect a common lung response to injury. Supportive (oxygen therapy, fluid therapy, nutritional support) and anti-inflammatory (steroidal and nonsteroidal) care while attempting to identify and treat (antibiotic therapy) the primary insult should be the goal in these cases. Corticosteroid

therapy and environmental temperature control have been suggested to be the key to successful therapy.

Authors' declaration of interests

No conflicts of interests have been declared.

Authorship

Both authors contributed to drafting and approval to the manuscript.

References

- Cottrill, C.M., O'Connor, W.N., Cudd, T. and Rantanen, N.W. (1987) Persistence of foetal circulatory pathways in a newborn foal. *Equine Vet. J.* **19**, 252-255.
- Declodt, A., Borowicz, H., Slowikowska, M., Chiers, K., Loon, G. and Niedzwiedz, A. (2017) Right ventricular function during acute exacerbation of severe equine asthma. *Equine Vet. J.* **49**, 603-608.
- Drummond, W.H. (1987) Neonatal pulmonary hypertension. *Equine Vet. J.* **19**, 169-171.
- Dufourni, A., Declodt, A., De Clercq, D., Saey, V., Chiers, K. and van Loon, G. (2018) Reversed patent ductus arteriosus and multiple congenital malformations in an 8-day-old Arabo-Friesian foal. *Equine Vet. Educ.* **30**, 315-321.
- Dunkel, B., Dolente, B. and Boston, R.C. (2005) Acute lung injury/acute respiratory distress syndrome in 15 foals. *Equine Vet. J.* **37**, 435-440.
- Hall, T.L., Magdesian, K.G. and Kittleson, M.D. (2010) Congenital cardiac defects in neonatal foals: 18 cases (1992-2007). *J. Vet. Intern. Med.* **24**, 206-212.
- Johansson, A.M., Gardner, S.Y., Atkins, C.E., LaFevers, D.H. and Breuhaus, B.A. (2007) Cardiovascular effects of acute pulmonary obstruction in horses with recurrent airway obstruction. *J. Vet. Intern. Med.* **21**, 302-307.
- Krichenko, A., Benson, L.N., Burrows, P., Mões, C.A., McLaughlin, P. and Freedom, R.M. (1989) Angiographic classification of the isolated, persistently patent ductus arteriosus and implications for percutaneous catheter occlusion. *Am. J. Cardiol.* **63**, 877-880.
- Lakritz, J., Wilson, W.D., Berry, C.R., Schrenzel, M.D., Carlson, G.P. and Madigan, J.E. (1993) Bronchointerstitial pneumonia and respiratory distress in young horses: clinical, clinicopathologic, radiographic, and pathological findings in 23 cases (1984-1989). *J. Vet. Intern. Med.* **7**, 277-288.
- Marr, C.M. (2015) The equine neonatal cardiovascular system in health and disease. *Vet. Clin. North Am. Equine Pract.* **31**, 545-565.
- Nakamura, K., Yamasaki, M., Ohta, H., Sasaki, N., Murakami, M., Bandula Kumara, W.R. and Takiguchi, M. (2011) Effects of sildenafil citrate on five dogs with Eisenmenger's syndrome. *J. Small Anim. Pract.* **52**, 595-598.
- Nout, Y.S., Hinchcliff, K.W., Samii, V.F., Kohn, C.W., Jose-Cunilleras, E. and Reed, S.M. (2002) Chronic pulmonary disease with radiographic interstitial opacity (interstitial pneumonia) in foals. *Equine Vet. J.* **34**, 542-548.
- Reimer, J.M., Marr, C.M., Reef, V.B. and Saik, J.E. (1993) Aortic origin of the right pulmonary artery and patent ductus arteriosus in a pony foal with pulmonary hypertension and right-sided heart failure. *Equine Vet. J.* **25**, 466-468.
- Saadi, A., Dalir-Naghadeh, B., Hashemi-Asl, S.M., Tehrani, A.A., Hobbenaghi, R., Mahmoudi, S.S. and Shalazar-Jalali, A. (2020) Right to left patent ductus arteriosus, acute bronchointerstitial pneumonia, pulmonary hypertension and cor pulmonale in a foal. *Equine Vet. Educ.* **32**, 459.
- Schneider, D.J. and Moore, J.W. (2006) Patent ductus arteriosus. *Circulation* **114**, 1873-1882.
- Simonneau, G., Gatzoulis, M.A., Adatia, I., Celermajer, D., Denton, C., Ghofrani, A., Gomez Sanchez, M.A., Krishna Kumar, R., Landzberg, M., Machado, R.F., Olschewski, H., Robbins, I.M. and Souza, R. (2013) Updated clinical classification of pulmonary hypertension. *J. Am. Coll. Cardiol.* **62**, D34-D41.
- Wilkins, P.M. (2003) Lower respiratory problems of the neonate. *Vet. Clin. North Am. Equine Pract.* **19**, 19-33.

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Case Report

Medial pterygoid myositis in a Thoroughbred gelding

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Keywords: horse; computed tomography; abscess; myositis; trismus

Summary

A 9-year-old Thoroughbred gelding was presented with a large swelling medial to the right mandible. Pain was elicited on palpation of the swelling, and purulent, severely malodorous exudate was emanating from a draining tract. Laboratory testing for *Strep. equi* subsp. *equi* was negative.

Standing head CT identified a large space-occupying lesion of heterogenous gas and soft tissue attenuation lying medial to the right mandible (**Fig 1a**). Additionally, there was an area of irregular bone lysis of the medial aspect of the mandible (**Fig 1b**). The right regional lymph nodes were enlarged and association with the lesion could not be excluded.

Placement of an oral speculum was markedly resented; however, oral examination under profound sedation identified a small area of severe, chronic buccal ulceration adjacent to the 411 tooth. Bacterial culture of the purulent exudate yielded a profuse growth of mixed anaerobes including *Peptostreptococcus* and *Prevotella* spp.

A diagnosis of a large abscess was made although the aetiology was unclear. The cavity was carefully debrided and lavaged under general anaesthesia. Upon entering the abscess cavity, a copious volume of foetid creamy-brown

fluid and inspissated purulent material was released, and large pieces of necrotic medial pterygoid muscle were removed. The skin incision was partially closed, and the cavity was packed with a gauze seton drain.

The horse was maintained on antibiotics and anti-inflammatories. By 5 days post-operatively, the cavity was filling well with granulation tissue; there was serous, odourless exudate, and the horse was bright and eating well. The horse returned home to rest until the cavity had healed completely.

One month post-operatively, the horse was dull with reduced masticatory excursion. The cavity had almost completely healed with only a small tract remaining. Repeat CT showed only small areas of gas attenuation remaining in the region of the healing tract.

In the absence of any temporomandibular joint or dental abnormalities, we hypothesised the trismus was due to inflammation of the previously necrotic muscle and so recommended to keep feeding the horse roughage to act as physiotherapy. A follow-up telephone conversation with the referring vet 6 weeks later confirmed the horse was progressing well – the discharging tract had healed completely, and the horse was eating well and maintaining his own body weight.

The use of standing head CT assisted with the diagnosis, enabled accurate and careful surgical planning, and assisted in monitoring progression of this case. Despite the complications encountered, the horse recovered satisfactorily overall. It is worth remembering that muscle function following trauma may be abnormal but, with appropriate physiotherapy, may return to normal in due course.

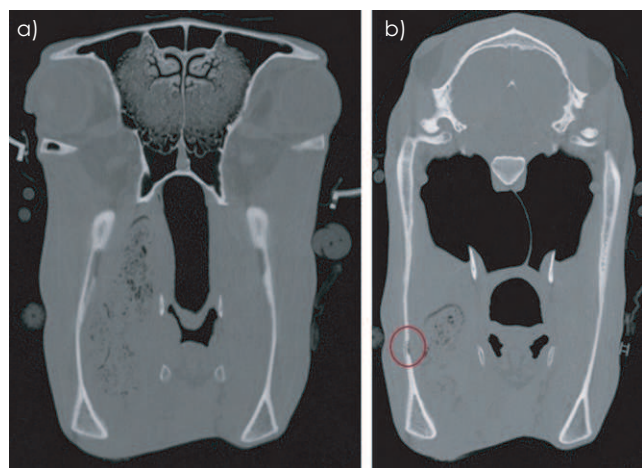


Fig 1: Transverse CT images. a) A large space-occupying lesion of heterogenous gas and soft tissue attenuation was identified, lying medial to the right mandible. b) A focal lucency was also present on the medial surface of the right mandible (red circle).

Key points

- Standing head CT should be considered in the diagnostic investigation of any lesion involving the equine head.
- Careful diagnostic investigations coupled with a thorough understanding of anatomy mean that surgical exploration and treatment can be safely achieved.
- Trismus is a possible side effect of trauma to the muscles of mastication. However, with appropriate physiotherapy, masticatory function can return to normal in due course.



Clinical Commentary

Medial pterygoid myositis in a Thoroughbred gelding – an imaging perspectiveR. Jones* 

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The case report by Tannahill *et al.* (2020) describes an interesting case with well-presented diagnostic images and a slightly unusual, delayed complication with the development of trismus some time after surgery and discharge from the hospital.

The authors describe the commonest causes of inter-mandibular abscessation and conclude that, due to the nature of the bacterial species cultured (*Peptostreptococcus* and *Prevotella* species), they felt that the likely origin of the infection to have been from an oral route. While no obvious site of entry was identified on oral examination, it is still entirely possible that there was direct inoculation via this route, from a small puncture or other wound, which may have healed. No external wounds or related dental disease was identified with oral examination or with the subsequently employed diagnostic imaging techniques, especially radiography and computed tomography (CT).

The imaging modalities employed in the case provide a good example of the advantages and disadvantages of each modality. Radiography is limited by superimposition of other structures, radiographic distortion due to obliquity, the inability to identify separate soft tissue and fluid filled structures and its relative insensitivity in identifying some bony pathology. Well-documented oblique radiographs are described to better evaluate the structures of the skull (Butler *et al.* 2017) as well as more bespoke, lesion-orientated obliques. The use of radiopaque probes (usually metallic), as described in this case, is also well recognised and can be invaluable in outlining tracts within tissues, both in the head and other parts of the body (Fig 1a and b). The use of a liquid radiographic positive contrast agent is usually less rewarding, if placed directly into a draining tract, as it tends to take the path of least resistance and not extend into the tract.

Ultrasonography is valuable for evaluation of soft tissues, fluid filled structures, cartilage and bone surfaces but its value becomes more limited in the presence of gas, mineralisation or foreign material as acoustic artefacts can occur. One of the most common acoustic artefacts encountered is that of acoustic shadowing (Reef 1998), seen at tissue interfaces where there is a large difference in acoustic impedance between the two tissues (e.g. soft-tissue mineral and soft-tissue gas interfaces). It becomes harder to evaluate the tissue deep to regions of acoustic shadowing. The converse of this is that, in some cases, gas can act as an ultrasonographic 'contrast material' and can be followed, within a tract, to determine direction and extent (Fig 2), which can be invaluable for traumatic injuries, such as puncture wounds adjacent to synovial structures. The acoustic shadow produced from a foreign body can also be helpful in identifying its presence, location and size (Fig 3a

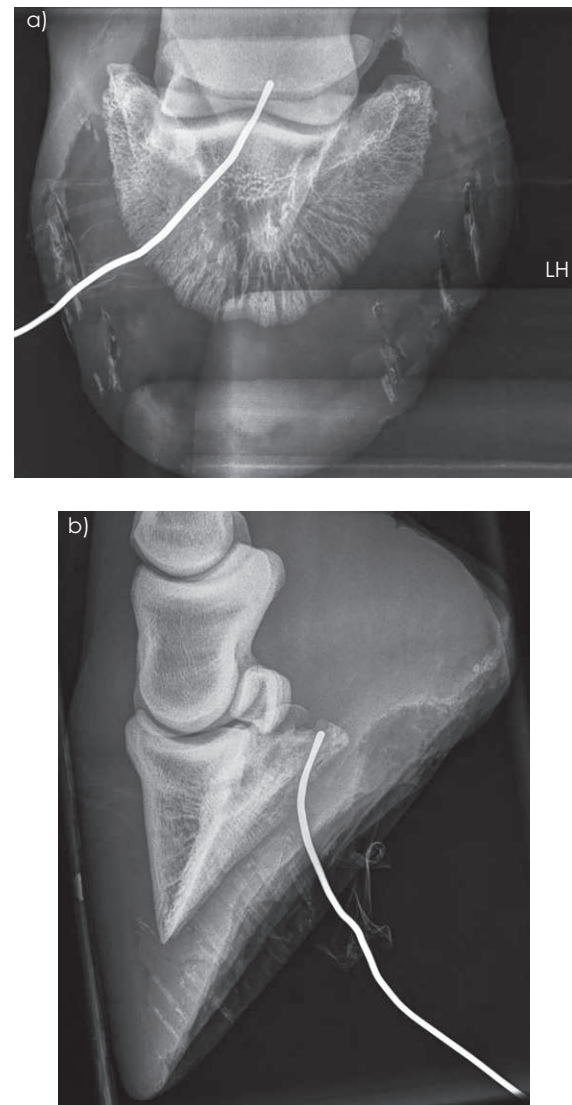


Fig 1: a) Example of the use of a metal probe to delineate a tract. Dorsoproximal-plantarodistal oblique radiograph of the foot, following a solar penetration, showing a metallic probe extending in from the medial aspect of the foot, superimposed on P3 and the DIP joint space and extending towards the axial midline with the end of the probe positioned just proximal to the distal horizontal border of the navicular bone. b) Lateromedial radiograph of the same foot as Fig 1a showing the metallic probe delineating a tract, from the solar penetration, extending proximally from the solar margin of the foot, plantar to the deep digital flexor tendon (DDFT) and superimposed of the wings of P3, indicating that there is no involvement of the DDFT, synovial or bony structures.

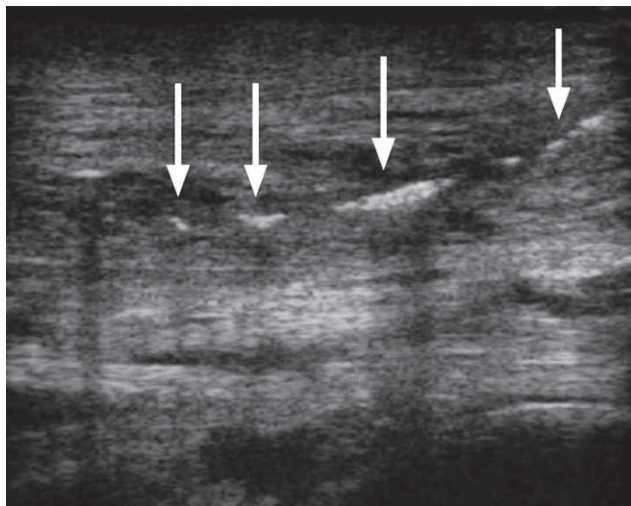


Fig 2: Longitudinal B mode ultrasound image of the dorsal aspect of the hock following a traumatic wound showing a number of hyperechoic foci with a distal acoustic shadow, consistent with gas, tracking through the soft tissue superficial to the lateral digital extensor tendon.

and b). Ultrasonography was not employed preoperatively in this case and is likely to have been of limited value for the previously described reasons. Its use at the time of re-examination revealed hyperechoic foci, consistent with gas, within a tract.

It is important to remember that while both radiography and ultrasonography have their limitations, they are still invaluable imaging modalities and remain at the forefront of first opinion and referral practice.

Standing computed tomography (CT) of the head was performed in this case and was clearly indicated to better evaluate soft tissue, bone and dental material. Computed tomography of the equine head, using standing sedation, is by now a well-documented procedure and its value for imaging of the equine head is well recognised (Manso-Diaz *et al.* 2015). It is well tolerated by the majority of horses and is comparatively safe. However, it still remains limited to a relatively small but ever-growing number of more specialist sites within the UK and throughout the world. The advantages of CT are the tomographic nature of the images produced, the ability to evaluate structures in multiple imaging planes, with no superimposition or imaging distortion due to obliquity, as well as spatial and contrast resolution when compared with radiography and also, in many cases, radiography and ultrasonography combined (Fig 4). The ability to more clearly evaluate the extent and nature of a lesion and its anatomical proximity to other structures is important for surgical planning. Computed tomography was also useful, in this case, in the post-operative evaluation, when trismus had developed. The authors describe a condition in people, myositis ossificans traumatica (Hanisch *et al.* 2018) in which heterotopic bone develops in regions of traumatised muscle tissue. It is clear from the post-operative CT images that this was not present, as mineralisation of soft tissues would have been clearly detectable in the CT images, as described in people with this condition (Fig 5).

The interesting complication of delayed onset trismus prompted further investigation with the diagnostic imaging performed indicating ongoing resolution of the soft tissue pathology. Common causes of trismus in the horse include

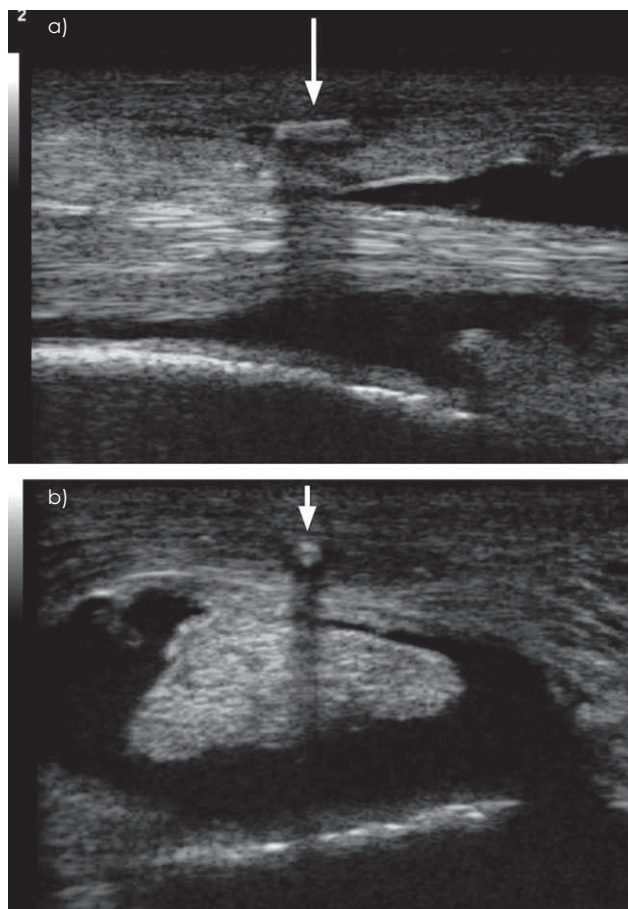


Fig 3: a) Longitudinal B mode ultrasound image of the dorsal aspect of the carpus showing a linear, hyperechoic structure with a distal acoustic shadow, consistent with a foreign body, superficial to the extensor carpi radialis (ECR) tendon and its sheath. Note the marked effusion of the tendon sheath. b) Transverse B mode ultrasound image, of the same case as image 3a, showing the foreign body in cross section and appearing as a small rounded hyperechoic structure with a distal acoustic shadow sitting just superficial to the ECR tendon and sheath. Note the marked effusion of the ECR tendon sheath with some inflammatory tissue within the sheath. The foreign body was a black thorn.

infection with *Clostridium tetani* which produces neurotoxins, the main one being tetanospasmin, which through its mechanism of action results in muscle contractions and spasm as well as other clinical signs, and trismus is not seen in isolation (Kay and Knottenbelt 2007). Other common causes of trismus in the horse include causes of temporomandibular pain, oral pain, muscle pain and trauma, including fractures (Figs 6a,b and 7a,b).

The authors rule out other causes of trismus and suggest that it is related to the muscle damage, the muscles' inability to regenerate rapidly and cited inflammation/scarring of the muscle as possible causes. Trismus due to muscle pathology has been previously described in horse. One report (Pearson *et al.* 2005) described myodegeneration, at varying stages of the masseter muscle in eight horses, which had difficulty opening the mouth and eating. Some of these horses also had more widespread muscular involvement. In a separate report (Aharonson-Raz *et al.* 2009), one horse was described

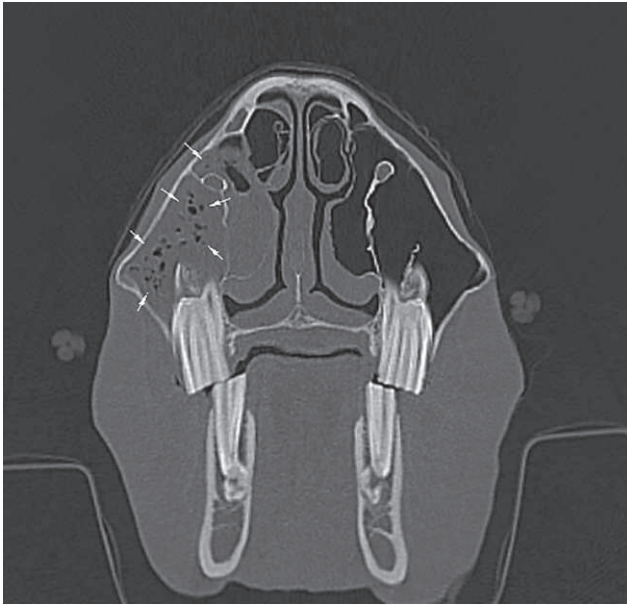


Fig 4: 3D MPR transverse CT image, positioned at the level of the 110 and 210 teeth, showing opacification of the rostral maxillary and ventral choanal sinus with soft tissue/fluid attenuating material. There are multiple hypoattenuation foci within the abnormal tissue in the rostral maxillary sinus, consistent with the presence of gas. This finding is consistent with the appearance of inspissated pus within the sinus.

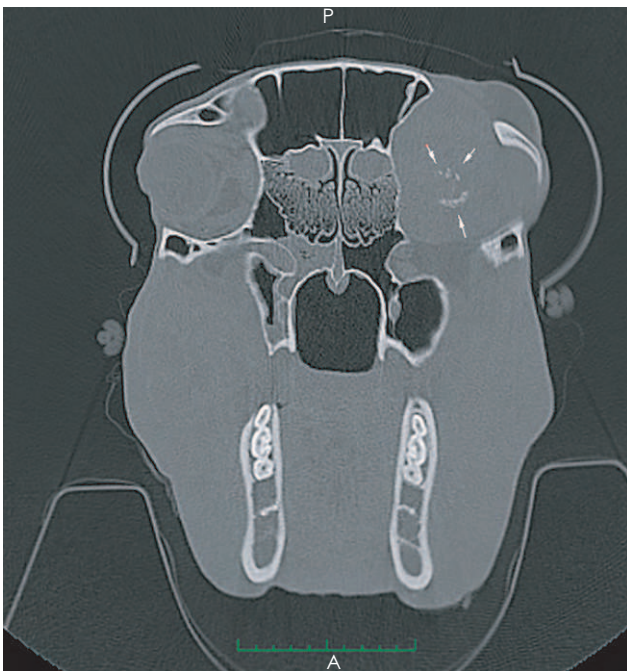


Fig 5: 3D MPR transverse CT image, positioned towards the rostral aspect of the orbit showing a large mass, which is isoattenuating compared with the adjacent soft tissue but containing multiple hyperattenuating foci, consistent with mineralisation within the mass. This mass is likely to be a melanoma.

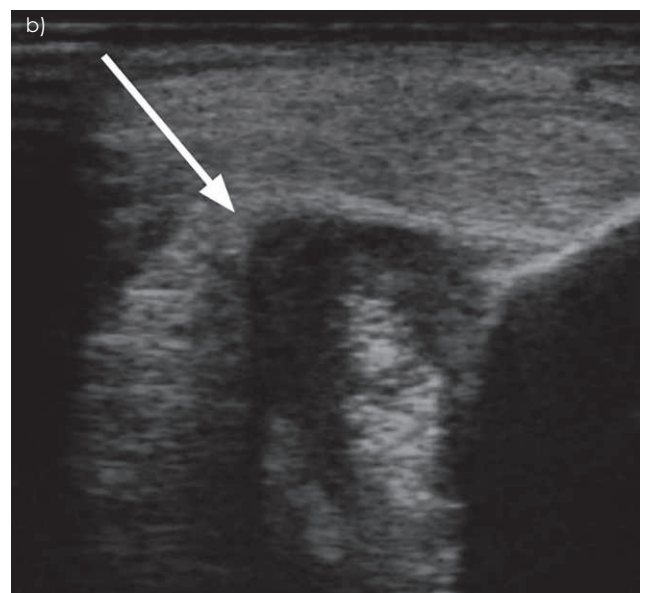
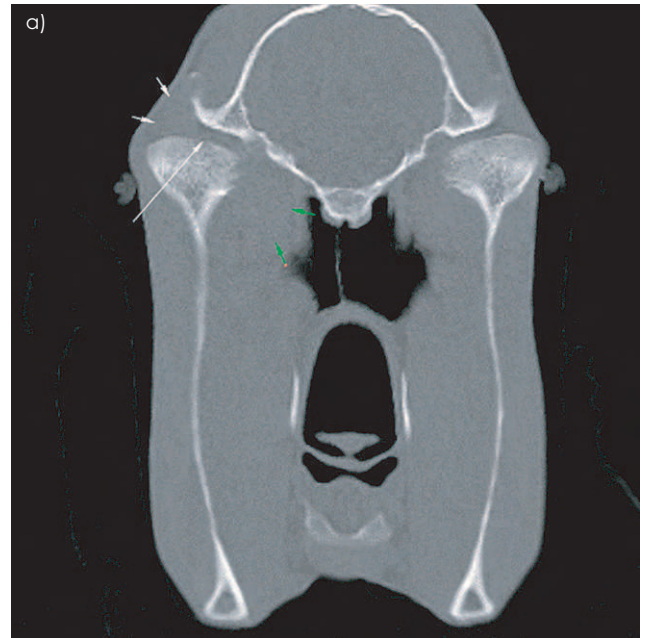


Fig 6: a) 3D MPR transverse CT image, positioned level with the temporomandibular joints (TMJs) of a case of sepsis of the left TMJ. There is widening of the left TMJ joint space (large white arrow) with an increased volume of soft tissue laterally (small white arrows) and in the region of the medial pterygoid muscle axially (green arrows). This image has been affected by motion. b) Transverse B mode ultrasound image of the same case as Fig 6a showing marked effusion of the TMJ. There are hyperechoic foci present within the effusion consistent with sepsis.

with fibrosis of the masseter muscle following abscessation and was suspected to be due to myositis. EMG findings, in this case, were consistent with degenerative muscle changes, with a biopsy confirming fibrosis. Ultrasound evaluation showed that the muscle appeared smaller and less echogenic than normal, consistent with fibrosis.

The authors advised continued feeding of roughage to act as physiotherapy and the horse went on to do well,

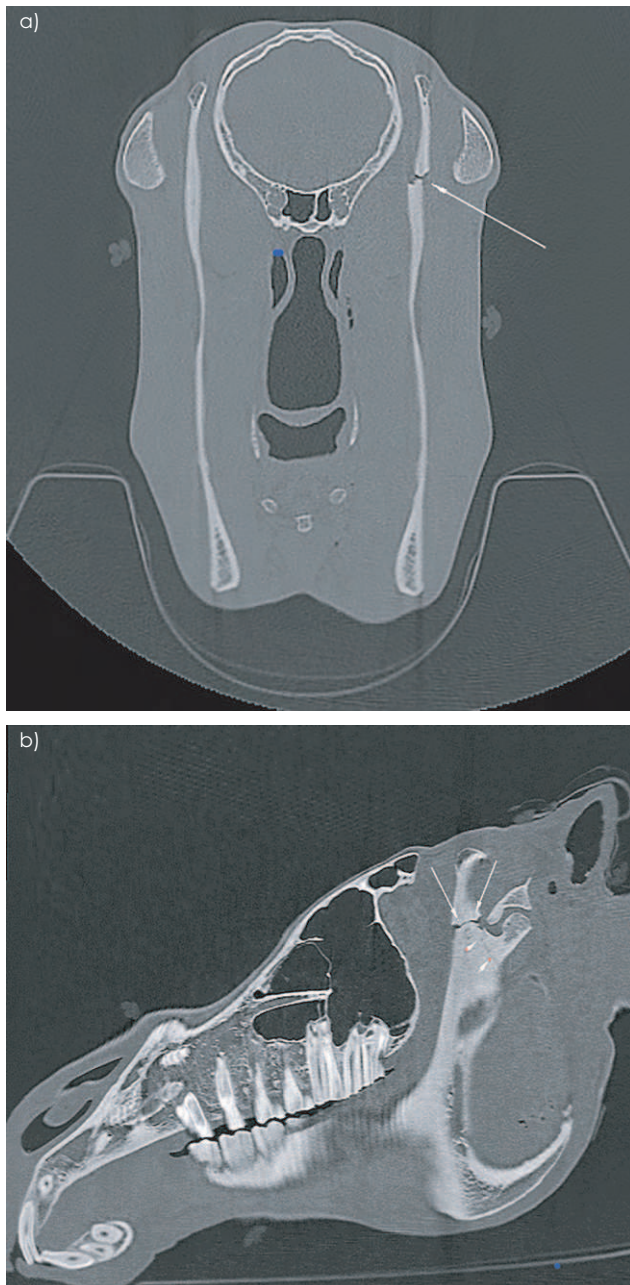


Fig 7: a) 3D MPR transverse CT image, positioned rostral to the TMJs, of a horse with trismus following a traumatic incident involving the skull, showing a horizontal fracture line, with slight displacement through the right coronoid process of the mandible (arrow). b) 3D MPR sagittal CT image of the same case as Fig 7a, positioned over the right mandible showing the horizontal fracture line through the coronoid process of the mandible (large arrows) with an additional obliquely orientated fracture line, indicating comminution, running in a caudoventral orientation (small arrows).

therefore the trismus was only a medium-term complication. Trismus is also described in people following treatment for oral cancers (Pantvaidya *et al.* 2019) and they advocate the aggressive use of rehabilitation, including physiotherapy, to prevent this from occurring.

In summary, this case report employed several different imaging modalities and provides a good example of the strengths and weakness of them all as well as where they can be used in conjunction with each other to maximise the information obtained.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

No legal or ethical review needed for this clinical commentary.

Source of funding

None.

References

- Aharonson-Raz, K., Milgram, J., Chai, O. and Sutton, G.A. (2009) Fibrosis of the masseter leading to trismus and dysphagia in a mare. *Vet. Rec.* **164**, 597-598.
- Butler, J., Colles, C., Dyson, S., Kold, S. and Poulos, P. (2017) *Clinical Radiology of the Horse*, 4th edn., Wiley-Blackwell, Oxford. pp 449-488.
- Hanisch, M., Hanisch, L., Frohlich, L.F., Werkmeister, R., Bohner, L. and Kleinheinz, J. (2018) Myositis ossificans traumatica of the masticatory muscles: aetiology, diagnosis and treatment. *Head Face Med.* **14**, 23.
- Kay, G. and Knottenbelt, D.C. (2007) Tetanus in equids: a report of 56 cases. *Equine Vet. Educ.* **19**, 107-112.
- Manso-Diaz, G., Garcia-Lopez, J.M., Maranda, L. and Taeymans, O. (2015) The role of head computed tomography in equine practice. *Equine Vet. Educ.* **27**, 136-145.
- Pantvaidya, G., Sivasanker, M., Ranganathan, P., Pai, P. and D'Cruz, A. (2019) Prospective cross-sectional study assessing prevalence and factors affecting trismus after multimodal; treatment for oral cancers. *Head Neck* **41**, 286-290.
- Pearson, E.G., Synder, S.P. and Saulez, M.N. (2005) Masseter degeneration as a cause of trismus or dysphagia in adult horses. *Vet. Rec.* **156**, 642-646.
- Reef, V. (1998) *Equine Diagnostic Ultrasound*, Saunders, Philadelphia. pp 26-32.
- Tannahill, V.J., Giavitto, A. and Munroe, G.A. (2020) Medial pterygoid myositis in a Thoroughbred gelding. *Equine Vet. Educ.* **32**, 465.

Case Report

Dental bridging as a treatment for large oral fistulae in two horses**N. Storms*** , **A. Salciccia, G. de la Rebière de Pouyade, L. Evrard and S. Grulke**

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Keywords: horse; oral fistula; dental bridging; polymethylmethacrylate; cerclage wire**Summary**

A 12-year-old, Westphalian gelding was presented for nasal discharge because of a large (2.5 × 3 cm) oromaxillary fistula after dental repulsion of the Triadan 209 4 years earlier. The second case, a 5-year-old Oldenburg mare was presented for a large (2.5 × 3.5 cm) orocutaneous fistula 7 weeks after dental repulsion of the Triadan 208. Conservative management including debridement of the fistula and placement of a dental plug was not attempted because the plug would have been unstable due to the size of the fistulae. Both horses were treated under general anaesthesia by placing a dental bridge composed of cerclage wire and polymethylmethacrylate (PMMA). The cerclage wire was inserted through the interdental space rostral and caudal to the fistula and crossing at the level of the missing tooth, creating an 8-shaped construct (**Fig 1**). PMMA was then used to seal the fistula. No significant



Fig 2: Control buccoscopy of Case 2 after 1.5 years showing correct placement of the construct, absence of tissue inflammation and only slight wear of the PMMA in the centre.

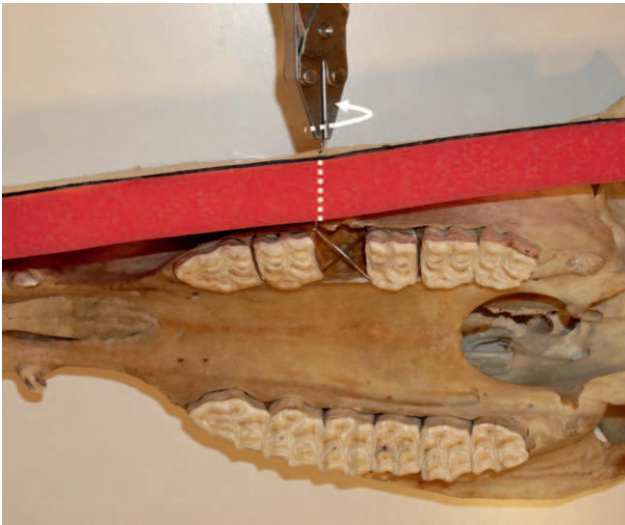


Fig 1: Schematic presentation of the surgical technique: after threading the cerclage wire through the drilled hole in the interdental space caudal to the fistula and looping it around the tooth rostral to the fistula (by passing it through the drilled hole at the rostral interdental space) both ends are exteriorised through a 1 cm cheek incision and tightened, creating an 8-shaped construct. The oral part of the fistula will then be sealed with PMMA.

complications occurred during or after the surgery. In both cases clinical signs did not recur. In the first case the dental bridge is currently (5 years after the intervention) in place. In Case 2 the construction was solidly in place after 1.5 years (**Fig 2**), the bridge was then removed and the fistula had healed completely.

Placement of a dental bridge is a relatively easy procedure that is very well tolerated by horses and avoids the need for intensive follow-up. A limit to the technique is the need of anchorage at the interdental spaces rostral and caudal to the fistula.

Key points

- The dental bridge composed of cerclage wire and PMMA provided efficient sealing of the oral fistulae even though they were very large.
- Advantages include not requiring specialised or expensive equipment, being a minimally invasive and one-step procedure.
- This technique is particularly indicated for fistulas at the level of Triadan '08' or '09'.



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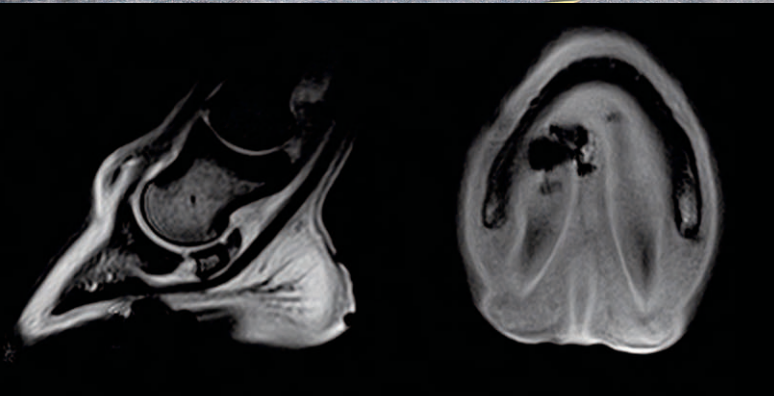
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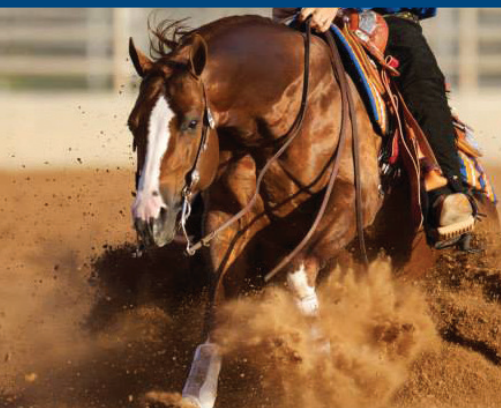


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PRECAUTIONS: As a class, bisphosphonates may be associated with gastrointestinal and renal toxicity. Sensitivity to drug associated adverse reactions varies with the individual patient. Renal and gastrointestinal adverse reactions may be associated with plasma concentrations of the drug. Bisphosphonates are excreted by the kidney; therefore, conditions causing renal impairment may increase plasma bisphosphonate concentrations resulting in an increased risk for adverse reactions. Concurrent administration of other potentially nephrotoxic drugs should be approached with caution and renal function should be monitored. Use of bisphosphonates in patients with conditions or diseases affecting renal function is not recommended. Administration of bisphosphonates has been associated with abdominal pain (colic), discomfort, and agitation in horses. Clinical signs usually occur shortly after drug administration and may be associated with alterations in intestinal motility. In horses treated with OSPPOS these clinical signs usually began within 2 hours of treatment. Horses should be monitored for at least 2 hours following administration of OSPPOS.

Bisphosphonates affect plasma concentrations of some minerals and electrolytes such as calcium, magnesium and potassium, immediately post-treatment, with effects lasting up to several hours. Caution should be used when administering bisphosphonates to horses with conditions affecting mineral or electrolyte homeostasis (e.g. hyperkalemic periodic paralysis, hypocalcemia, etc.).

The safe use of OSPPOS has not been evaluated in horses less than 4 years of age. The effect of bisphosphonates on the skeleton of growing horses has not been studied; however, bisphosphonates inhibit osteoclast activity which impacts bone turnover and may affect bone growth.

Bisphosphonates should not be used in pregnant or lactating mares, or mares intended for breeding. The safe use of OSPPOS has not been evaluated in breeding horses or pregnant or lactating mares. Bisphosphonates are incorporated into the bone matrix, from where they are gradually released over periods of months to years. The extent of bisphosphonate incorporation into adult bone, and hence, the amount available for release back into the systemic circulation, is directly related to the total dose and duration of bisphosphonate use. Bisphosphonates have been shown to cause fetal developmental abnormalities in laboratory animals. The uptake of bisphosphonates into fetal bone may be greater than into maternal bone creating a possible risk for skeletal or other abnormalities in the fetus. Many drugs, including bisphosphonates, may be excreted in milk and may be absorbed by nursing animals.

Increased bone fragility has been observed in animals treated with bisphosphonates at high doses or for long periods of time. Bisphosphonates inhibit bone resorption and decrease bone turnover which may lead to an inability to repair micro damage within the bone. In humans, atypical femur fractures have been reported in patients on long term bisphosphonate therapy; however, a causal relationship has not been established.

ADVERSE REACTIONS: The most common adverse reactions reported in the field study were clinical signs of discomfort or nervousness, colic and/or pawing. Other signs reported were lip licking, yawning, head shaking, injection site swelling, and hives/pruritus.



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Review Article

Treatment of equine oro-nasal and oro-maxillary fistulae

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Keywords: horse; oro-sinus fistula; oro-nasal fistula; equine sinusitis; oral surgery

Summary

Equine oro-nasal or oro-sinus fistulae are usually problematic disorders to treat. As these lesions are mainly a sequel to standard dental repulsions, it is obvious that safer exodontia techniques such as oral extraction should now be used. The initial treatment of such fistulae is to ensure that there is a healthy granulating alveolus, without any dental or alveolar sequestrae and that all epithelium lining the fistula is removed. Provided there is a tooth on either side of the fistula, the initial and usually successful treatment is the use of an acrylic alveolar plug attached to adequately prepared adjacent teeth. Reinforcing such prostheses with wire tied between adjacent teeth will stabilise such prostheses. For fistulae that extend far onto the hard palate or those at the Triadan 06 or 11 alveolar sites that cannot be treated by acrylic prostheses, a variety of surgical treatments including; mucoperiosteal sliding flap, transposition of facial muscles, maxillary bone flap or an ear cartilage graft are all potential therapies, but there are no large, objective long-term reports on their success available.

Introduction

Oro-nasal and oro-sinus fistulae can be frustrating disorders to successfully treat. Oro-sinus fistulae usually cause more marked clinical signs of upper airway contamination and infection than oro-nasal fistulae; some of the latter can have asymptomatic periods when at grass or if fed a chopped diet. There is little evidence-based study of the treatment of these disorders, mainly case reports of single or small numbers of horses or opinionated review articles such as this.

'Prevention is better than cure'

Most equine oro-nasal and oro-sinus (oro-maxillary) fistulae (*antrum* is a redundant anatomical term for the maxillary sinus and the term *oro-antral fistula* appears equally redundant!) are caused by damage to the apical aspect of the alveolus during standard cheek teeth repulsion using a wide dental punch. Because of the high level of post-operative problems it causes, standard repulsion is no longer an acceptable technique for routine equine dental extractions (Dixon and Gerard 2019). The obvious way to avoid creating these fistulae is to use an alternative cheek teeth extraction technique that limits the damage to the apical aspect of the alveolus. If an intact clinical crown is present, oral extraction is a safer technique with a study showing 205 consecutive maxillary cheek teeth oral

extractions without any oro-nasal/sinus fistula formation (R. Kennedy 2019, unpublished observations).

Teeth with fractured clinical crowns can be extracted using the minimally invasive transbuccal (MIT) technique or by Steinmann pin repulsion. Both techniques will be more successful if maximal loosening of the remaining tooth is achieved by using oral extractors or dental picks prior to pin repulsion or MIT extraction. Repulsion using a narrow (e.g. 5 mm diameter) Steinmann pin produces less localised damage to the apical aspect of the alveolus than a standard repulsion and is more likely to heal effectively. All repulsions via the thin-walled apical aspect of the alveolus create a communication between the oral cavity and the overlying nasal or sinus cavity. Unless this defect heals by granulation tissue, a fistula will ensue.

Alveolar infection, such as that which occurs with sequestration of alveolar wall fragments is the most common post-extraction complication in horses (R. Kennedy 2019, unpublished observations). Alveolar infection disrupts the post-extraction blood clot, retarding alveolar healing and thus increasing the chance of fistula formation. If following dental repulsion, an alveolus is packed very deeply with a solid packing material such as polymethyl methacrylate (PMMA), this material will physically prevent closure of the alveolar site containing the packing material, and also predispose to fistula formation.

In some horses with severe periapical infection, the thin alveolar bone wall between the infected and an adjacent healthy tooth may be lost due to infection, or it may be lost due to iatrogenic damage during dental extraction. This results in exposed cementum (rather than periodontal tissue or granulation tissue covered alveolar bone) on one side of the extraction site. Granulation tissue from other sites in a healing alveolus cannot attach to this exposed peripheral cementum at the affected side of the alveolus. Fistula development is likely to occur in these cases, unless some alveolar soft tissue remains at a more apical alveolar level that can help seal this aspect of the alveolus.

Some chronically infected, fractured teeth (especially those caused by infundibular caries-related fractures) can have extensive infection or even sequestration of their alveolar and adjacent supporting maxillary bone and may develop alveolar fistulae even prior to their extraction. If the alveolar and hard palate bone loss and subsequent fistula formation extends deep onto the hard palate (especially with deep periodontal infection of palatally displaced caries-related sagittal dental fractures or palatally positioned supernumerary teeth), these cases will be very problematic to treat, because an interdental prosthesis will be ineffective in

sealing the hard palate aspect of the defect. If these fistulae are caudally located (at Triadan 09-11 alveoli), it may not even be possible to gain adequate access to perform a sliding muco-periosteal flap and a muscle or an ear cartilage graft may be the best options as described later.

With long-term fistulae – especially of the maxillary 06 alveoli, the rostral aspect of the alveolar bone and thus the complete alveolus may fully atrophy, with the nasal side of the fistula now just consisting of a shallow defect on the floor of the nasal cavity (**Fig 1**), with an inflammatory-induced atrophy of the adjacent aspect of the ventral nasal conchus also usually present. In such cases there is no alveolus remaining to place any packing in. Additionally, with a fistula of the 06 (and less commonly of the 11 alveolus), there is an absence of a tooth on both sides of the fistula to attach an acrylic alveolar plug to, as acrylic cannot be securely fixed to soft tissue.

Ensure a healthy alveolus is present

The initial treatment of oro-nasal or oro-maxillary fistulae is to ensure the presence of a healthy alveolus, that is, one that is lined on all sides by healthy granulation tissue and without the presence of any embedded dental or bone fragments by clinical examinations and imaging, especially by computed tomography (Hargreaves and Dixon 2018). On digital examination, no hard calcified structure should be palpable in an extraction alveolus by 2 weeks post extraction (some exposed alveolar bone ridges may be palpable before this time).

Once a healthy alveolus is achieved, a balance must be struck between preventing further food entering the nasal cavity or sinuses by alveolar packing and allowing alveolar closure more apically in the alveolus by granulation tissue. Rigid alveolar packing should not extend more than one-third of the way up the alveolus in order to allow alveolar closure by granulation tissue more dorsally, especially at the critical apical alveolar site. The use of a compressible alveolar packing material, such as surgical gauze allows granulation tissue to grow into some of the packed alveolus, but there is a risk that this packing becomes embedded into the granulation tissue. Covering such packing with a thick layer of Vaseline will prevent it becoming embedded.

If an active sinus infection remains, oro-maxillary fistula treatment may not succeed because continuing exudate drainage through the fistula will prevent healing at this site. Concurrent treatment of secondary sinusitis, including removal of all food material can be performed sinusoscopically.

Removal of ingrowing epithelium

Unless the apical aspect of the alveolus becomes sealed by granulation tissue within 2–3 weeks following extraction, nasal or sinus mucosal epithelium will start growing down into the alveolus (**Fig 2**) and when fully epithelialised, this epithelium will permanently prevent alveolar healing at this site (**Fig 3**).

Dorsal migration of oral epithelium into the occlusal aspect of the alveolus is much less problematic as alveolar healing needs to first occur at the narrower more apical site. If an oronasal/sinus fistula does develop, examination *per os* using a small flexible endoscope, equine dental mirror and head light, or preferably with an oral endoscope, will show the in-growing sinus or nasal epithelium (usually shiny and pink) lining the dorsal aspect of the fistula that contrasts with the irregular and usually darker surface of alveolar granulation tissue.

Sinus or nasal epithelium growing down into the dorsal aspect of a fistula can be very effectively removed using a diode laser *per os*. It is impossible to sufficiently angle the tip of a flexible endoscope containing a diode laser fibre to allow 360 degree transendoscopic debridement of ingrowing epithelium at the apical aspect of an alveolus. Trans-endoscopic *per-nasum* laser debridement will likewise only allow debridement of the caudo-ventral aspect of an oro-nasal fistula. The intra-oral use of a digitally held laser fibre under endoscopic or oroscopic guidance is very effective in removing in-growing epithelium without causing further alveolar bone damage to the apical aspect of the fistula (**Fig 4**). Additionally, judicious use of the laser fibre will stimulate an intense inflammatory response of the underlying connective tissue that should increase granulation tissue proliferation and help healing. However, excessive laser energy may damage the underlying alveolar bone and lead to its sequestration and further delayed alveolar healing. Laser debridement usually does not cause any haemorrhage

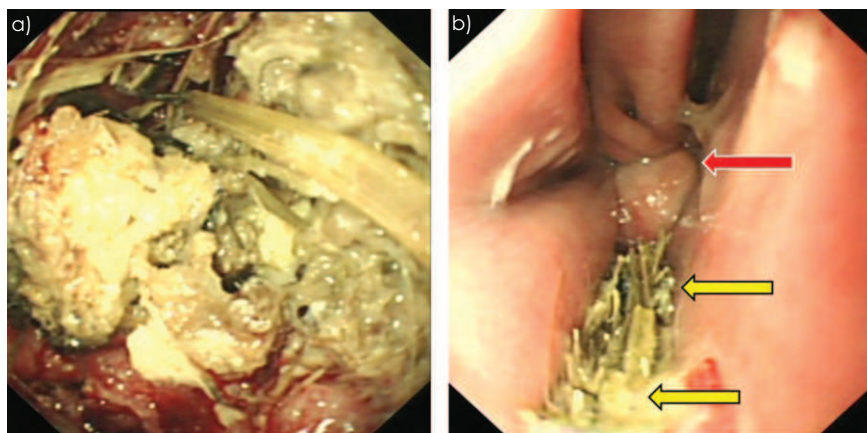


Fig 1: a) Nasal endoscopy of a horse presenting with chronic malodorous purulent unilateral nasal discharge shows the ventral meatus to contain long-stem food and inspissated pus. b) Following nasal lavage, a distorted ventral nasal concha (red arrow), and complete alveolar bone atrophy with food protruding from the oronasal fistula (yellow arrows) are evident.

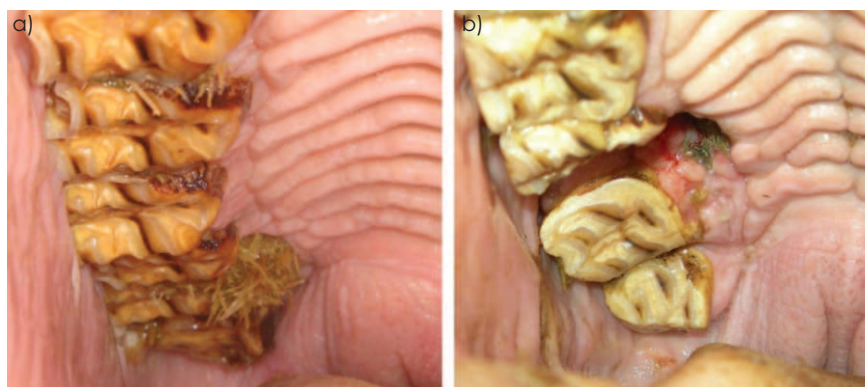


Fig 2: a) This horse presented with an oro-sinus fistula at a 109 extraction site. b) Following removal of food, the fistula, which is not fully epithelialised extends circa 2 cm on to the hard palate.

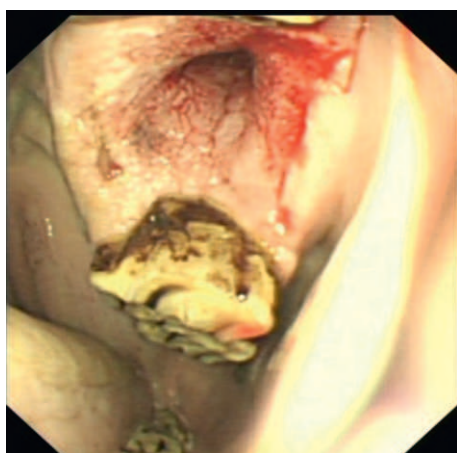


Fig 3: Chronic, fully epithelialised, oro-sinus fistula at a 209 extraction site. This fistula is relatively small, without interproximal bone loss and is within a deep alveolus with plenty of submucosal connective tissue. As expected, it responded fully to debridement and placement of an acrylic interdental prosthesis.

and consequently a PMMA alveolar plug can be immediately placed in the affected alveolus following laser debridement.

Curettage of epithelium at the apical aspect of the alveolus can also be performed using specialised, right-angled, equine dental curettes. However, there is a danger that structural aspects of the alveolar apex can be further damaged whilst debriding the fistula mucosa, thus enlarging the defect. Additionally, curettage will always cause haemorrhage that will drip down over the adjacent interdental surfaces that may preclude placing a PMMA prosthesis immediately following curette debridement.

PMMA (acrylic) alveolar plugs

Polymethyl methacrylate alveolar plugs are the least invasive and safest treatment for oronasal or oro-maxillary fistulae and should be the first line of treatment (Dixon and Brammer 1997). In the presence of a healthy alveolus, an acrylic plug firmly retained in place for 4–6 weeks will prevent alveolar food contamination and thus allow granulation tissue to close the apical aspect of the alveoli and so successfully treat the

fistula. The primary problem with this technique is an inability to keep the PMMA plug firmly in position for this length of time. After this period, the normal rostral and caudal drift of adjacent teeth into the extraction space will compress the sides of the acrylic plug and usually keep it firmly in place, sometimes for many years.

A major reason for the failure of PMMA alveolar plug retention is inadequate preparation of the adjacent interdental surfaces it is attached to. All dental surfaces in the oral cavity are covered by a biofilm (pellicle) consisting of an organic matrix with myriads of embedded bacteria (**Fig 5**) and PMMA cannot effectively adhere to this surface. This biofilm must be fully removed from the interproximal (interdental) aspects of the clinical crowns of the two adjacent teeth, initially by high pressure rubbing with dry swabs and then, in this clinic, by application of a 40% phosphoric acid gel for 1–2 min (**Fig 6**), followed by a thorough rinsing of these sites with water along with higher volume lavage of the horse's mouth. The prepared surfaces should then be fully dried, using compressed air, or with dry swabs followed by alcohol or PMMA solvent soaked swabs, whose contents will quickly evaporate leaving a dry surface. Other operators prepare the interdental surfaces of adjacent teeth by cleaning with swabs and then lightly abrading them with a motorised diastema burr or fine sandpaper, thus exposing a clean and dry layer of peripheral cementum that will effectively bind to semi-moist PMMA.

After the above preparation, it is essential that some PMMA be applied immediately and also that the prepared surfaces should not be allowed to become contaminated with saliva, that will also prevent PMMA adhesion. Some types of PMMA such as bone cements, may have a less exothermic reaction during polymerisation than others, such as some hoof acrylics, and are less likely to cause thermal insult to the alveolar bone or the pulp horns of adjacent teeth. Bis-acryl based composite resins have a lower exothermic reaction compared to acrylics (Rice *et al.* 2012).

A thin layer of semi-liquid PMMA should be placed over the prepared interdental surfaces and some minutes later when the remaining PMMA is semi-solid, a 3–4 cm cube of semisolid PMMA should be placed over the alveolus and digitally pressed rostrally and caudally onto the existing PMMA. The PMMA plug should not be compressed into the alveolus for more than an estimated depth of 2–3 cm. The occlusal aspect of the PMMA plug should be made hollow

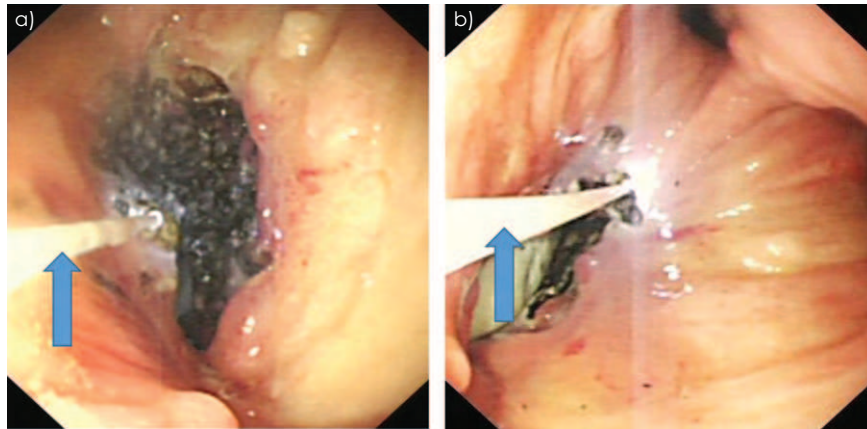


Fig 4: a) Oral endoscopic image of a fully epithelised chronic nasal fistula. A digitally-held diode laser fibre (arrow) is being used to debride the more apical aspects of the ingrowing sinus mucosa. This debridement will have to include all the fistula surface. b) Limited transendoscopic laser (arrow) debridement was performed trans-nasally on the dorso-caudal aspect of the fistula.

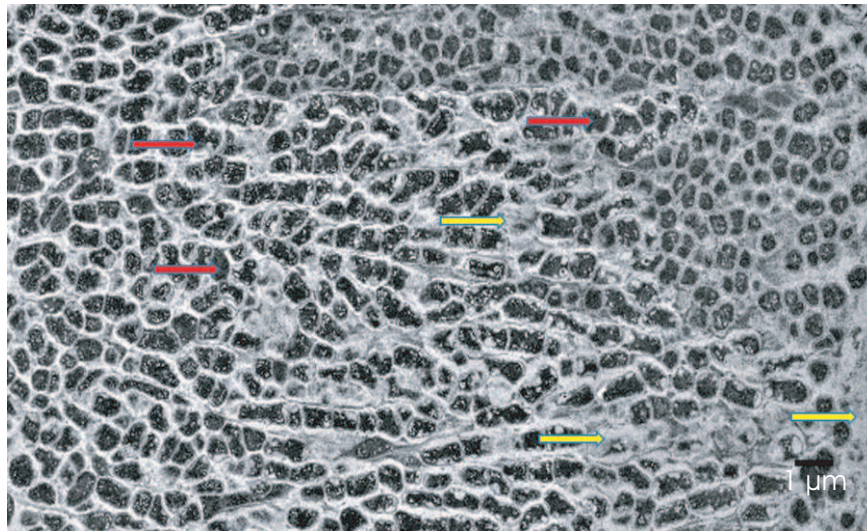


Fig 5: Transmission electron microscopic image of the normal biofilm (pellicle) that covers an equine tooth. It is composed of myriads of bacteria (darker granular structures shown on cross-section) (red arrows) embedded in paler organic matrix (yellow arrows).

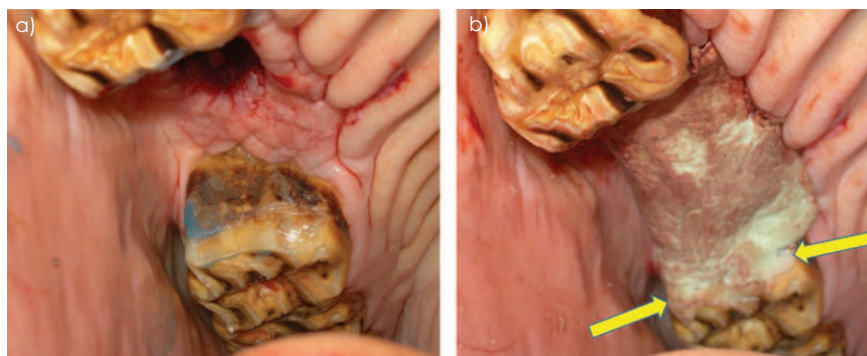


Fig 6: a) This horse has a small oronasal fistula at the Triadan 107 site without hard palate involvement but has limited loss of interproximal alveolar bone over 108. The fistula has been debrided of mucosa and the interproximal areas of the adjacent teeth have been cleaned and covered with a 40% phosphoric acid gel. b) A polymethyl methacrylate (PMMA) (bone cement) prosthesis has been attached to 106 and 108 to seal the fistula. Note the absence of occlusally protruding PMMA that is fully attached interproximally (yellow arrow).

with full attachment to the inter-dental sides of the adjacent teeth. The PMMA should never protrude below the occlusal surface as occlusal pressure will likely cause the plug to become dislodged when the horse masticates. Any loose pieces of PMMA protruding buccally or palatally should be removed as these will later cause soft tissue trauma when hardened. If the PMMA becomes too hard and does not attach firmly, it should be immediately replaced.

In a small proportion of horses, it may not be possible to retain the PMMA plug using the above technique. In such cases, the PMMA plug can be retained using intra-dental stainless steel wire reinforcement as described by Gaughan (1998) and as well illustrated in the accompanying article (Storms *et al.* 2020). However, the multiple buccal incisions required to attach these wires using the latter technique, risks damaging branches of the buccal nerve or the parotid duct. A technique using stainless steel wire to reinforce a maxillary Triadan 07 acrylic plug can be performed using a single buccal incision or intraorally by drilling between the Triadan

07 and 08 and tightening the wire around the rostral aspect of the Triadan 06 (**Fig 7**).

Following the insertion of all acrylic alveolar plugs, owners should be advised that if their horse suffers any acute-onset oral discomfort such as quidding, anorexia, salivation or abnormal head carriage in the following months, the horse should promptly have an oral examination because a displaced acrylic plug can cause marked buccal or lingual soft tissue damage rapidly. Additionally, the opposite tooth will super-erupt and elongate into the extraction space and later could displace the acrylic prosthesis before the alveolus has fully healed. Therefore such overgrowths on opposing teeth should be reduced (have odontoplasty).

Oro maxillary fistulas at diastemata

The presence of a deep diastema between the upper Triadan 9s, 10s and 11s can cause deep periodontal disease and in some cases (particularly older patients) can lead to a small oro-sinus fistula (**Fig 8**). Careful examination of the interdental (interproximal) space between these teeth and the use of a probe may reveal a fistula. Alternatively, high pressure lavage of the diastema with lukewarm water using a diastema pump may cause a nasal discharge of food and/or mucopurulent tinged fluid. Most of these cases can be successfully treated, initially by debriding the interproximal space to ensure that all loose food is removed, including by use of diastema forceps, Hedstrom files held by a long needle holder and by high-pressure lavage. After drying the interproximal space (pressurised air or by using opened surgical swabs on a diastema forceps), calcium hydroxide paste or baseliner can be applied deep into the defect and the occlusal aspect of the diastema can be filled with polysiloxane soft impression material or PMMA. If facilities are available, filling this site with endodontic restorative material after a suitable site preparation is optimal. Treatment of this disorder has been reported to have a very high success rate (Hawkes *et al.* 2008).

Sinoscopy of the maxillary sinuses (fenestration of the maxillary septal bulla is usually not required) is readily

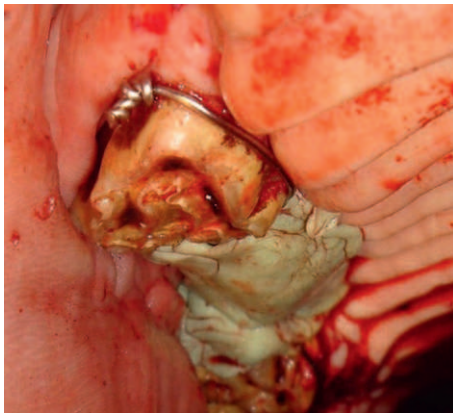


Fig 7: A wire-reinforced acrylic prosthesis attached to Triadan 106 and 108 is covering a debrided fistula at the 107 alveolar site and also a slight palatal defect. Note the full contact of the prosthesis at the interproximal sites and also its hollowed-out occlusal surface to prevent excessive masticatory pressure and loosening.

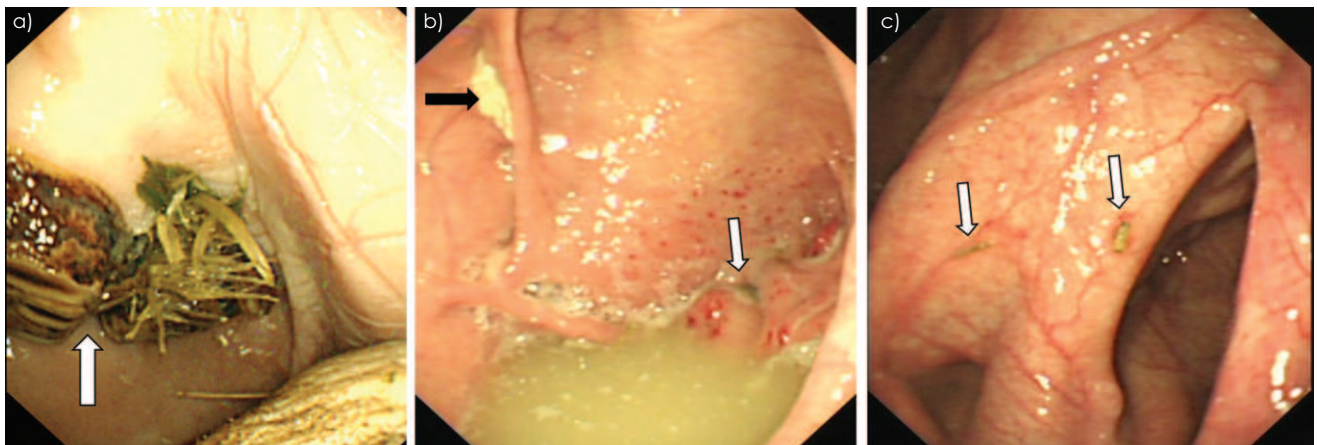


Fig 8: a) Intraoral view of a horse with chronic, low-grade, mucopurulent right-sided nasal discharge showing a 110–111 diastema (arrow) with some periodontal food packing also on the palatal aspect of 111. b) Sinoscopy shows a green-tinged mucopurulent exudate within the right caudal maxillary sinus, and some inspissated pus (black arrow) and food fragments (white arrows). c) Close-up view showing food particles (white arrows) in affected sinus.

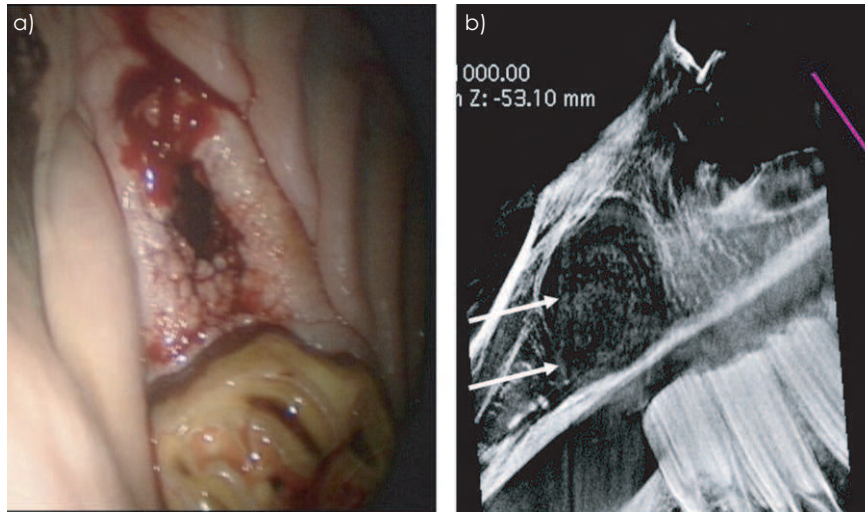


Fig 9: a) This oronasal fistula has been present for over 12 months following 106 extraction. b) A transverse CT image shows complete loss of the rostral 106 alveolar bone and a greatly expanded alveolus (formerly containing food material) lying within the nasal cavity (arrows). (Image courtesy of Richard Reardon).

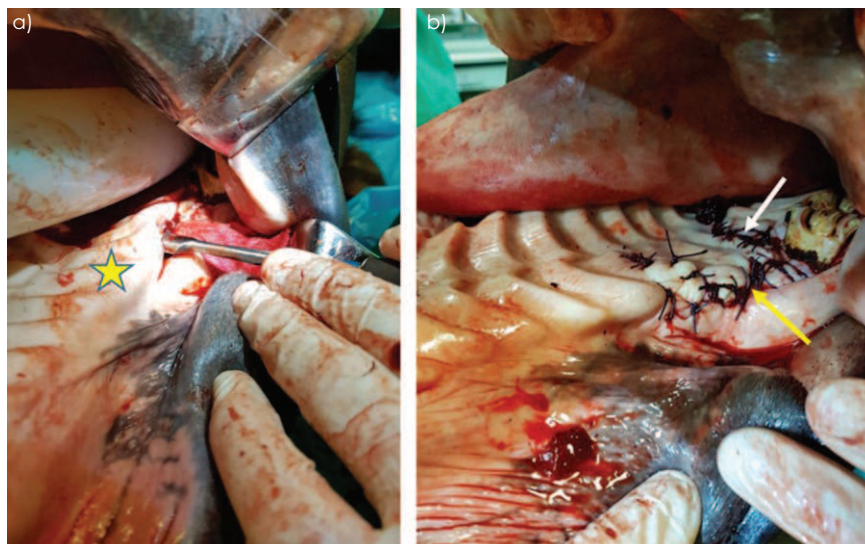


Fig 10: a) Intraoperative image of horse shown in Fig 9 showing the elevation of a full-thickness hard palate mucoperiosteal flap (star) using a periosteal elevator. A surgical swab is protruding from the 106 fistula site. b) Tension-relieving sutures have been placed on both sides of the mucoperiosteal flap (white arrow) along with palatal flap to buccal sutures (yellow arrow). (Image courtesy of Richard Reardon).

performed via the concho-frontal sinus in these cases and the affected compartments can be sinoscopically lavaged and any long pieces of fibrous food (not commonly present with this disorder) removed with transendoscopic forceps.

Fistulas extending on to the hard palate

As noted, an oro-nasal/sinus fistula may extend from the usual alveolar site to over 3 cm into the hard palate. Wire-reinforced interdental acrylic prostheses may be extended 1–2 cm palatally to treat some of these fistulas. However, if larger palatal defects are present the use of acrylic alveolar plugs as described above will be ineffective in treating these fistulae and the following options are possible.

Sliding mucoperiosteal flap

A mucoperiosteal sliding flap as described by Barakzai and Dixon (2005) can be used to close oro-nasal fistulas, including those with some hard palate involvement. Because horses are herbivores, they cannot open their mouths very wide and this surgery cannot be performed *per os* (unlike in carnivore or omnivore species) on fistulae located at Triadan 07 alveoli or more caudally, unless the commissures of the lips are sectioned (commissurotomy) to allow reasonable surgical access to the fistula. As much as possible of the oral epithelium that has migrated into the occlusal aspect of the fistula and as thick layer as possible of underlying subcutaneous tissue should be elevated at the buccal aspect of the fistula to help close the buccal side of the

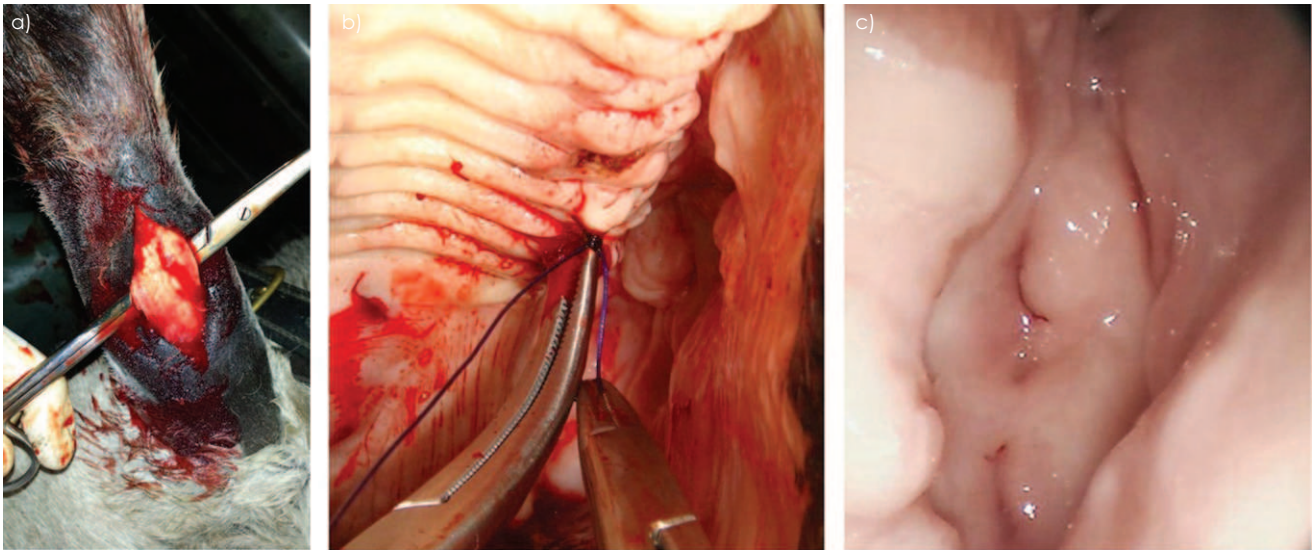


Fig 11: a) shows the harvesting of an ear cartilage graft. b) shows the cartilage graft being sutured within an oro-sinus fistula that formed following extraction of multiple maxillary cheek teeth. c) taken some months later shows the healed fistula, with oral epithelium now covering the cartilage graft. (Images courtesy of Manfred Stoll).

fistula and thus reduce the tension on the hard palate sliding flap. If there is extensive scarring at this buccal site, any elevation of buccal mucosa will be difficult.

A complete thickness mucoperiosteal hard palate flap whose buccal aspect is the same width as the alveolus should then be elevated (Figs 9 and 10). It is desirable to preserve the greater palatine artery by careful dissection at this site, which is facilitated in some horses where the artery lies in a deep bony groove. However, if this dissection removes too much subcutaneous tissue from the mucoperiosteal flap, the flap may dehisce more distally. In most cases, this artery has to be ligated on both sides of the sliding flap.

In order to achieve a tension free sliding flap, the parallel incisions should be made at least to the midline of the hard palate, then widening the flap if it needs to be extended much further. Before suturing the sides of the flap, one should ensure that its distal aspect can close the fistula without excessive tension. Closure of the sides of the flap should be performed in a buccal direction. It may be helpful to then place flat acrylic interdental prostheses with a palatal extension to temporarily protect the flap. Success with this technique largely depends on achieving a tension-free flap. This technique is most suitable for a Triadan 06, 07 or 08 fistula but can be used (with difficulty) as far caudally as the Triadan 09s.

Ear cartilage graft

Aural cartilage grafts have been successfully used to repair oronasal/sinus fistula in small animals and this technique has been described by Stoll (2017) to repair an equine sinonasal fistula (Fig 11). The cartilage graft which is excised from the caudo-lateral aspect of the ear via a long vertical incision should be the same shape and at least one centimetre wider than the fistula to be repaired. A *per os* dissection that splits the oral and nasal/sinus mucosa around the circumference of the fistula to a depth of 10 mm should then be performed. The cartilage graft is embedded submucosally around the

defect and sutured into position with absorbable sutures. A buccal mucosa flap was advised by Stoll (2017) to cover and protect the cartilage graft from the oral environment although in small animals, such cartilage grafts are left unprotected.

Bone flap

Easley and Freeman (2016) have described a technique used to successfully treat a chronic sinonasal fistula at the Triadan 06 position where as noted; an acrylic plug cannot be effectively used. Using a horizontal dissection plane, the maxillary bone lateral to the affected alveolus is initially identified. A ventrally hinged maxillary bone flap of the same dimensions as the fistula is cut and bent ventro-medially to close the defect. The dissection site for this procedure needs to avoid branches of the dorsal buccal nerve and the parotid duct.

Transposition of facial muscles to treat fistula

Treatment of oronasal and orosinus fistula by transposing facial muscles including the levator nasolabialis muscle (Orsini *et al.* 1992) or preferably, the levator labii superior muscle has been well described by Brink (2006) and Schumacher and Brink (2011). The transposed muscle is used to physically occlude the affected alveolus and thus allow permanent closure of oro-nasal or oro-sinus fistulae. Both of these procedures involve facial dissection and possibly risk damaging the dorsal buccal nerve or parotid duct. Additionally, there will be loss of function of the transposed muscle and subsequently some cosmetic facial changes associated with this surgery.

Buccal mucosal flap

Stoll (2017) has also described the use of a dorsally hinged thick buccal mucosal and submucosal graft to occlude a

maxillary 207 alveolar fistula. This technique results in the buccal epithelium facing dorsally towards the nasal cavity. The loss of interproximal bone may preclude its use and it is advisable to catheterise the parotid duct prior this procedure.

Post-operative treatment

Feeding horses a soft diet such as soaked grass or high-fibre pellets for a week or so may remove some pressure on the acrylic prostheses or sites of surgical soft tissue repair during early stages of healing.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this review article.

Source of funding

None.

Acknowledgements

To Manfred Stoll and Richard Reardon for use of their images and to Richard Reardon for reviewing the manuscript.

References

- Barakzai, S.Z. and Dixon, P.M. (2005) Sliding mucoperiosteal hard palate flap for treatment of a persistent oronasal fistula. *Equine Vet. Educ.* **17**, 287-292.
- Brink, P. (2006) Levator labii superioris muscle transposition to treat oromaxillary sinus fistula in three horses. *Vet. Surg.* **35**, 596-600.
- Dixon, P.M. and Brammer, S. (1997) Post-extraction oro-maxillary (antral) fistula: is bone cement the answer? *Proceedings of the 5th World Veterinary Dental Congress Birmingham*. pp 147 - 150.
- Dixon, P.M. and Gerard, M.P. (2019) Oral cavity and salivary glands. In: *Equine Surgery*, 5th edn., Eds: J.A. Auer, J.A. Stick, J.M. Kummerle and T. Prange, Elsevier, St Louis, Missouri. pp 440-473.
- Easley, J.T. and Freeman, D.E. (2016) Surgical repair of a chronic, oronasal fistula in a horse using an alveolar bone flap. *Equine Vet. Educ.* **28**, 550-555.
- Gaughan, E.M. (1998) Dental surgery in horses. *Vet Clin North Am Equine Pract* **14**, 381-397.
- Hargreaves, L. and Dixon, J.J. (2018) Computed tomographic description of the highly variable imaging features of equine oromaxillary sinus and oronasal fistulae. *Vet. Radiol. Ultrasound*. **59**, 571-576.
- Hawkes, C.S., Easley, J., Barakzai, S.Z. and Dixon, P.M. (2008) Treatment of oromaxillary fistulae in nine standing horses (2002-2006). *Equine Vet. J.* **40**, 546-551.
- Orsini, P.G., Ross, M.W. and Hamir, A.N. (1992) Levator nasolabialis muscle transposition to prevent an oro-maxillary sinus fistula after tooth extraction in horses. *Vet. Surg.* **21**, 150-156.
- Rice, C.A., Riehl, J., Broman, K., Soukup, J.W. and Gengler, W.R. (2012) Comparing the degree of exothermic polymerization in commonly used acrylic and provisional composite resins for intraoral appliances. *J. Vet. Dent.* **172**, 78-83.
- Schumacher, J. and Brink, P. (2011) Treatment of horses for a facial or oral fistula. *Equine Vet. Educ.* **23**, 242-248.
- Stoll, M. (2017) Orosinus and oronasal fistula after tooth extraction. Ear cartilage transplantation in a donkey in comparison to other fistula treatments. *Proceedings of the 26th European Veterinary Dental Forum, Malaga*. pp 154.
- Storms, N., Salciccia, A., De La Rebiere De Puyade, G., Evrard, L. and Grulke, S. (2020) Dental bridging as a treatment for large oral fistulae in two horses. *Equine Vet. Educ.* **32**, 470.

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Review Article

What can we learn from visual and objective assessment of non-lame and lame horses in straight lines, on the lunge and ridden?

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Keywords: horse; kinematics; work-quality; biomechanics; training

Summary

Traditionally and when using objective gait analysis, horses with and without lameness are most frequently assessed trotting in straight lines in hand. Valuable information can be gained from assessment on the lunge and ridden in walk, trot and canter. No studies have quantified lameness during all aforementioned conditions and gaits at once, despite the rapid recent development in equine gait analysis methods. Objective methodologies, previously confined to gait laboratories, are currently being expanded to field technologies using accelerometers and inertial measurement units (IMUs). This publication aims to describe normal gait and the spectrum of pain-related gait abnormalities and other musculoskeletal adaptations to pain that can be observed in walk, trot and canter during in hand and ridden assessment in straight lines and on a circle on hard and soft surfaces. In addition, it aims to describe briefly how IMUs have been used and areas for further research in the light of what we know from subjective lameness examinations and what is possible with IMUs.

Introduction

Lameness presents one of the most common health problems in horses (Dyson *et al.* 2008; Egenvall *et al.* 2009, 2013a; Sloet van Oldruitenborgh-Oosterbaan *et al.* 2010; Greve and Dyson 2014), which justifies the effort invested in objective lameness quantification (Keegan *et al.* 2004; Pfau *et al.* 2005; Rhodin *et al.* 2016). Freedom from lameness in straight lines is not a reliable indicator of the absence of musculoskeletal pain (Licka *et al.* 2004; Dyson and Greve 2016). Lameness examinations should ideally include assessment in hand, on the lunge in walk, trot and canter with associated transitions on both the left and right reins, and also ridden unless the horse is too lame (Dyson and Greve 2016). However, there have been no studies quantifying lameness during all aforementioned conditions and gaits at once. Other reviews on equine gait analysis have been published (Clayton 1991; Barrey 1999; Keegan 2007; Weishaupt 2007; Hobbs *et al.* 2010; Pfau *et al.* 2016a), but this review of the literature and discussion based on extensive clinical experience of lameness investigation aims to (1) describe the gaits of non-lame horses; (2) describe the spectrum of pain-related gait abnormalities and other musculoskeletal adaptations to pain that can be observed in hand in straight lines, on the lunge on hard and soft surfaces and ridden; (3) describe how inertial measurement units (IMUs) have been used and how they may enhance lameness recognition; (4) discuss areas for

further research in the light of what we know from subjective lameness examinations and what is possible with IMUs.

To comprehensively describe the spectrum of pain-related gait abnormalities and other musculoskeletal adaptations to pain; it is necessary to review biomechanical studies of experimentally-induced lameness, observational studies of both non-lame horses assessed under a variety of different movement conditions and naturally occurring lameness. There is insufficient description of how normal horses move under a variety of circumstances e.g. in hand, on the lunge and ridden and on different surfaces.

How should a horse free from lameness move?

Non-lame horses in trot in straight lines have highly symmetrical peak vertical forces, stance durations and stance impulses (the integral of a force over the time interval for which it acts) of the limbs during the left and right diagonal stance phases (Merkens *et al.* 1993a; Weishaupt *et al.* 2004b). Twelve non-lame horses were assessed at trot in straight lines, with an accelerometer placed at the level of the 13th thoracic vertebra (Halling Thomsen *et al.* 2010a). There was a high degree of overall left/right symmetry of dorsoventral trunk acceleration, of loading of the left and right diagonal pairs of limbs and in the symmetry of the temporal phase of the left/right diagonal stance phases within a stride. The hindlimbs should track up at both walk and trot, with the hindlimbs following the tracks of the forelimbs (i.e. on two tracks) (Jönsson *et al.* 2014; Dyson 2016). The trot has two periods of suspension, with a sinusoidal pattern of dorsoventral movement of the head and trunk, with two oscillations per stride (Buchner *et al.* 1996b; Faber *et al.* 2000; Warner *et al.* 2010; Greve *et al.* 2017a). There should be symmetry of head nodding and the movement of the tubera sacrale (Merkens *et al.* 1993a). The horse's trunk should be more or less vertical when walking, trotting or cantering in straight lines (Clayton 1994a,b, 1995; Dyson 2016).

On the lunge, there is increased duty factor (increased stance/stride time) for the inside forelimb (Hobbs *et al.* 2011) and measurable asymmetry of hindlimb gait mimicking hindlimb lameness (Rhodin *et al.* 2013). When turning, the horse should lean into the circle (Clayton and Sha 2006; Hobbs *et al.* 2011), according to the radius of the circle and speed (Pfau *et al.* 2012) and the level of training (Greve and Dyson 2016). A decrease in radius requires more lateral bending (the body rotation about the

vertical axis; **Table 1**) and thus greater musculoskeletal effort to generate this bend (Clayton 2012). In a study of 13 non-lame dressage horses, selected based on a comprehensive lameness examination including flexion tests and assessment in hand, on the lunge and ridden, horses ≤ 6 years of age leant more than predicted into a circle during lunging than older horses (Greve and Dyson 2016). Horses which scored ≥ 7 in ridden work-quality using a 0–10 FEI dressage scale, leant less than predicted compared with horses that scored ≤ 6 .

When ridden, based on the aims of correct biomechanical training of locomotor responses in dressage and eventing, the horse should ideally work 'on the bit' (Henriquet 2004). A horse is said to be on the bit when 'the neck is more or less raised and arched according to the stage of training and the extension or collection of the pace, accepting the bridle with a light and consistent soft submissive contact. The head should remain in a steady position, as a rule slightly in front of the vertical, with a supple poll as the highest point of the neck, and no resistance should be offered to the Athlete' (FEI Dressage Rules 2016). The position should be maintained without strong permanent pressure (McLean and McGreevy 2010). The horse should flex, extend and rotate the thoracolumbar vertebral column (**Table 1**) without any tension (spasm) of the epaxial muscles (Johnston *et al.* 2002, 2004; Clayton 2004, 2012; Wennerstrand *et al.* 2004; van Weeren 2007, 2013; van Weeren *et al.* 2010). The horse should be willing to go forwards, be pushing energetically with the hindlimbs with satisfactory impulsion and engagement for the type of horse, producing propulsive forces by flexing the lumbosacral joint (Clayton 2004, 2012; Dutto *et al.* 2006; Dyson 2016). 'Impulsion is the term used to describe the transmission of an eager and energetic, yet controlled, propulsive energy generated from the hind quarters into the athletic movement of the horse. Its ultimate expression can be shown only through the horse's soft and swinging back guided by gentle contact with the Athlete's hand' (FEI Dressage Rules 2016).

Laterality – can a pain-free non-lame horse move asymmetrically?

Handedness or laterality describes the preference of one side of the body or limb compared with the other and is well-recognised in man and animals (McGreevy and Rogers 2005;

van Heel *et al.* 2006, 2011; McGreevy and Thomson 2006; Abrams and Panaggio 2012). The majority of humans are right-handed (Abrams and Panaggio 2012). Traditionally, riders handle horses from the left side, which may influence the laterality observed in adult horses (Farmer *et al.* 2010). Foals exhibited no left vs. right preference, whereas young horses (2 years of age) showed higher frequency of motor laterality (Lucidi *et al.* 2013). This was measured as the direction of cutting into a circle as an indicator of motor bias to the right compared with the left, despite bilateral handling of both groups prior to the assessments. Healthy non-pain-related gait in man can be asymmetrical (Nardello *et al.* 2009).

It was recently shown that minor left vs. right asymmetries (up 1.8 cm) of dorsoventral movement of the tubera coxae in straight lines could be measured in horses with no subjective signs of gait abnormalities related to musculoskeletal pain detected in hand, on the lunge and ridden (Greve and Dyson 2016). Horses were selected for inclusion based on visual assessment by a lameness expert. The horses exhibited no facial signs of discomfort (e.g. ears back, a fixed stare or mouth open [Mullard *et al.* 2017; Dyson *et al.* 2017a] or other behavioural signs of pain [Dyson *et al.* 2017b, 2018]). The horses were willing to work, and remained the same with changes in speed, during transitions and when assessed under different movement conditions (Dyson 2014), consistent with the absence of lameness (Johnston *et al.* 2004; Clayton 2014). They moved with a high degree of symmetry in the thoracolumbosacral region, with good range of rotational and translational motion and did not try to avoid self-carriage or working on the bit (Greve *et al.* 2017a). The horses leaned similarly on the left and right reins on a circle (Greve and Dyson 2016) and pushed energetically with the hindlimbs, with satisfactory impulsion and engagement producing propulsive forces by flexing the lumbosacral joint (Dyson 2016; Greve 2016) and were not resistant if asked to perform more collected work. There was no indication that the measured asymmetries were pain related and it is assumed that they could reflect functional motor laterality. If the observed asymmetry is non-pain-related, it would be unlikely to change with diagnostic analgesia (Keg *et al.* 1996). It is potentially unreliable to rely on a single parameter (e.g. tubera sacrale asymmetry >3 mm [Keegan *et al.* 2011]) to determine if a horse has a painful musculoskeletal disorder. There appears to be a 'grey zone' of horses that move asymmetrically due to functional motor laterality (Wiggers *et al.* 2015). Assessment of as many parameters as possible should improve the robustness of the decision of whether a horse has a pain-related gait abnormality..

TABLE 1: Rotational and translational movements

Rotational movement	
Axial rotation	Rotation around the x-axis (craniocaudal axis) or roll
Flexion–extension	Rotation around the y-axis (lateral–lateral axis or termed mediolateral axis) or pitch
Lateral bending	Rotation around the z-axis (dorsoventral axis) or yaw/heading
Translational movement	
Dorsoventral	Displacement at the vertical axis [z-axis]
Lateral–lateral	Displacement at the lateral–lateral axis [y-axis] also termed mediolateral axis or side-to-side movement
Craniocaudal	Displacement at the long axis [x-axis] aligned with the horse, forward–backward

The biomechanics of lameness

The definition of lameness has recently been debated (van Weeren *et al.* 2017; Bathe *et al.* 2018) but can perhaps be simplified as 'a clinical sign, a manifestation of pain or a mechanical defect, that results in a gait abnormality characterised by limping' (Ross 2011a). Forelimb lameness is characterised by an asymmetrical head nod. There was decreased dorsoventral movement of the head during the lame stance phase and increased movement during the non-lame stance phase in 11 Dutch Warmblood horses with experimentally induced unilateral pain causing forelimb lameness during the stance phase (Buchner *et al.* 1996b).

There was also a reduction in vertical acceleration of the head, associated with a lower minimum head position during the non-lame forelimb stance compared with the lame forelimb stance.

During both experimentally induced unilateral pain causing hindlimb lameness during the stance phase (Buchner *et al.* 1996b) and naturally occurring hindlimb lameness (May and Wyn-Jones 1987; Buchner *et al.* 1993), the whole pelvis exhibited less lowering (Fig 1) during the stance phase of the lame limb and less lifting (Fig 2) just after the stance phase of the lame limb. However, there is increased vertical displacement of the tuber coxae on the side of the lame limb compared with the contralateral limb (May and Wyn-Jones 1987) (Fig 3), so that with right hindlimb lameness, the vertical motion of the right tuber coxae during right hindlimb stance phase is diminished or absent and increased during the left hindlimb stance phase (May and Wyn-Jones 1987; Buchner 2013). The pelvis appears to rotate towards the lame side and the whole pelvis moves up less after the lame hindlimb stance compared with the sound hindlimb stance (Buchner *et al.* 1993, 1996b) (Fig 4). Newton's second law of physics, that force is the product of mass times acceleration, explains why lame horses experience a decreased peak vertical ground reaction force (GRF) in the lame limb by reducing the vertical acceleration of the trunk, head and pelvis during the lame limb stance phase (Buchner *et al.* 1996b; Pfau *et al.* 2016a).

Hindlimb lameness may induce a head nod and, less frequently, forelimb lameness may induce asymmetrical movement of the tubera sacrale (Weishaupt *et al.* 2004a, 2006; Kelmer *et al.* 2005; Rhodin *et al.* 2013; Dyson 2014). Previous studies were restricted to unilateral lameness in unriden horses in hand in straight lines with pain during the stance phase (May and Wyn-Jones 1987; Buchner *et al.* 1993, 1996a,b; Vorstenbosch *et al.* 1997). These studies did not investigate lungeing exercise or ridden horses, or those with lameness in more than one limb. On the lunge with experimentally induced unilateral hindlimb lameness, it was concluded that when the lame limb is on the outside, the horse may appear symmetrical (Rhodin *et al.* 2013), because the natural circle-induced asymmetry of the hindlimbs cancels out the lameness, whereas the lameness may be accentuated when the lame hindlimb is on the inside of the circle $\pm$ head nod. The results cannot be generalised to naturally occurring lameness in which lameness may appear worse with the lame hindlimb on the outside of a circle, or to horses with lameness in more than one limb. Lameness may result in reduced metacarpophalangeal or metatarsophalangeal joint extension of the lame limb, which is proportional to a decrease in vertical GRF of the lame limb, or increased fetlock extension because of compromised function of the suspensory apparatus. This may be easier to appreciate in walk than trot (Riemersma *et al.* 1988; Buchner *et al.* 1996a; Clayton 2014) because of the relatively longer stance phase of each step compared with faster gaits (Clayton *et al.* 2013).

What can be learnt from visual and objective observation of the whole horse?

Most studies have focussed on unilateral forelimb and hindlimb lameness, whereas in reality, it is common to have

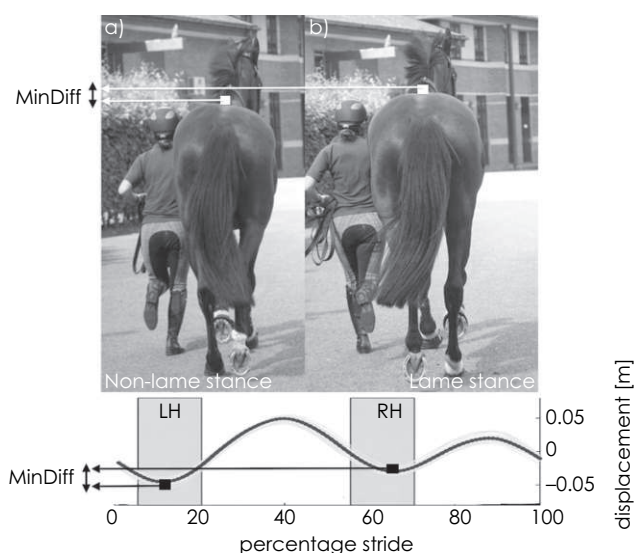


Fig 1: MinDiff. Movement of the tubera sacrale of a horse with right hindlimb lameness. The stride curve shows the average movement of 36 strides of the tubera sacrale. The grey boxes illustrate the approximate time of mid stance (centred around the lowest point) during LH and RH or during RF and LF stance. Solid grey line = mean; light grey shading = s.d. MinDiff is the difference in the minimum height (the lowest point of the trunk near midstance) of the left and right hindlimb stance phases. The whole pelvis exhibited less lowering during the stance phase of the lame limb (right hindlimb) compared with the sound hindlimb (left hindlimb). The figure is stylised, with the horse appearing smaller in the left image, to demonstrate the principle of measurement of MinDiff.

bilateral forelimb or hindlimb lameness or coexistent forelimb and hindlimb lameness (Buchner *et al.* 1995; Dyson and Murray 2012; Greve and Dyson 2014; Barstow and Dyson 2015; Maliye *et al.* 2015; Bragança *et al.* 2016; Maliye and Marshall 2016). It is acknowledged that many of the subjective observations cannot be measured, but repetitive and consistent observations among lame horses by lameness clinicians and alterations in these observations following resolution of pain with diagnostic analgesia add weight to their veracity.

Walk and trot in straight lines

Some observations (e.g. foot placement, metacarpophalangeal joint extension) of a lame horse are easier to appreciate at the walk because of the slower footfall compared with trot (Clayton *et al.* 2013). Trot is suitable for detecting asymmetries associated with lameness, because it is a symmetrical gait (Hildebrand 1965), implying equal steps and forces in the contralateral limbs (Clayton 2014). Lame horses decrease structural stress by moving with a flatter trajectory (less suspension) and increase stance duration of the affected limb, thus spreading the force over a longer period (Clayton 1986, 2014; Buchner *et al.* 1996a,b; Clayton *et al.* 2000; Weishaupt *et al.* 2004b, 2006); although with severe lameness, the stance duration may not increase. However, since forces are not visible to the human eye, it is the alterations in movement that form the basis of lameness examinations (Clayton 2005, 2014).

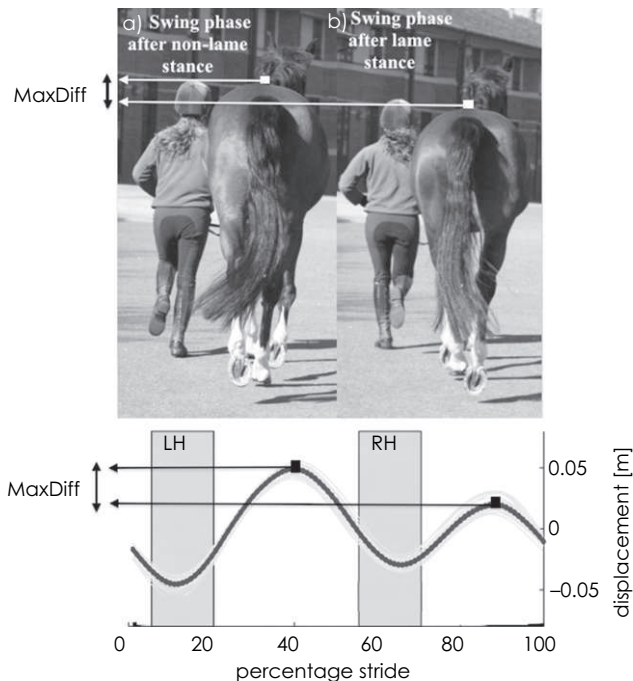


Fig 2: MaxDiff. Movement of the tubera sacrale in a horse with right hindlimb lameness. The stride curve shows the average movement of 36 strides of the tubera sacrale. Solid dark grey line = mean; light grey shading = s.d. The grey boxes illustrate the approximate time of mid stance (centred around the lowest point) during LH and RH or during RF and LF stance. MaxDiff is the difference in the maximum height (the highest point of the trunk during the suspension phase of the left hindlimb [non lame]) and the maximum height (the highest point of the trunk during the suspension phase of the right hindlimb [lame]). The whole pelvis exhibited less lifting just after the stance phase of the lame limb. The figure is stylised, with the horse appearing smaller in the right image, to demonstrate the principle of measurement of MaxDiff.

If a horse has bilaterally symmetrical forelimb or hindlimb lameness, there is less suspension after both diagonal stance phases, which may be manifest merely as short steps and rigidity (Buchner *et al.* 1995; Bragança *et al.* 2016; Greve *et al.* 2017a). Failure to push actively with the hindlimbs results in lack of hindlimb impulsion and engagement (Clayton 2014; Dyson 2016). Horses with hindlimb lameness had significantly lower vertical peak force in the lame limb compared with the contralateral limb and compared with ataxic and non-lame horses (Ishihara *et al.* 2009).

Lameness examinations should ideally always include assessment from the side, from behind and as the horse moves towards the observer. The perspective from which horses were assessed is often not mentioned (Keegan *et al.* 2010; McCracken *et al.* 2012). From the side, it may be easier to assess how well the horse pushes from behind, the height of arc of the foot flight of each limb, whether there is toe drag of one or more limbs and the degree of extension of the metacarpophalangeal and metatarsophalangeal joints (Riemersma *et al.* 1988; Buchner *et al.* 1996a; Clayton 2014; Dyson 2016). It is important to listen to the regularity of rhythm, the presence or absence of toe drag, the sound of footfalls which may reflect GRF and the left right symmetry of sound, bearing in mind that different foot shapes (e.g. asymmetrical

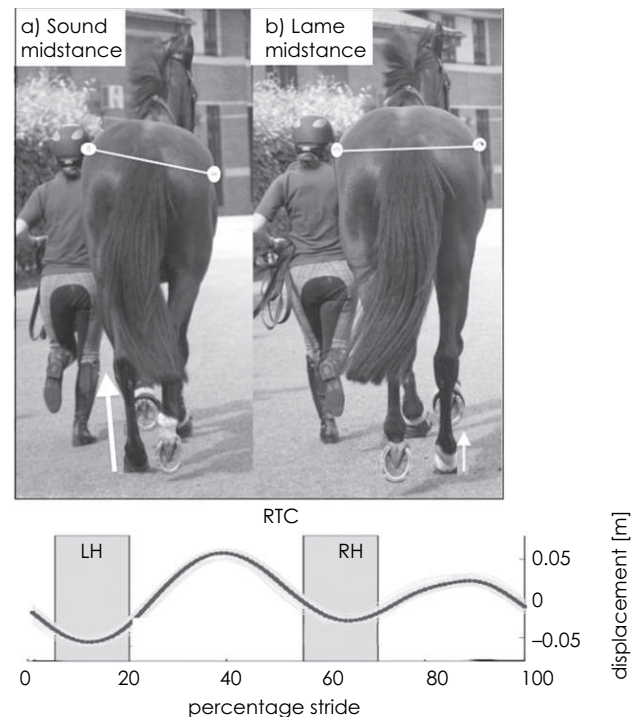


Fig 3: Hip hike difference (HHD). Movement of the left and right tubera coxae in a horse with right hindlimb lameness during a) the midstance of the left hindlimb (non-lame limb) and b) the midstance of the right hindlimb stance (the lame limb). The stride curve shows the average movement of 36 strides of the right tubera coxae (RTC). The grey boxes illustrate the approximate time of mid stance (centred around the lowest point) during LH and RH or during RF and LF stance. Solid dark grey line = mean; light grey shading = s.d. The RTC reaches a lower height during the contralateral (left hindlimb/non-lame hindlimb) than during the right hindlimb (lame hindlimb stance). During the non-lame hindlimb stance phase, there is increased pelvic movement more obvious on the lame side (RTC), because of an increased force (the large white arrow), greater extension of the left metatarsophalangeal joint, more rotation of the pelvis and increased push-off. During the lame hindlimb stance phase, there is reduced pelvic movement, because of a small amount of force (the small white arrow), reduced extension of the right metatarsophalangeal joint, a very little amount of rotation of the pelvis and reduced push-off.

front feet) and limb lengths can have an influence. From behind, the movement symmetry of the hindquarters is commonly assessed (Fuller *et al.* 2006; Hewetson *et al.* 2006; Greve and Dyson 2013a, 2014). Paradoxically, asymmetrical movement of the tubera sacrale and tubera coxae may sometimes be easier to evaluate as the horse comes towards the veterinarian, particularly if a high tail carriage obscures the tubera sacrale (May and Wyn-Jones 1987; Ross 2014; Dyson 2016). A horse with unilateral gluteal muscle atrophy or with asymmetry in height of the tubera sacrale may potentially confound interpretation (Dalin *et al.* 1985; Dyson 2016). Placing markers on the tubera coxae may facilitate interpretation (May and Wyn-Jones 1987). Compared with walking, trotting is a faster gait; thus, the limbs are loaded more during the stance phase and the limbs have to flex more during the suspension phase (Clayton *et al.* 2013).

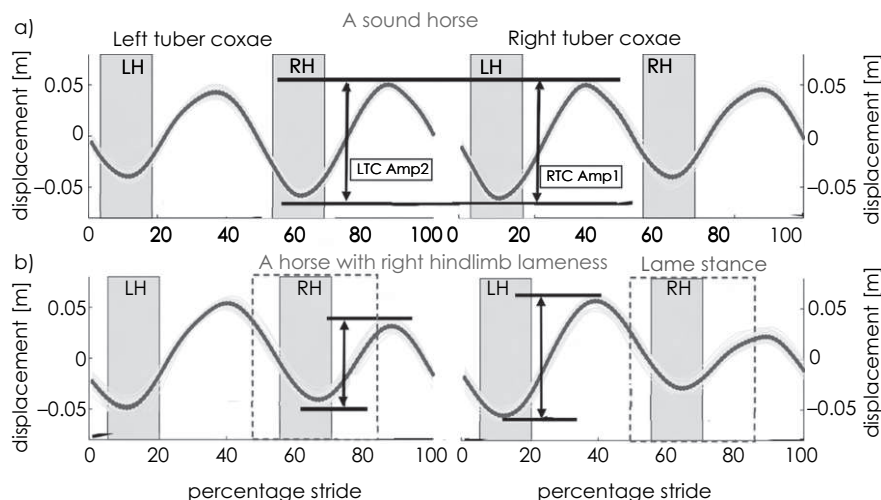


Fig 4: Hip hike differences (HHD) in a non-lame and a lame horse. Movement of the left and right tubera coxae during an average of 36 strides in a) a sound horse and b) a horse with right hindlimb lameness. The stride curve shows the average movement of 36 strides of the right and left tuber coxae. Solid dark grey line = mean; light grey shading = s.d. The boxes indicate the lame hindlimb stance phase. Hip hike differences (HHD) are defined as the difference in the upwards amplitude of the left tuber coxae (LTC) during the contralateral hindlimb stance (LTC Amp2) minus the upwards movement amplitude of the right tuber coxae (RTC) during the contralateral hindlimb stance before touchdown of the right hindlimb (RTC Ampup 1) [$HHD = LTC\ Amp2 - RTC\ Amp1$]. Hip hike difference compares movement amplitudes between the LTC and RTC (May and Wyn-Jones 1987) and it is the most sensitive parameter for change after improvements in gait by diagnostic analgesia (Pfau et al. 2014).

Horses with hindlimb lameness may decrease the flexion of the lame limb, sometimes resulting in audible and visible toe drag. Toe drag may also occur because the pelvis rises less after push-off by a painful hindlimb. The horse has to flex the hindlimb more or the toe will drag on the ground. However, toe drag is not always abolished following resolution of lameness after diagnostic analgesia (Ross 2011b; Dyson et al. 2018), perhaps because of alterations in neural feedback loops and loss of gait stability which may persist when pain has resolved (Hassan et al. 2002; Terrier et al. 2013; Van den Hoorn et al. 2015a,b).

Horses with hindlimb lameness also adapt in a variety of other ways. A horse may consistently drift to one side, usually towards the side of the least lame or sound hindlimb, effectively moving on three tracks, which may decrease the magnitude of the observed pelvic displacement (Ross 2014). The lame hindlimb may be swung in under the trunk during protraction and then be moved outwards, to be placed on the ground in line with the ipsilateral forelimb. A horse may move with either a base-wide or a base-narrow hindlimb stance, sometimes crossing the hind feet during protraction (plaiting) (Barstow and Dyson 2015). Horses with desmopathy of the accessory ligament of the deep digital flexor tendon of a hindlimb may have an inability to load the heel fully or may intermittently knuckle the metatarsophalangeal joint (Eliashar et al. 2005).

Subjective and objective observations indicate that forelimb lameness may influence hindlimb gait and hindlimb lameness may alter forelimb gait (Rhodin et al. 2013; Maliye et al. 2015; Maliye and Marshall 2016). Why of two horses with a similar degree of hindlimb lameness, one may exhibit a head nod and the other does not merits further investigation. By assessing a horse in straight lines and on circles, it may be possible to differentiate between genuine coexistent forelimb and hindlimb lameness and an apparent head nod or croup asymmetry that is secondary (Ross 2014; Dyson 2016).

Lungeing

During lungeing, speed and the radius of the circle influence the symmetry of the trot. Small circle diameter and/or fast trotting speeds result in an asymmetric motion pattern that mimics lameness of the inside hindlimb (Pfau et al. 2012; Starke et al. 2012a; Halling Thomsen et al. 2014). Many, but not all, forelimb lamenesses are accentuated on a circle (Parkes et al. 2013). A retrospective study of 702 horses with pain localised to the foot demonstrated that 73% were lamer on the lunge on a firm surface compared with a soft surface (Parkes et al. 2013). On a firm surface, all the horses had a higher median lameness grade when the lamest limb was on the inside of the circle, which may be related to a greater limb angle of the inside limb on a firm surface compared with the outside limb and thus a greater stress on the foot (Chateau et al. 2005; Hobbs et al. 2011).

Body lean on a circle is normal (Pfau et al. 2012). However, lameness may modify the horse's body posture with a tendency to lean in, so that the body is no longer perpendicular to the ground (Brocklehurst et al. 2014) (Fig 5), which may render evaluation of the symmetry of the hindquarters more difficult. In a study of 13 lame horses, it was demonstrated that some horses adapt to lameness by increasing body lean on one rein compared with the other during lungeing (Greve et al. 2018). Following improvement in lameness using diagnostic analgesia, body lean became more symmetrical between reins. It is well-documented in the human literature that pain may be detrimental to the motor (movement, strength, activation) and sensory (proprioception, balance) components of muscle function (Hassan et al. 2002; Hirata et al. 2011; Zhang et al. 2015). It is possible that different trunk leaning patterns, limb inclinations and limb flexion patterns alter limb forces and reduce pain.

A horse with hindlimb lameness may break to canter (Dyson and Murray 2003) if it is asked to move faster with

bigger steps in trot, rather than increase the step length (Clayton 1994b). Overt lameness is rarely seen in canter; however, evaluation in canter may provide useful information (Dyson and Murray 2003). Canter is an asymmetrical gait, in which the hindlimbs are flexed simultaneously, and the flexion–extension motion of the vertebral column, particularly the lumbosacral joint, contributes to changes in stride length (Clayton 1994a). Close placement of the hindlimbs spatially and temporally (so-called ‘bunny-hopping’) in canter can be seen in horses with hindlimb lameness (Dyson and Murray 2003; Clayton 2014; Dyson 2016). This may result in more even load bearing between the two hindlimbs, to minimise the vertical forces experienced in the lame limb. However, other horses place the hindlimbs further apart than normal. Maintaining a croup high posture in a downward transition may reflect bilateral hindlimb lameness to facilitate a dynamic mechanism for shifting weight cranially in horses with induced hindlimb lameness in trot (Rhodin *et al.* 2013; Clayton 2014). Limb forces determine the cost of locomotion and the load experienced by musculoskeletal structures (Kram and Taylor 1990), which may explain why some horses adapt to pain by trying to avoid high forces in a painful limb and thus may spontaneously break from canter to trot, become disunited (i.e. the horse changes the leading and trailing hindlimbs but not the forelimbs) in canter or change leading forelimbs. The gait may become four-time because of the disassociation of landing of the diagonal placement of the trailing forelimb and leading hindlimb (Dyson and Murray 2003), or the suspension phase may be lost.



Fig 5: A horse with multilimb lameness or a low-grade lameness may not show an overt lameness in hand. The horse's performance may be compromised on the lunge and when ridden exhibiting restricted range of movement of the thoracolumbar region. On the lunge, as shown in this picture, the horse may lean the body inwards, avoid bending of the trunk and look to the outside, while the inside hindlimb crosses in under the trunk towards the contralateral forelimb during protraction. This may well be a manifestation of lameness (Dyson 2016) but can be described subjectively and can be quantified objectively if, for example, symmetry and range of motion of translational and rotational motion of thoracolumbosacral movement are measured and body lean angle determined.

Transitions between gaits

Transitions between gaits in mammals occur to reduce the peak forces and thus the mechanical stress on the musculoskeletal system (Farley and Taylor 1991). An increase in speed without changing gait requires greater energy expenditure per unit time measured as rates of oxygen consumption (Hoyt and Taylor 1981). The ability of the horse to perform a clean transition between walk and trot was significantly associated with the level of training of the horse (Argue and Clayton 1993a). Transitions between trot and canter were performed without intermediate steps (Argue and Clayton 1993b). It is a common clinical observation that some horses with hindlimb lameness may jump into trot from walk rather than perform smooth transitions; however, it remains to be investigated using objective methods how different sources of musculoskeletal pain influence transitions.

Stumbling

Stumbling on forelimbs or hindlimbs is quite a common observation in lame horses but has received little investigation. It is well-documented in human beings that, in the presence of musculoskeletal pain, there may be alterations in neural feedback loops and loss of gait stability (Terrier *et al.* 2013; Van den Hoorn *et al.* 2015a,b) and it is possible that the same occurs in horses. In both people and horses, the propensity to stumble is higher at slower speeds.

Ridden

Ridden lameness in trot

Lameness, particularly in the hindlimbs, may not be detectable or only mild in hand and on the lunge and assessment of the horse ridden may be crucial to identify or accentuate lameness (Licka *et al.* 2004; de Cocq *et al.* 2009; Barstow and Dyson 2015; Dyson and Greve 2016; Dyson and Rasotto 2016). However, examination ridden is not a substitute for assessment in hand and on the lunge, because some lamenesses are only apparent in hand and/or on the lunge. In rising trot, naturally occurring hindlimb lameness is usually accentuated when the rider sits on the diagonal of the lame hindlimb; however, the patterns for forelimb lameness are less consistent (Licka *et al.* 2004; Greve and Dyson 2013b; Robartes *et al.* 2013; Dyson 2014; Martin *et al.* 2016). Lameness may only be apparent riding consecutive 10 m diameter circles to the left and to the right due to the weight of the rider and the increased biomechanical forces in circles (Licka *et al.* 2004; Chateau *et al.* 2005). Some horses may slow the rhythm when uncomfortable (Back *et al.* 1993; Clayton 2014), whereas others become tense and accelerate (Dyson *et al.* 2017b, 2018). Lameness may also be altered by whether the horse is ridden on a long rein or to a contact i.e. with rein tension (Dyson and Rasotto 2016). Horses with hindlimb lameness may resist trotting up an incline because the vertical and propulsive forces in the hindlimbs are increased (Dutto *et al.* 2004b). However, a horse with forelimb lameness may resist trotting downhill, probably due to the high braking forces experienced in the forelimbs, as shown in non-lame dogs (Lee 2011).

The influence of collection and lateral movements

In some instances, lameness is only evident during maximum collection or in specific movements ridden such as shoulder-in, travers, half pass, canter pirouettes and flying changes

(Dyson 2009, 2016). The biomechanical features of collection included a slower forward moving velocity, increased inclination of the pelvis, increased flexion of the vertebral column at the lumbosacral junction, and increased angulations of the hindlimb joints (Holmström *et al.* 1995a,b; Weishaupt *et al.* 2009; Egenvall *et al.* 2013b). Collected trot has higher stride impulses than working trot and the higher degree of collection, the more pronounced shift in impulse towards the hindquarters, indicating increased weightbearing function of the hindlimbs (Weishaupt *et al.* 2009). Compared with passage and collected trot, piaffe has even more inclination of the pelvis during the entire stride cycle (Holmström *et al.* 1995a,b). During lateral movements such as shoulder-in and travers, the horse moves with the body in an orientation in which the long axis of the horse is not aligned with the direction in which the horse is moving. This induces significant differences in the forces applied to a horse's thoracic region compared with moving in straight lines, as measured using a force mat underneath the saddle (de Cocq *et al.* 2010).

Canter in the ridden horse and flying changes

Horses with pain may be resistant to canter or may be unable to collect or extend the canter (Clayton 1994a). Change in movement of the thoracolumbosacral region may alter the forces translated via the saddle to the rider, altering movement of the rider's pelvis. A bilateral forelimb lameness may be evident as a short-stepping, jarry canter (there is a high impact transmitted through the rider's seat and back) in order to minimise the vertical forces experienced in the lame limbs (Dyson 2013; Clayton 2014). In many equestrian disciplines, horses are taught to change leads in canter initiated from the hindlimbs during the suspension phase 'flying changes' (Clayton 1994a; FEI Dressage Rules 2016) i.e. 'the horse changes from canter with one forelimb leading (e.g. right forelimb) to canter with the other forelimb leading (e.g. left forelimb) during the suspension phase of the stride' (Dyson 2016). In canter, tarsal and metatarsophalangeal joints of the trailing hindlimb were more loaded than those of the leading hindlimb (Back *et al.* 1997); however, GRF was higher in the leading hindlimb (Merkens *et al.* 1993b). Limb forces determine the cost of locomotion and the load experienced by musculoskeletal structures (Kram and Taylor 1990). Canter is initiated by the trailing hindlimb which transiently bears weight alone. This may explain why some horses may adapt to pain by not wanting to perform flying changes or not wanting to canter correctly on one rein.

Adaptations of thoracolumbosacral movement

Altered movement of the thoracolumbosacral region has frequently been attributed to pathological changes in the thoracolumbosacral region. However, lameness can induce similar symptoms (Gómez Álvarez *et al.* 2007, 2008; van Weeren 2007; Dyson 2009, 2011; Greve *et al.* 2017b). The tendency of the saddle to consistently slip to one side may be a manifestation of hindlimb lameness (Greve and Dyson 2013a, 2014), with the saddle usually slipping to the side of the lame(r) limb, but sometimes slipping to the side of the non-lame or less lame limb (Greve and Dyson 2013a). Presumably this reflects altered thoracolumbar movement. In sitting trot compared with rising trot, a horse with primary back pain often adapts by further reducing the movement of the thoracolumbosacral region (Dyson 2009, 2016). A lame

horse with secondary altered thoracolumbosacral ROM may show no change in sitting trot compared with rising trot (Dyson 2009, 2011).

Lameness and jumping

Some horses show signs of musculoskeletal pain, but not overt lameness, such as unwillingness to land from a jump with the left forelimb leading in canter, with subclinical right forelimb lameness because of the larger ground reaction force in the trailing forelimb on landing (Schamhardt *et al.* 1993), larger peak flexor joint moments in the distal limb joints (Meershoek *et al.* 2001) and high maximal vertical deceleration (Hernlund *et al.* 2013). Alternatively, if lame on the right forelimb, the horse may jump to the right, still landing with the correct lead, but placing the non-lame left forelimb between the two hindlimbs to redistribute load (Dutto *et al.* 2004a; Dyson 2016). In association with subclinical hindlimb lameness, a horse may jump crookedly across a fence with the hindlimbs drifting towards the lame limb (Benoit 2006). One hindlimb generates 4.5 times more work lifting off for a jump compared with walking (Clayton *et al.* 2001; Dutto *et al.* 2004a).

Behavioural changes in ridden horses reflecting musculoskeletal pain

Leaning on the bit, taking an uneven contact, tilting the head, opening the mouth, tongue lolling, raising the head, becoming over bent, ears back, stiffness in the neck or thoracolumbosacral region, crookedness, difficulties to turn in one direction, reluctance to go forwards or undue hurrying, evasiveness and spookiness can all be the manifestations of lameness (Dyson *et al.* 2017a,b, 2018). When pain is abolished by diagnostic analgesia, there is often a complete transformation of willingness to work, balance, engagement, impulsion and quality of contact with the bit, emphasising the degree of pain that the horse had been experiencing (Dyson 2009, 2011, 2014, 2016; Dyson *et al.* 2017a, 2018).

What are the limitations of subjective assessment of gait?

Veterinarians vary in their ability both to detect and to grade lameness seen in straight lines and subjective evaluation of lameness using numerical grading systems are only marginally acceptable for lameness of mild severity (Keegan *et al.* 1998, 2010; Arkell *et al.* 2006; Fuller *et al.* 2006; Hewetson *et al.* 2006). Intraobserver agreement is generally better than interobserver agreement (Keegan *et al.* 1998). However, these studies had limitations because the horses were not assessed from the side or at different gaits. In addition, the variability could also be related to the inadequacy of training of the veterinarians of what to look for, the lack of practice in the application of grading schemes, the variety of grading schemes used (Dyson 2011, 2014) and bias. In one study, veterinary students' assessment of lameness was improved through the use of video tutorials including freeze frame, slow motion and audio (Barstow *et al.* 2014). Our ability to detect asymmetry of movement of the hindquarters may be limited. A computer model was devised to determine the ability of inexperienced assessors and experienced clinicians to assess asymmetry between two objects and naturally occurring lameness by evaluating the movement of the tubera coxae (Parkes *et al.* 2009). The experienced clinicians performed better than the inexperienced observers with the data from

naturally occurring lameness (Parkes *et al.* 2009), although even with real lameness-based data asymmetries in movement of <25% were not detected. However, in a more recent study of so-called normal horses, assessed by veterinarians with a range of experience, and also objectively using IMUs, an expert was able to detect asymmetries of 10% (Starke *et al.* 2012b).

In a comparison of subjective and objective gait evaluations (Keegan *et al.* 2013), evaluators agreed on classification of horses into three mutually exclusive lameness categories (right limb lameness severity greater than left limb lameness severity, left limb lameness severity greater than right limb lameness severity or equal right and left limb lameness severity) for 58.8% ($\kappa = 0.37$) and 54.7% ($\kappa = 0.31$) of horses for forelimb and hindlimb lameness, respectively. All IMU results for forelimb and hindlimb lameness were positively and significantly correlated with the results of the subjective evaluations. Agreement between objective and subjective evaluations was fair to moderate for forelimb lameness and slight to fair for hindlimb lameness. When forelimb lameness of variable degrees was induced experimentally, asymmetry was detected using IMUs at a lower sole pressure than the consensus opinion of three experienced clinicians (McCracken *et al.* 2012).

How can IMUs help us discriminate between non-painful and painful gait asymmetry?

There are several commercially systems available for objective gait assessment in the field: a uniaxial accelerometer to measure acceleration (Keegan *et al.* 2004); a triaxial accelerometer to measure vertical acceleration (Halling Thomsen *et al.* 2010a,b); and combined triaxial accelerometers, gyroscopes and magnetometers (IMUs) to measure movement in six degrees of freedom (Pfau *et al.* 2005). IMUs have been attached to the head, the tubera sacrale and the tubera coxae for lameness assessment (Pfau *et al.* 2007, 2012, 2013, 2014, 2016b; Starke *et al.* 2012a,b). Additional IMUs have been placed on the dorsal midline for quantification of thoracolumbosacral movement (Pfau *et al.* 2005; Warner *et al.* 2010; Martin *et al.* 2014; Heim *et al.* 2016; Greve *et al.* 2017a,b). Addition of a withers' sensor may facilitate differentiation between forelimb and hindlimb lameness (Bragança 2017; Rhodin *et al.* 2018). Uniaxial accelerometers may be useful for assessment of unilateral lameness (Rhodin *et al.* 2013). There are limitations to the time resolution of the human eye (10–15 samples per second) (Sweet 1953; Näsänen *et al.* 2006). To prevent errors in detection of signal amplitude, it is recommended that the sample frequency is five times the frequency of the event being detected (Winter 1982). This means that the human eye's time resolution is just enough, but borderline for what is necessary (Keegan 2011) if a horse trots at 4 m/s, because it will then take 1.5 strides/s (Keegan *et al.* 2001). An objective, precise and accurate method to detect asymmetries below the threshold of the human eye is certainly justifiable (Parkes *et al.* 2009).

The use of IMUs provides objective, reproducible data (assuming that the lameness does not alter spontaneously and the speed is constant) and may facilitate identification of the lame limb. However, a horse with either bilateral or multilimb lameness may show no obvious asymmetry

(Buchner *et al.* 1995; Bragança *et al.* 2016; Greve *et al.* 2017b) and a subjectively non-lame horse, selected based on a comprehensive lameness examination, may exhibit gait asymmetry above the objective threshold defined for lameness (Greve and Dyson 2016).

Thoracolumbosacral range of motion and symmetry of movement and mean pelvic roll are quantifiable with IMUs (Greve 2016; Greve *et al.* 2017b). Horses with ≥ 1 source of pain increase their range of motion and symmetry of movement of flexion–extension ($^{\circ}$) at the midthoracic region, axial rotation ($^{\circ}$) at the thoracolumbar region and lateral–lateral motion (cm) at the lumbar region when lameness was subjectively maximally improved by diagnostic analgesia (Greve *et al.* 2017b). Mean pelvic roll as an estimate for body lean angle became more symmetrical between turn directions on the lunge given consistent lungeing technique when lameness was subjectively maximally improved by diagnostic analgesia (Greve 2016).

Inertial measurement units have been used to quantify lameness in clinical cases before and after diagnostic analgesia in both forelimb lameness (Rungsri *et al.* 2014; Maliye *et al.* 2015) and hindlimb lameness (Pfau *et al.* 2014; Maliye and Marshall 2016), eliminating user bias. Evaluation of 28 horses with forelimb lameness ($\pm$ concurrent hindlimb lameness) before and after diagnostic analgesia demonstrated an improvement in symmetry of hindlimb gait measured using IMUs, after improvement in forelimb lameness, indicating that forelimb lameness could cause reduced push-off by the contralateral hindlimb (Maliye *et al.* 2015). IMUs were used to compare objectively the responses to palmar digital (just proximal to the ungular cartilages) nerve blocks, palmar nerve blocks (at the base of the proximal sesamoid bones) and intra-articular analgesia of the distal interphalangeal joint in 22 horses (Rungsri *et al.* 2014). Not surprisingly there were variable responses to each block within and among horses. A variable degree of baseline lameness within horses on the 2 days of the examinations was documented.

In a study of 13 horses, hindlimb lameness was graded subjectively and objectively before and after diagnostic analgesia; six horses became subjectively sound, two improved but had residual lameness and five switched lameness to the contralateral limb (Pfau *et al.* 2014). There was a consistent increase in symmetry for upward movement difference and range of motion of the tubera coxae and for sacral displacement minima measured using IMUs, verifying that the clinical assessment of pelvic movement, which is generally used for hindlimb lameness assessment, is a sensitive indicator of lameness. Ten of 37 horses with hindlimb lameness had a head nod mimicking ipsilateral forelimb lameness (Maliye and Marshall 2016). There was a measurable decrease in head movement asymmetry after improvement in hindlimb lameness by diagnostic analgesia, verifying the clinical observation that head nod may be secondary to hindlimb lameness.

The use of objective gait analysis has unquestionably increased our understanding of the biomechanics of lameness. It can highlight asymmetries that might otherwise be overlooked, particularly the objective measurement of the movement of the withers, which can be difficult to see with our eyes, which can be used to determine if the horse has primary hindlimb lameness or primary forelimb lameness (Bragança 2017; Rhodin *et al.* 2018).

Further areas of research in the light of what we know from subjective lameness examinations and what is possible with IMUs

A close link between hindlimb gait and the kinematics of the vertebral column has been demonstrated (Greve 2016; Greve *et al.* 2017a,b). We need to determine why some obviously lame horses do not have saddle slip, whereas some mildly lame horses have marked saddle slip (Greve and Dyson 2013a, 2014). Assessment of a larger number of horses with hindlimb lameness both with and without saddle slip before and after diagnostic analgesia may help to establish the exact mechanics of saddle slip. Use of wireless IMUs may enable the determination of the rotational and translational motion of the thoracic and lumbar regions (Martin *et al.* 2017). Ideally, lateral angular displacement should also be assessed (Hicks 2013).

Quantification of other parameters to distinguish lame from non-lame is warranted to improve the diagnostic accuracy. Body lean on a circle and thoracolumbar motion should be incorporated into lameness examinations (Greve *et al.* 2016, 2017b, 2018; Greve 2016) and observations of hindlimb flight on a circle (Dyson 2016). It is possible that crossing the lame hindlimb in under the trunk during protraction on a circle could be quantified using IMUs mounted on the hindlimbs or using optical motion capture. In addition, horses with bilateral hindlimb lameness clinically lack hindlimb impulsion and engagement (Dyson and Murray 2003). In man, a camera with integrated IMUs has been used to measure rotational motion between sensors (Alves *et al.* 2003). It is possible that this method may be useful in quantifying the inclination of the pelvis as an objective measure of hindlimb engagement in addition to hindlimb protraction angle, which would be particularly useful in horses with lameness in >1 limb.

It is likely that the technology will improve further, with smaller instruments, to be able to measure orientation with very high accuracy over a long time, similar to the technology used in rockets and airplanes (King 1998). We could make use of exact angles to investigate e.g. 'thoracolumbosacral shape' and to quantify improved hindlimb engagement ridden. Knowledge of the exact angles of the thoracolumbosacral region when ridden may also help to elucidate the mechanics of saddle slip (Greve and Dyson 2013a, 2014). In addition, it may contribute to the development of even more sensitive and specific parameters to quantify lameness and thus improve the overall diagnostic potential objective gait analysis to detect lameness.

The development of a database of kinematic (using IMUs and GPS) and kinetic (using force-measuring shoes that are designed similar to a normal shoe to avoid influencing the limb kinematics) measurements in non-lame horses and horses with clinically diagnosed musculoskeletal disorders may enable better understanding of the different ways in which horses adapt to pain causing lameness. Knowledge of translational and rotational kinematic parameters of the thoracolumbosacral region, body lean angle, GRFs and limb kinematics as a function of loading condition, gait, speed, circle radius and surface type for unilateral lameness or lameness in more than one limb may be helpful.

Conclusions

Inertial measurement units have been used to quantify lameness based on the measured symmetry of vertical movement between strides of tubera sacrale and the head. Measurements of other features of a horse's gait that are altered in association with musculoskeletal pain, such as body lean angle and thoracolumbosacral range of motion and symmetry of movement, can also be quantified. There is no doubt that we cannot question the ability of IMUs to detect minor asymmetries below the threshold of the human eye. However, it is clear that the role of IMUs should be complementary to thorough clinical assessment, because there are many features of alterations in gait that have not yet been quantified. IMUs permit objectivity in assessment of variations in the degree of lameness within and between examinations and alterations in gait after an intervention such as diagnostic analgesia, but are not a substitute for subjective appraisal of the whole horse.

Authors' declaration of interests

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Ethical animal research

Not applicable.

Source of funding

None.

Authorship

Both authors have contributed to all parts of the study.

References

- Abrams, D.M. and Panaggio, M.J. (2012) A model balancing cooperation and competition can explain our right-handed world and the dominance of left-handed athletes. *J. Royal Soc. Interface* **9**, 2718-2722.
- Alves, J., Lobo, J. and Dias, J. (2003) Camera-inertial sensor modelling and alignment for visual navigation. *Mach. Intell. Robot. Control* **5**, 103-111.
- Argue, C.K. and Clayton, H.M. (1993a) A preliminary study of transitions between the walk and trot in dressage horses. *Acta Anat.* **146**, 179-182.
- Argue, C.K. and Clayton, H.M. (1993b) A study of transitions between the trot and canter in dressage horses. *J. Equine. Vet. Sci.* **13**, 171-174.
- Arkell, M., Archer, R., Guilian, F. and May, S. (2006) Evidence of bias affecting the interpretation of the results of local anaesthetic nerve blocks when assessing lameness in horses. *Vet. Rec.* **159**, 346-349.
- Back, W., Barneveld, A., van Weeren, P.R. and van den Bogert, A.J. (1993) Kinematic gait analysis in equine carpal lameness. *Acta Anat.* **146**, 86-89.
- Back, W., Schamhardt, H.C. and Barneveld, A. (1997) Kinematic comparison of the leading and trailing fore- and hindlimbs at the canter. *Equine Vet. J.* **29**, Suppl. **23**, 80-83.

- Barrey, E. (1999) Methods, applications and limitations of gait analysis in horses. *Vet. J.* **157**, 7-22.
- Barstow, A. and Dyson, S. (2015) Clinical features and diagnosis of sacroiliac joint region pain in 296 horses: 2004-2014. *Equine Vet. Educ.* **27**, 637-647.
- Barstow, A., Pfau, T., Bolt, D.M., Smith, R.K. and Weller, R. (2014) Design and validation of a computer-aided learning program to enhance students' ability to recognize lameness in the horse. *J. Vet. Med. Educ.* **41**, 1-8.
- Bathe, S., Judy, C. and Dyson, S. (2018) Do we have to redefine lameness in the era of quantitative lameness analysis? *Equine Vet. J.* **50**, 273.
- Benoit, P. (2006) How to perform a specialised examination of the jumping sport horse. *Proc. Am. Assoc. Equine Practnrs.* **52**, 597-599.
- Bragança, F. (2017) Where are we and where are we going with objective lameness evaluation? *Proceedings of the 56th BEVA Congress*, Liverpool. pp 198-199.
- Bragança, F., Mancini, I., Brommer, H., Malda, J., Visser, J. and van Weeren, P. (2016) Compensatory mechanism of gait adaptation to bilateral stifle joint injuries in Shetland ponies at trot. *Equine Vet. J.* **48**, 17.
- Brocklehurst, C., Weller, R. and Pfau, T. (2014) Effect of turn direction on body lean angle in the horse in trot and canter. *Vet. J.* **199**, 258-262.
- Buchner, H.H.F. (2013) Gait adaptation in lameness. In: *Equine Locomotion*, 2nd edn., Eds: W. Back and H. Clayton, Saunders, London. pp 175-197.
- Buchner, H.H.F., Kastner, J., Girtler, D. and Knezevic, P.F. (1993) Quantification of hindlimb lameness in the horse. *Acta Anat.* **146**, 196-199.
- Buchner, H.H.F., Savelberg, H.H.C.M., Schamhardt, H.C. and Barneveld, A. (1995) Bilateral lameness in horses – A kinematic study. *Vet. Q* **17**, 103-105.
- Buchner, H.H.F., Savelberg, H.H.C.M., Schamhardt, H.C. and Barneveld, A. (1996a) Limb movement adaptations in horses with experimentally induced fore- or hindlimb lameness. *Equine Vet. J.* **28**, 63-70.
- Buchner, H.H.F., Savelberg, H.H.C.M., Schamhardt, H.C. and Barneveld, A. (1996b) Head and trunk movement adaptations in horses with experimentally induced fore or hind limb lameness. *Equine Vet. J.* **28**, 71-76.
- Chateau, H., Degueurce, C. and Denoix, J.-M. (2005) Three-dimensional kinematics of the equine distal forelimb: effects of a sharp turn at the walk. *Equine Vet. J.* **37**, 12-18.
- Clayton, H.M. (1986) Cinematographic analysis of the gait of lame horses. II. Chronic sesamoiditis. *J. Equine. Vet. Sci.* **6**, 310-320.
- Clayton, H.M. (1991) Advances in motion analysis. *Vet. Clin. North Am. Equine Pract.* **7**, 365-382.
- Clayton, H.M. (1994a) Comparison of the collected, working, medium and extended canters. *Equine Vet. J.* **26**, Suppl. **17**, 16-19.
- Clayton, H.M. (1994b) Comparison of the stride kinematics of the collected, working, medium and extended trot in horses. *Equine Vet. J.* **26**, 230-234.
- Clayton, H.M. (1995) Comparison of the stride kinematics of the collected, working, medium and extended walks in horses. *Am. J. Vet. Res.* **56**, 849-852.
- Clayton, H.M. (2004) The mysteries of self-carriage. *Vet. Connect.* **14**, 17.
- Clayton, H.M. (2005) The force plate: established technology, new applications. *Vet. J.* **169**, 15-16.
- Clayton, H.M. (2012) Equine back pain reviewed from a motor control perspective. *Comp. Exerc. Phys.* **8**, 145-152.
- Clayton, H.M. and Sha, D.H. (2006) Head and body centre of mass movement in horses trotting on a circular path. *Equine Vet. J.* **38**, Suppl. **36**, 462-467.
- Clayton, H.M. (2014) Biomechanics of lameness. *Proc. AAEP Focus on the Sport Horse*, Louisville, Kentucky. pp 1-3.
- Clayton, H.M., Willemen, M.A., Schamhardt, H.C., Lanovaz, J.L. and Colborne, G.R. (2000) Kinematics and ground reaction forces in horses with superficial digital flexor tendinitis. *Am. J. Vet. Res.* **61**, 191-196.
- Clayton, H.M., Hodson, E., Lanovaz, J.L. and Colborne, G.R. (2001) The hind limb in walking horses: 2. Net joint moments and joint powers. *Equine Vet. J.* **33**, 44-48.
- Clayton, H.M., Chateau, C.H. and Back, W. (2013) Forelimb function. In: *Equine Locomotion*, 2nd edn., Eds: W. Back and H. Clayton, Saunders, London. pp 99-126.
- de Cocq, P., Prinsen, H., Springer, N.C.N., van Weeren, P.R., Schroeder, M., Muller, M. and van Leeuwen, J.L. (2009) The effect of rising and sitting trot on back movements and head - neck position of the horse. *Equine Vet. J.* **41**, 423-427.
- de Cocq, P., Mooren, M., Dortmans, A., van Weeren, P.R., Timmerman, M., Muller, M. and van Leeuwen, J.L. (2010) Saddle forces and leg forces during lateral movements in dressage. *Equine Vet. J.* **42**, Suppl. **38**, 644-649.
- Dalin, G., Magnusson, L.E. and Thafvelin, B.C. (1985) Retrospective study of hindquarter asymmetry in Standardbred trotters and its correlation with performance. *Equine Vet. J.* **17**, 292-296.
- Dutto, D.J., Hoyt, D.F., Clayton, H., Cogger, E.A. and Wickler, S.J. (2004a) Moments and power generated by the horse *Equus caballus* hind limb during jumping. *J. Exp. Biol.* **207**, 667-674.
- Dutto, D.J., Hoyt, D.F., Cogger, E.A. and Wickler, S.J. (2004b) Ground reaction forces in horses trotting up an incline and on the level over a range of speeds. *J. Exp. Biol.* **207**, 3507-3514.
- Dutto, D.J., Hoyt, D.F., Clayton, H.M., Cogger, E.A. and Wickler, S.J. (2006) Joint work and power for both the forelimb and hindlimb during trotting in the horse. *J. Exp. Biol.* **209**, 3990-3999.
- Dyson, S. (2009) The clinician's eye view of hindlimb lameness in the horse: technology and cognitive evaluation. *Equine Vet. J.* **41**, 99-100.
- Dyson, S. (2011) Can lameness be reliably graded? *Equine Vet. J.* **43**, 379-382.
- Dyson, S. (2013) Equine lameness: clinical judgement meets advanced diagnostic imaging. *Proc. Am. Assoc. Equine Practnrs.* **59**, 92-122.
- Dyson, S. (2014) Recognition of lameness: man versus machine. *Vet. J.* **201**, 245-248.
- Dyson, S. (2016) Evaluation of poor performance in competition horses: a musculoskeletal perspective. Part 1 Clinical assessment. *Equine Vet. Educ.* **28**, 284-293.
- Dyson, S. and Greve, L. (2016) Subjective gait assessment of 57 sports horses in normal work: a comparison of the response to flexion tests, movement in hand, on the lunge and ridden. *J. Equine. Vet. Sci.* **38**, 1-7.
- Dyson, S. and Murray, R. (2003) Pain associated with the sacroiliac joint region: a clinical study of 74 horses. *Equine Vet. J.* **35**, 240-245.
- Dyson, S. and Murray, R. (2012) Management of hindlimb proximal suspensory desmopathy by neurectomy of the deep branch of the lateral plantar nerve and plantar fasciotomy: 155 horses 2003-2008. *Equine Vet. J.* **44**, 361-367.
- Dyson, S. and Rasotto, R. (2016) Idiopathic hopping-like forelimb lameness syndrome in ridden horses: 46 horses 2002-2014. *Equine Vet. Educ.* **28**, 30-39.
- Dyson, P.K., Jackson, B.F., Pfeiffer, D.U. and Price, J.S. (2008) Days lost from training by two- and three-year-old Thoroughbred horses: a survey of seven UK training yards. *Equine Vet. J.* **40**, 650-657.
- Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2017a) Can the presence of musculoskeletal pain be determined from the facial expressions of ridden horses, FEReq? *J. Vet. Behav.* **19**, 78-89.
- Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2017b) Development of an ethogram for a pain scoring system in ridden horses and its application to determine the presence of musculoskeletal pain. *J. Vet. Behav.* **23**, 47-57.
- Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2018) Behavioural observations and comparisons of non-lame horses and lame

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- horses before and after resolution of lameness by diagnostic analgesia. *J. Vet. Behav.* **26**, 64-75.
- Egenvall, A., Lönnell, C. and Roepstorff, L. (2009) Analysis of morbidity and mortality data in riding school horses, with special regard to locomotor problems. *Prev. Vet. Med.* **88**, 193-204.
- Egenvall, A., Tranquille, C.A., Lönnell, A.C., Bitschnau, C., Oomen, A., Hernlund, E., Montavon, S., Franko, M.A., Murray, R.C., Weishaupt, M.A., van Weeren, P.R. and Roepstorff, L. (2013a) Days-lost to training and competition in relation to workload in 263 elite show-jumping horses in four European countries. *Prev. Vet. Med.* **112**, 387-400.
- Egenvall, A., Byström, A., Weishaupt, M.A. and Roepstorff, L. (2013b) Horse-rider interaction. In: *Equine Locomotion*, 2nd edn., Eds: W. Back and H. Clayton, Saunders, London. pp 341-368.
- Eliashar, E., Dyson, S., Archer, A., Singer, E. and Smith, R. (2005) Two clinical manifestations of desmopathy of the accessory ligament of the deep digital flexor tendon in the hindlimb of 23 horses. *Equine Vet. J.* **37**, 495-500.
- Faber, M., Schamhardt, H., van Weeren, R., Johnston, C., Roepstorff, L. and Barneveldt, A. (2000) Basic three-dimensional kinematics of the vertebral column of horses walking on a treadmill. *Am. J. Vet. Res.* **61**, 399-406.
- Farley, C.T. and Taylor, C.R. (1991) A mechanical trigger for the trot-gallop transition in horses. *Science* **253**, 306-308.
- Farmer, K., Krueger, K. and Byrne, R.W. (2010) Visual laterality in the domestic horse *Equus caballus* interacting with humans. *Anim. Cogn.* **13**, 229-238.
- FEI Dressage Rules. (2016) [online], available: http://www.fei.org/sites/default/files/DRE-Rules_2016_GA-approved_clean.pdf [Accessed 4 June 2016].
- Fuller, C., Bladon, B., Driver, A. and Barr, A. (2006) The intra- and inter-assessor reliability of measurement of functional outcome by lameness scoring in horses. *Vet. J.* **171**, 281-286.
- Gómez Álvarez, C.B., Wennerstrand, J., Bobbert, M.F., Lamers, L., Johnston, C., Back, W. and van Weeren, P.R. (2007) The effect of induced forelimb lameness on thoracolumbar kinematics during treadmill locomotion. *Equine Vet. J.* **39**, 197-201.
- Gómez Álvarez, C.B., Wennerstrand, J., Bobbert, M.F., Lamers, L., Johnston, C., Back, W. and van Weeren, P.R. (2008) The effect of induced hindlimb lameness on thoracolumbar kinematics during treadmill locomotion. *Equine Vet. J.* **40**, 147-152.
- Greve, L. (2016) *Objective Assessment Of Thoracolumbar Movement And Posture In Subjectively Sound Horses And Those With Hindlimb Lameness*. Thesis, Royal Veterinary College, London.
- Greve, L. and Dyson, S. (2013a) An investigation of the relationship between hindlimb lameness and saddle-slip. *Equine Vet. J.* **45**, 570-577.
- Greve, L. and Dyson, S. (2013b) The horse-rider-saddle interaction. *Vet. J.* **195**, 275-281.
- Greve, L. and Dyson, S. (2014) The interrelationship of lameness, saddle-slip and back shape in the general sports horse population. *Equine Vet. J.* **46**, 687-694.
- Greve, L. and Dyson, S. (2016) Body lean angle in sound dressage horses in-hand, on the lunge and ridden. *Vet. J.* **217**, 52-57.
- Greve, L., Pfau, T. and Dyson, S. (2017a) Thoracolumbar movement in sound horses trotting in straight lines in hand and on the lunge. *Vet. J.* **220**, 95-104.
- Greve, L., Pfau, T. and Dyson, S. (2017b) Alterations in thoracolumbar movement when pain causing lameness has been improved by diagnostic analgesia. *Vet. J.* **224**, 55-63.
- Greve, L., Pfau, T. and Dyson, S. (2018) Alterations in body lean angle in lame horses before and after diagnostic analgesia in straight lines in hand and on the lunge. *Vet. J.* **239**, 1-6.
- Halling Thomsen, M., Persson, A.B., Jensen, A.T., Sørensen, H. and Andersen, P.H. (2010a) Agreement between accelerometric symmetry scores and clinical lameness scores during experimentally induced transient distension of the metacarpophalangeal joint in horses. *Equine Vet. J.* **42**, Suppl. **38**, 510-515.
- Halling Thomsen, M., Tolver Jensen, A., Sørensen, H., Lindegaard, C. and Haubro Andersen, P. (2010b) Symmetry indices based on accelerometric data in trotting horses. *J. Biomech.* **43**, 2608-2612.
- Halling Thomsen, M., Sahl-Tjørnholm, C., Sørensen, H. and Tolver Jensen, A. (2014) Effect of lungeing and circle size on movement symmetry in sound riding horses. *Equine Vet. J.* **46**, Suppl. **46**, 49-50.
- Hassan, B.S., Doherty, S.A., Mockett, S. and Doherty, M. (2002) Effect of pain reduction on postural sway, proprioception, and quadriceps strength in subjects with knee osteoarthritis. *Ann. Rheum. Dis.* **61**, 422-428.
- van Heel, M.C.V., Kroekenstoel, A.M., van Dierendonck, M.C., van Weeren, P.R. and Back, W. (2006) Uneven feet in a foal may develop as a consequence of lateral grazing behaviour induced by conformational traits. *Equine Vet. J.* **38**, 646-651.
- van Heel, M.C.V., van Dierendonck, M.C., Kroekenstoel, A.M. and Back, W. (2011) Lateralised motor behaviour leads to increased unevenness in front feet and asymmetry in athletic performance in young mature Warmblood horses. *Equine Vet. J.* **42**, 444-450.
- Heim, C., Pfau, T., Gerber, V., Schweizer, C., Doherr, M., Schüpbach-Regula, G. and Witte, S. (2016) Determination of vertebral range of motion using inertial measurements units in 27 Franches-Montagnes stallions and comparison between conditions and with a mixed population. *Equine Vet. J.* **48**, 509-516.
- Henriquet, M. (2004) The time to learn. In: *Henriquet on Dressage*. 1st edn., Eds: M. Henriquet and C. Durand, Trafalgar Square Publishing, Vermont, pp 72-122.
- Hernlund, E., Egenvall, A., Peterson, M., Mahaffey, C. and Roepstorff, L. (2013) Hoof accelerations at hoof-surface impact for stride types and functional limb types relevant to show jumping horses. *Vet. J.* **193**, e27-e32.
- Hewetson, M., Christley, R., Hunt, I. and Voute, L. (2006) Investigation of the reliability of observational gait analysis for the assessment of lameness in horses. *Vet. Rec.* **158**, 852-858.
- Hicks, A.D. (2013) *Kinetic and Kinematic Evaluation Of Compensatory Movements Of The Head, Pelvis And Thoracolumbar Spine Associated With Asymmetrical Weight Bearing Of The Pelvic Limbs In Dogs*. A Dissertation Presented for the Doctor of Philosophy Degree, The University of Tennessee, Knoxville, pp 1-90.
- Hildebrand, M. (1965) Symmetrical gaits of horses. *Science* **150**, 701-708.
- Hirata, R.P., Ervilha, U.F., Arendt-Nielsen, L. and Graven-Nielsen, T. (2011) Experimental muscle pain challenges the postural stability during quiet stance and unexpected posture perturbation. *J. Pain* **12**, 911-919.
- Hobbs, S.J., Levine, D., Richards, J., Clayton, H., Tate, J. and Walker, R. (2010) Motion analysis and its use in equine practice and research. *Wien. Tierarztl. Mschr.* **97**, 55-64.
- Hobbs, S.J., Licka, T. and Polman, R. (2011) The difference in kinematics of horses walking, trotting and cantering on a flat and banked 10 m circle. *Equine Vet. J.* **43**, 686-694.
- Holmström, M., Fredricson, I. and Drevemo, S. (1995a) Biokinematic effects of collection on the trotting gaits in the elite dressage horse. *Equine Vet. J.* **27**, 281-287.
- Holmström, M., Fredricson, I. and Drevemo, S. (1995b) Variation in angular pattern adaptation from trot in hand to passage and piaffe in the Grand Prix dressage horse. *Equine Vet. J.* **27**, Suppl. **18**, 132-137.
- Hoyt, D.F. and Taylor, C.R. (1981) Gait and the energetics of locomotion in horses. *Nature* **292**, 239-240.
- Ishihara, A., Reed, S.M., Rajala-Schultz, P.J., Robertson, J.T. and Bertone, A.L. (2009) Use of kinetic gait analysis for detection, quantification, and differentiation of hind limb lameness and spinal ataxia in horses. *J. Am. Vet. Med. Assoc.* **234**, 644-651.
- Johnston, C., Holm, K.R., Erichsen, C., Eksell, P. and Drevemo, S. (2002) Effect of conformational aspects on the movement of the equine back. *Equine Vet. J.* **34**, Suppl. **34**, 314-318.

- Johnston, C., Holm, K.R., Erichsen, C., Eksell, P. and Drevemo, S. (2004) Kinematic evaluation of the back in fully functioning riding horses. *Equine Vet. J.* **36**, 495-498.
- Jönsson, L., Egenvall, A., Roepstorff, L., Nösholm, A., Dalin, G. and Philipsson, J. (2014) Associations of health status and conformation with longevity and lifetime competition performance in young Swedish Warmblood riding horses: 8238 cases 1983-2005. *J. Am. Vet. Med. Assoc.* **244**, 1449-1461.
- Keegan, K.G. (2007) Evidence-based lameness detection and quantification. *Vet. Clin. North Am. Equine Pract.* **23**, 403-423.
- Keegan, K.G. (2011) Gait analysis for quantification of lameness. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M.W. Ross and S.J. Dyson, Saunders, Philadelphia. pp 245-251.
- Keegan, K.G., Wilson, D.A., Smith, B., Gaughan, E., Pleasant, R., Lillich, J., Kramer, J., Howard, R., Bacon-Miller, C., Davis, E., May, K., Cheramie, H., Valentino, P. and van Herreveld, P. (1998) Evaluation of mild lameness in horses trotting on a treadmill by clinicians, interns or residents and correlation of their assessments with kinematic gait analysis. *Am. J. Vet. Res.* **59**, 1370-1377.
- Keegan, K.G., Pai, P.F., Wilson, D.A. and Smith, B. (2001) Signal decomposition method of evaluating head movement to measure induced forelimb lameness in horses trotting on a treadmill. *Equine Vet. J.* **33**, 446-451.
- Keegan, K.G., Yonezawa, Y., Pai, P.F., Wilson, D.A. and Kramer, J. (2004) Evaluation of a sensor-based system of motion analysis for detection and quantification of forelimb and hind limb lameness in horses. *Am. J. Vet. Res.* **65**, 665-670.
- Keegan, K.G., Dent, E., Wilson, D., Janicek, J., Lacurubba, A., Walsh, D., Casselss, M., Esther, T., Schiltz, P., Frees, K., Wilhite, C., Clark, J., Pollitt, C., Shaw, R. and Norris, T. (2010) Repeatability of subjective evaluation of lameness. *Equine Vet. J.* **42**, 92-97.
- Keegan, K.G., Kramer, J., Yonezawa, Y., Maki, H., Pai, P.F., Dent, E.V., Kellerman, T.E., Wilson, D.A. and Reed, S.K. (2011) Assessment of repeatability of a wireless inertial sensor-based lameness evaluation system for horses. *Am. J. Vet. Res.* **72**, 1156-1163.
- Keegan, K., Wilson, D., Kramer, J., Reed, S., Yonezawa, Y., Maki, H., Pai, P. and Lopes, M. (2013) Comparison of a body-mounted inertial sensor system-based method with subjective evaluation for detection of lameness in horses. *Am. J. Vet. Res.* **74**, 17-24.
- Keg, P.R., Schamhardt, H.C., van Weeren, P.R. and Barneveld, A. (1996) The effect of diagnostic regional nerve blocks in the forelimb on the locomotion of clinically sound horses. *Vet. Q* **18**, Suppl. **2**, 106-109.
- Kelmer, G., Keegan, K.G., Kramer, J., Wilson, D.A., Pai, F.P. and Singh, P. (2005) Computer-assisted kinematic evaluation of induced compensatory movements resembling lameness in horses trotting on a treadmill. *Am. J. Vet. Res.* **66**, 646-655.
- King, A.D. (1998) Inertial navigation – forty years of evolution. *GEC Rev.* **13**, 140-149.
- Kram, R. and Taylor, C.R. (1990) Energetics of running: a new perspective. *Nature* **346**, 265-267.
- Lee, D.V. (2011) Effects of grade and mass distribution on the mechanics of trotting in dogs. *J. Exp. Biol.* **214**, 402-411.
- Licka, T., Kapaun, M. and Peham, C. (2004) Influence of rider on lameness in trotting horses. *Equine Vet. J.* **36**, Suppl. **8**, 734-736.
- Lucidi, P., Bacco, G., Sticco, M., Mazzoleni, G., Benvenuti, M., Bernabo, N. and Trentini, R. (2013) Assessment of motor laterality in foals and young horses *Equus caballus* through an analysis of derailment at trot. *Phys. Behav.* **109**, 8-13.
- Maliye, S. and Marshall, J.F. (2016) Objective assessment of the compensatory effect of clinical hind limb lameness in horses: 37 cases 2011-2014. *J. Am. Vet. Med. Assoc.* **249**, 940-944.
- Maliye, S., Voute, L.C. and Marshall, J.F. (2015) Naturally-occurring forelimb lameness in the horse results in significant compensatory load redistribution during trotting. *Vet. J.* **204**, 208-213.
- Martin, P., Chateau, H., Pourcelot, P., Duray, L. and Cheze, L. (2014) Comparison between inertial sensors and motion capture system to quantify flexion-extension motion in the back of a horse. *Equine Vet. J.* **46**, Suppl. **46**, 43.
- Martin, P., Cheze, L., Pourcelot, P., Desquilbet, L., Duray, L. and Chateau, H. (2016) Effect of the rider position during rising trot on the horses biomechanics back and trunk kinematics and pressure under the saddle. *J. Biomech.* **49**, 1027-1033.
- Martin, P., Cheze, L., Pourcelot, P., Desquilbet, L., Duray, L. and Chateau, H. (2017) Effects of large saddle panels on the biomechanics of the equine back during rising trot: preliminary results. *J. Equine. Vet. Sci.* **48**, 15-22.
- May, S.A. and Wyn-Jones, G. (1987) Identification of hind limb lameness. *Equine Vet. J.* **19**, 185-188.
- McCracken, M.J., Kramer, J., Keegan, K.G., Lopes, M., Wilson, D.A., Reed, S.K., LaCarrubba, A. and Rasch, M. (2012) Comparison of an inertial sensor system of lameness quantification with subjective lameness evaluation. *Equine Vet. J.* **44**, Suppl. **6**, 652-656.
- McGreevy, P.D. and Rogers, L.J. (2005) Motor and sensory laterality in thoroughbred horses. *Appl. Anim. Behav. Sci.* **92**, 337-352.
- McGreevy, P.D. and Thomson, P.C. (2006) Differences in motor laterality between breeds of performance horse. *Appl. Anim. Behav. Sci.* **99**, 183-190.
- McLean, A. and McGreevy, P. (2010) Horse-training techniques that may defy the principles of learning theory and compromise welfare. *J. Vet. Behav.* **5**, 187-195.
- Meershoek, L., Roepstorff, L., Schamhardt, H., Johnston, C. and Bobbert, M. (2001) Joint moments in the distal forelimb of jumping horses during landing. *Equine Vet. J.* **33**, 410-415.
- Merkens, H.W., Schamhardt, H.C., Osch, G.J.V.M. and van den Bogert, A.J. (1993a) Ground reaction force patterns of Dutch Warmblood horses at normal trot. *Equine Vet. J.* **25**, 134-137.
- Merkens, H.W., Schamhardt, H.C., van Osch, G.J. and Hartman, W. (1993b) Ground reaction force patterns of Dutch warmbloods at the canter. *Am. J. Vet. Res.* **54**, 670-674.
- Mullard, J., Berger, J., Ellis, A. and Dyson, S. (2017) Development of an ethogram to describe facial expressions in ridden horses FEReq. *J. Vet. Behav.* **18**, 7-12.
- Nardello, F., Ardigó, L.P. and Minetti, A.E. (2009) Human locomotion: Right/left symmetry in 3D trajectory of body centre of mass. *Gait Posture*. **30**, Suppl. **2**, 802-810.
- Näsänen, R., Ojanpää, H., Tanskanen, T. and Päällysaho, J. (2006) Estimation of temporal resolution of object identification in human vision. *Exp. Brain Res.* **172**, 64.
- Parkes, R.S., Weller, R., Groth, A.M., May, S. and Pfau, T. (2009) Evidence of the development of 'domain-restricted' expertise in the recognition of asymmetric motion characteristics of hindlimb lameness in the horse. *Equine Vet. J.* **41**, 112-117.
- Parkes, R.S., Newton, R.J. and Dyson, S. (2013) An investigation of risk factors for foot-related lameness in a United Kingdom referral population of horses. *Vet. J.* **196**, 218-225.
- Pfau, T., Witte, T.H. and Wilson, A.M. (2005) A method for deriving displacement data during cyclical movement using an inertial sensor. *J. Exp. Biol.* **208**, 2503-2514.
- Pfau, T., Robilliard, J., Weller, R., Jespers, K., Eliashar, E. and Wilson, A.M. (2007) Assessment of mild hindlimb lameness during over ground locomotion using linear discriminant analysis of inertial sensor data. *Equine Vet. J.* **39**, 407-413.
- Pfau, T., Stubbs, N., Kaiser, L., Brow, L. and Clayton, H. (2012) Effect of trotting speed and circle radius on movement symmetry in horses during lunging on a soft surface. *Am. J. Vet. Res.* **73**, 1890-1899.
- Pfau, T., Starke, S., Tröster, S. and Roepstorff, L. (2013) Estimation of vertical tuber coxae movement in the horse from a single inertial measurement unit. *Vet. J.* **198**, 498-503.
- Pfau, T., Spicer-Jenkins, C., Smith, R.K., Bolt, D.M., Fiske-Jackson, A. and Witte, T.H. (2014) Identifying optimal parameters for quantification of changes in pelvic movement symmetry as a response to diagnostic analgesia in the hindlimbs of horses. *Equine Vet. J.* **46**, Suppl. **6**, 759-763.

- Pfau, T., Jennings, C., Mitchell, H., Olsen, E., Walker, A., Egenvall, A., Troester, S., Weller, R. and Rhodin, M. (2016a) Lungeing on hard and soft surfaces: movement symmetry of trotting horses considered sound by their owners. *Equine Vet. J.* **48**, Suppl. **1**, 83-89.
- Pfau, T., Fiske-Jackson, A. and Rhodin, M. (2016b) Quantitative assessment of gait parameters in horses: Useful for aiding clinical decision making?. *Equine Vet. Educ.* **28**, 209-215.
- Rhodin, M., Pfau, T., Roepstorff, L. and Egenvall, A. (2013) Effect of lungeing on head and pelvic movement asymmetry in horses with induced lameness. *Vet. J.* **198**, Suppl. **1**, 39-45.
- Rhodin, M., Roepstorff, L., French, A., Keegan, K.G., Pfau, T. and Egenvall, A. (2016) Head and pelvic movement asymmetry during lungeing in horses showing symmetrical movement on the straight. *Equine Vet. J.* **48**, 315-320.
- Rhodin, M., Persson-Sjodin, E., Egenvall, A., Serra Bragança, F.M., Pfau, T., Roepstorff, L., Weishaupt, M.A., Thomsen, M.H., van Weeren, P.R. and Herlund, E. (2018) Vertical symmetry of the withers in horses with induced forelimb and hindlimb lameness at trot. *Equine Vet. J.* **50**, 818-824.
- Riemersma, D.J., Schamhardt, H.C., Hartman, W. and Lammertink, J.L. (1988) Kinetics and kinematics of the equine hind limb: in vivo tendon loads and force plate measurements in ponies. *Am. J. Vet. Res.* **49**, 1344-1352.
- Robartes, H., Fairhurst, H. and Pfau, T. (2013) Head and pelvic movement symmetry in horses during circular motion and in rising trot: towards establishing guidelines for lameness examinations. *Vet. J.* **198**, 52-58.
- Ross, M.W. (2011a) Lameness in horses: basic facts before starting. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M.W. Ross and S.J. Dyson, Saunders, Philadelphia, pp 3-8.
- Ross, M. (2011b) Movement. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M.W. Ross and S.J. Dyson, Saunders, Philadelphia, pp 64-80.
- Ross, M.W. (2014) *Is it Back Pain or Hind Limb Lameness?* Proc. Ontario Vet. Med. Assoc. Conferences, Milton, Canada, pp 243-248.
- Rungsri, P.K., Staeker, W., Leelamankong, P., Estrada, R.J., Schulze, T. and Lischer, C.J. (2014) Use of body-mounted inertial sensors to objectively evaluate the response to perineural analgesia of the distal limb and intra-articular analgesia of the distal interphalangeal joint in horses with forelimb lameness. *J. Equine Vet. Sci.* **34**, 972-977.
- Schamhardt, H.C., Merckens, H.W., Vogel, V. and Willekens, C. (1993) External loads of the limbs of jumping horses at take off and landing. *Am. J. Vet. Res.* **54**, 675-680.
- Sloet van Oldruitenborgh-Oosterbaan, M.M., Genzel, W. and van Weeren, P.R. (2010) A pilot study on factors influencing the career of Dutch sport horses. *Equine Vet. J.* **42**, Suppl. **38**, 28-32.
- Starke, S.D., Willems, E., May, S.A. and Pfau, T. (2012a) Vertical head and trunk movement adaptations to sound horses trotting in a circle on a hard surface. *Vet. J.* **193**, 73-80.
- Starke, S.D., Willems, E., Head, M., May, S.A. and Pfau, T. (2012b) Proximal hindlimb flexion in the horse: effect on movement symmetry and implications for defining soundness. *Equine Vet. J.* **44**, 657-663.
- Sweet, A.L. (1953) Temporal discrimination by the human eye. *Am. J. Psychol.* **662**, 185-198.
- Terrier, P., Luthi, F. and Dériaz, O. (2013) Do orthopaedic shoes improve local dynamic stability of gait? An observational study in patients with chronic foot and ankle injuries. *BMC Musculoskeletal Dis.* **14**, 94.
- Van den Hoorn, W., Hodges, P., Dieën, J. and Hug, F. (2015a) Effect of acute noxious stimulation to the leg or back on muscle synergies during walking. *J. Neurophys.* **113**, 244-254.
- Van den Hoorn, W., Hug, F., Hodges, P., Buijn, S. and Dieën, J. (2015b) Effects of noxious stimulation to the back or calf muscles on gait stability. *J. Biomech.* **48**, 4109-4115.
- Vorstenbosch, M.A., Buchner, H.H.F., Savelberg, H.H., Schamhardt, H.C. and Barneveld, A. (1997) Modeling study of compensatory head movements in lame horses. *Am. J. Vet. Res.* **58**, 713-718.
- Warner, S.M., Koch, T.O. and Pfau, T. (2010) Inertial sensors for assessment of back movement in horses during locomotion over ground. *Equine Vet. J.* **42**, 417-424.
- van Weeren, P.R. (2013) History. In: *Equine Locomotion*, 2nd edn., Eds: W. Back and H. Clayton, Saunders, London, pp 1-30.
- van Weeren, P.R. (2007) *What Moves and How in the Back? Functional Anatomy*. Conferencia Internacional De Caballos De Deporte, San José, Costa Rica, pp 81-93.
- van Weeren, P.R., McGowan, C. and Haussler, K.K. (2010) Development of a structural and functional understanding of the equine back. *Equine Vet. J.* **42**, Suppl. **38**, 393-400.
- van Weeren, R., Pfau, T., Rhodi, M., Roepstorff, L., Bragança, F. and Weishaupt, M. (2017) Do we have to redefine lameness in the era of quantitative gait analysis? *Equine Vet. J.* **49**, 567-569.
- Weishaupt, M.A. (2007) Adaptation strategies of horses with lameness. *Vet. Clin. North Am. Equine Pract.* **24**, 79-100.
- Weishaupt, M.A., Wiestner, T., Hogg, H.P., Jordan, P. and Auer, J.A. (2004a) Compensatory load redistribution of horses with induced weightbearing hindlimb lameness trotting on a treadmill. *Equine Vet. J.* **36**, Suppl. **8**, 727-733.
- Weishaupt, M.A., Wiestner, T., Hogg, H.P., Jordan, P. and Auer, J.A. (2004b) Vertical ground reaction force-time histories of sound Warmblood horses trotting on a treadmill. *Vet. J.* **168**, 304-311.
- Weishaupt, M.A., Wiestner, T., Hogg, H.P., Jordan, P. and Auer, J.A. (2006) Compensatory load distribution of horses with induced weight-bearing forelimb lameness trotting on a treadmill. *Vet. J.* **171**, 135-146.
- Weishaupt, M.A., Byström, A., von Peinen, K., Wiestner, T., Meyer, H., Waldern, N., Johnston, C., van Weeren, P.R. and Roepstorff, L. (2009) Kinetics and kinematics of the passage. *Equine Vet. J.* **41**, 263-267.
- Wennerstrand, J., Johnston, C., Holm, R.K., Erichsen, C., Eksell, P. and Drevemo, S. (2004) Kinematic evaluation of the back in the sport horse with back pain. *Equine Vet. J.* **36**, 707-711.
- Wiggers, N., Nauwelaerts, S.L.P., Hobbs, S.J., Bool, S., Wolschrijn, C.F. and Back, W. (2015) Functional locomotor consequences of uneven forefeet for trot symmetry in individual riding horses. *PLoS ONE* **10**, e0114836, 1-14.
- Winter, D.A. (1982) Camera speeds for normal and pathological gait analyses. *Med. Biol. Eng. Comput.* **20**, 408-412.
- Zhang, Z., Lion, A., Chary-Valckenaere, I., Loeuille, D., Rat, A.C., Paysant, J. and Perrin, P.P. (2015) Diurnal variation on balance control in patients with symptomatic knee osteoarthritis. *Arch. Gerontol. Geriatr.* **61**, 109-114.

Original Article

Prospective study of blackthorn injury and synovitis in 35 horses

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Keywords: horse; blackthorn; synovitis

Summary

The objective of this prospective clinical study was to investigate the cause and describe the presentation, diagnosis, treatment techniques and outcome of *Prunus spinosa* (blackthorn) injury and synovitis in the horse. In all cases presented with blackthorn injury and synovitis, surgical treatment was performed within 24 h, using a two-stage procedure: 1-Perisynovial technique using ultrasound guided electrosurgical dissection; 2-Endoscopic technique. The diagnosis was confirmed by retrieval of black plant material from or close to the affected synovial structure. Mean lameness score on presentation was 4/5 (range 1–5). The most commonly affected structures were extensor tendon sheaths (12/35) and fetlock joints (11/35). All cases had thorn material removed, 80% had thorn material removed at surgery and in 49% it was intra-synovial. On presentation, the mean synovial fluid total protein level (TP) was 47.6 g/L (range 18–66); mean total nucleated cell count (TNCC) was 176×10^9 cells/L (range 12–312). Two days post-surgery, mean total protein levels were 33 g/L (range 16–52), mean TNCC was 13×10^9 cells/L (range 1–35). At 5 days post-surgery, the mean total protein was 23 g/L (range 12–28) and TNCC was 5×10^9 cells/L (range 1–12). All synovial fluid cultures were negative. Twenty-eight (80%) horses were sound 5 days post-operatively, seven (20%) were not lame in walk; they all returned to full work in an average time of 8 weeks (range 3–48 weeks). Surgery achieved accurate identification and removal of thorn material. In contrast to previous studies of synovial sepsis, these cases had a positive outcome despite high pre- and post-operative synovial fluid TP and TNCC. These findings suggest that *Prunus spinosus* (blackthorn) synovitis has a different aetiology to synovitis originating from sepsis or other types of contamination.

Introduction

Blackthorn (*Prunus spinosus*) (Fig 1), a member of the Rosacea family, is reported in human medicine to cause infections and tissue reactions (Sharma and Meredith 2004). Blackthorn synovitis is a rare cause of mono-arthritis in people, and is difficult to diagnose (Goupille *et al.* 1990; Tiwari and Beriha 2015), but plant thorn synovitis has not been reported in the horse, although synovitis from other sources is common.

In the author's hospital, plant thorn synovitis caused by blackthorn is a common problem in horses involved in fox hunting. These horses jump hedges containing blackthorn, frequently passing through the top of the hedge resulting in thorn penetration of various synovial structures of their limbs.

Ultrasound-guided removal of soft tissue foreign bodies has been described in humans, yielding encouraging results



Fig 1: *Prunus spinosus* (blackthorn) plant.

(Tung *et al.* 2007; Callegari *et al.* 2009), and needle localisation has been reported to reduce the required incision length and depth and help to minimise the risk of damage to surrounding tissue (Nwawka *et al.* 2014). Endoscopic debridement and lavage for treatment of synovial sepsis in human (Dory and Wantelet 1985; Jackson 1985; Parisien and Shaffer 1990; Kuo *et al.* 2011) and veterinary medicine (McIlwraith 2002) are considered to offer several advantages over lavage and arthrotomy, including improved visualisation and access.

Blackthorn is a native shrub with substantial thorns that is traditionally used in Britain and other parts of northern Europe to make cattle-proof hedging. Although blackthorn synovitis is a common condition affecting horses in many regions of the UK, it has not been reported.

This prospective study describes the presentation, diagnosis, treatment and outcome of blackthorn synovitis in a group of 35 horses. It then goes on to describe the surgical techniques that have been applied to treat this condition. This involves an electro-surgery technique using a needle placed under ultrasound guidance to provide a guide for the incision onto the thorn fragment, for removal of peri-synovial thorn fragments, followed by an endoscopically guided fragment retrieval from synovial structures. In all cases, with no concurrent intra synovial soft tissue injuries, the long and short-term outcomes were excellent.

Materials and methods

Study design and case selection

A prospective study of blackthorn injury and synovitis was reported. All horses that presented in the winter fox hunting

seasons of October 2013–March 2015 with the following: acute onset synovitis within 24 h of hunting, and a history of jumping at least one hedge containing blackthorn, were included in the study. Cases without confirmed blackthorn penetration, those that received antibiotic medication prior to referral and cases with significant concurrent soft tissue injury were excluded. Horses with blackthorn injury but no synovitis were also excluded.

All cases were subjected to a standardised clinical assessment, surgical treatment and aftercare. Thorn penetration was confirmed by removal of black plant material from the site prior to surgery and/or retrieval of black plant material at surgery. A diagnosis of synovitis was based on identification of an elevated total nucleated cell count (TNCC) and an elevated total protein level (TP) in synovial fluid of the affected structure. The following figures were considered as normal ranges for synovial fluid analysis; TNCC $<3.5 \times 10^9$ cells/L with TP <25 g/L (Robinson *et al.* 2017). Horses were operated on the day after admission because they were fatigued. Antibiotics were administered perioperatively from 30 min prior to surgery.

Case presentation and assessment

Lameness was graded (AAEP lameness scale, Swanson 1984). A synoviocentesis sample was analysed for TNCC (ProCyt Dx™)¹ and TP level (Catalyst Dx™)¹. The remaining fluid was submitted for bacterial culture. An average of 0.5–1.0 mL synovial fluid was placed in two blood culture media bottles (Hemoline™ Performance Duo™)², one aerobic and one anaerobic, which were incubated at 37 degrees for 8 days.

Ultrasonography

High-resolution ultrasonography with a linear 15 MHz probe (Logic S7 Expert)³, was performed. The image of any suspected thorn fragments was recorded, and its position marked with a skin staple. Thorn fragments were identified as an acoustic shadow produced in both transverse and longitudinal planes. Horses received a single dose of flunixin meglumine (Flunixin Injection)⁴, 1.1 mg/kg i.v. following diagnosis. A 5-day course of oxytetracycline (Engemycin 10% [DD])⁵, 5 mg/kg bwt i.v. q.12 h was initiated with the first dose administered 30 min prior to surgery (BEVA 2016).

Surgery

Under routine general anaesthesia, the horse was positioned in dorsal recumbency and the affected limb was clipped, prepared and draped. Any remaining palpable and or visible cutaneous thorn fragments were removed using Halsted mosquito forceps to squeeze the skin.

Stage 1 Peri-synovial technique

An ultrasound guided technique was deployed using a needle marker to enable an electrocautery incision to be made directly onto the thorn fragment.

The ultrasound probe was gas sterilised. Hydrus gel (Intra-site gel)⁶ was placed on the skin as an acoustic couple. A 0.9 × 40 mm hypodermic needle was advanced at 20–35° to the skin surface in the plane of the linear transducer, under ultrasound guidance, until the tip was in contact with the thorn fragment (Fig 2). Care was taken to ensure that the needle tip was seen to touch and move the thorn (Fig 3). A monopolar electrosurgery instrument (Art E-1)⁷ was used, with the base electrode applied to the lateral aspect of the



Fig 2: 0.9 × 40 mm needle placed at 30° through the skin on the dorsal aspect of the metacarpophalangeal joint, in the plane of the longitudinal linear transducer.

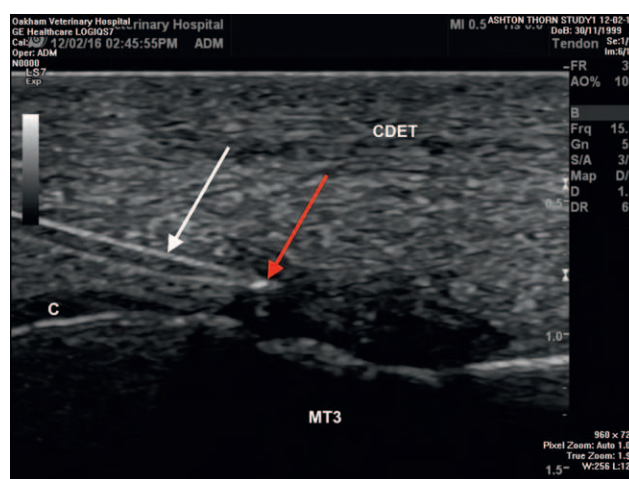


Fig 3: Longitudinal ultrasound image of the dorsal aspect of the metacarpophalangeal joint; 0.9 × 40 mm needle (white arrow), thorn fragment (red arrow), common digital extensor tendon (CDET), cartilage (C), third metatarsal bone (MT3).

thorax, secured by the operating table pads. An incision is made along the needle shaft to expose the tip and thorn fragment. Halsted mosquito forceps were used to retract the tissues, and then retrieve the fragment (Fig 4). Swab sticks (Cotton buds)⁸ were used in some cases to swab fluid, blood and charred tissue from the incision.

The incision was lavaged with Hartmann's polyionic crystalloid solution and closed with 3.5 M C-16 cutting nylon (Monosoft™)⁹ cruciate skin sutures.

Stage 2 Endoscopic techniques

Endoscopic evaluation with a 4.5 mm 30 arthroscope and HD 1080p camera (Linvatec)¹⁰ was performed using standard portals (McIlwraith *et al.* 2015). The resolution afforded by this system was considered necessary to identify small thorn fragments. Large thorn fragments (Fig 5) were removed with rongeurs, small fragments (Fig 6) with a synovial resector blade (Apex™ and Cuda™)¹¹ and suction. In order to minimise the number of portals required, very small fragments were removed by flushing through an appropriately placed



Fig 4: Electrocautery incision along the shaft of the needle; thorn fragment (red arrow).

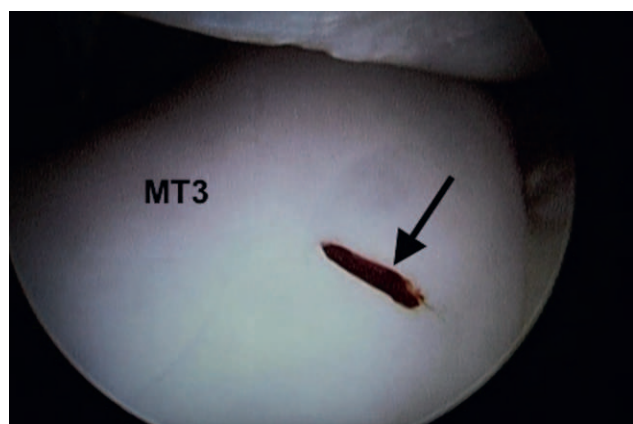


Fig 5: Arthroscopic view of the dorsal pouch of the metatarsophalangeal joint; Condyle of the third metacarpal bone (MTC3), thorn fragment (black arrow).

0.9 mm × 40 mm needle. When thorn entry sites could be seen on the skin over the synovial structure, a needle was placed through the entry site to identify the region of synovial penetration. Local synovectomy was performed to reveal thorn fragments that were otherwise hidden. In cases where an area of haemorrhage and disruption of the synovium was seen, this was also debrided with the synovial resector to reveal thorn fragments. In cases presenting with more than one synovial structure involved, data are presented for the structure with the highest TNCC, only (6 cases), although all affected structures were treated.

The majority of structures were lavaged with 5 L of Hartmann's solution (range 2–15 L), but larger volumes were used when multiple thorn fragments were found. Portals were

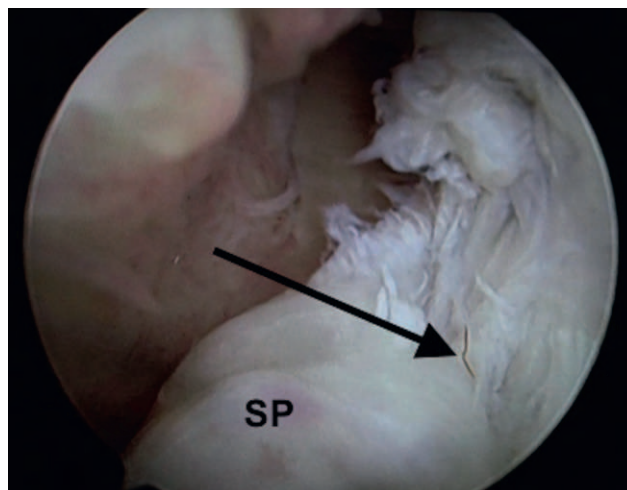


Fig 6: Arthroscopic view of the palmar pouch of the metatarsophalangeal joint; small thorn fragment (arrow), synovial pad of the proximal recess of the joint (SP).

closed with 3.5 M C-16 cutting nylon (Monosoft™)⁹ cruciate skin sutures.

Diagnosis

Thorn material was confirmed by direct visual examination of the material extracted by instruments in all cases. In addition, in some cases, the fluid obtained in the suction bottle from the synovial resector was poured through a large gauze swab to produce a filtrate, this was examined microscopically (Leica DME).¹² The identification of very dark coloured plant material was considered to confirm that it was blackthorn.

Post-operative care

A sterile nonadherent dressing was applied to the surgical site, followed by a single layer padded bandage.

Horses were hospitalised and monitored for 5 days. Dressings were changed and synoviocentesis was repeated at 2 and 5 days post-surgery.

Follow-up

Clients were contacted by telephone at 4 and 12 weeks post-treatment to obtain outcome data regarding soundness and when they returned to work. In the cases that had not returned to work by 12 weeks, the owners were contacted each month until the horse returned to full work.

Results

Seventy-five horses presented with suspected blackthorn plant thorn synovitis in the study period. Fourteen cases were excluded due to significant injury to soft tissue structures from the thorn; all these cases had lacerations of the superficial and/or deep digital flexor tendons in the digital flexor tendon sheath. Twelve cases in which thorn penetration could not be confirmed either at surgery or physical examination were excluded; the synovial resector was not used in these cases therefore there was no filtrate available for microscopic examination. Eight cases were excluded as they had already received antibiotics prior to referral. Six cases that did not have the standard follow-up were excluded. Thirty-five cases met the inclusion criteria.

Horses included 7 mares and 28 geldings, representing the following disciplines: 16 Hunters, 4 Point-to-point racehorses, 8 Eventers. Their breeds were 16 Irish hunters, 8 Sports horses, 4 Thoroughbreds, 4 Ponies, 2 Warmbloods and 1 Cob. The mean age was 9 years (range 4–17).

All cases presented with a profound synovial effusion, periarticular heat, swelling and pain on flexion. The most frequent lameness grade was 4/5 (range 1–5). There were twice as many forelimb (23/35) cases as hindlimb cases (12/35). All cases had black plant material extracted from peri-synovial structures and/or the intra-synovial space. In 20% (7/

35) of cases, black plant material was removed from the region of synovial involvement before surgery but was not found at surgery. In 80% (28/35) of cases, black plant material was retrieved at surgery; in 49% (17/35) it was removed from the intra-synovial space, and in 25% (7/35) there were multiple intra-synovial fragments removed (**Table 1**). The most commonly affected structures were extensor tendon sheaths (12/35), and fetlock joints (11/35). In 6 of 7 carpal joints, free thorn material was located. Intra-articular thorn material was found in 5 of 11 fetlock joints, including 4 under the dorsoproximal synovial pad and in 3 on the intersesamoidean

TABLE 1: Clinical presentation, surgical findings and results of 35 horses with confirmed plant thorn synovitis

Case	Lame (AAEP)		Limb	Synovial site	TNCC ($\times 10^{-9}$)			Total protein g/L			Thorns	Site	Thorn debris	In work (weeks)
	T0	T120			T0	T48	T120	T0	T48	T120				
1	4	0	RF	MCPJ	104	16	4	66	43	22	2	S,PS	N	6
2	1	0	RH	DFTS	231	8	2	56	36	20	1	PS	N	4
3	5	0	RF	MCPJ	300	–	–	58	–	–	0		Y	26
4	3	0	LF	LDETS	300	35	8	46	43	28	7	PS	N	4
5	4	0	RF	MCJ	213	6	12	51	37	22	1	S	Y	–
6	4	0	RF	MCJ	196	21	3	43	31	12	1	PS	Y	5
7	4	0	RH	LDETS	157	–	–	32	–	–	1	S	N	3
8	5	0	RH	MTPJ	155	4	1	42	38	21	8	S,PS	Y	3
9	4	0	RH	FPJ	41	–	–	36	–	–	1	S	N	4
10	4	0	RF	MCPJ	191	11	7	54	37	16	0		Y	2
11	4	<4	LH	MTPJ	109	1	–	46	22	–	1	PS	N	–
12	2	<4	LF	MCJ	285	15	12	61	45	23	1	S	N	2
13	4	0	RF	MCPJ	206	11	5	44	28	15	1	PS	N	3
14	2	<4	LF	ECRTS	180	9	4	36	31	26	0		Y	48
15	4	<4	LH	FPJ	116	–	–	43	–	–	1	S	Y	4
16	4	0	RF	MCJ	199	4	4	41	28	20	1	PS	Y	–
17	3	0	LF	DFTS	120	1	–	43	26	–	1	PS	N	–
18	4	<4	RF	ECRTS	26	2	–	36	23	–	1	S	N	–
19	5	0	RH	MTPJ	173	33	12	57	30	26	1	S	Y	5
20	4	0	LF	LDETS	209	12	–	43	16	–	1	S	N	3
21	5	<4	RH	MTPJ	173	4	1	48	20	20	5	S	Y	4
22	4	0	LF	ECRTS	411	–	–	56	–	–	3	S	N	4
23	4	<4	RF	ABCJ	312	6	1	55	30	26	0		N	5
24	4	0	LH	MTPJ	294	7	6	50	16	34	1	S	N	4
25	5	0	LH	DFTS	41	34	2	30	18	14	0			4
26	4	0	LF	ECRTS	209	–	–	46	–	–	1	S	N	8
27	–	0	RF	ABCJ	244	24	–	51	30	–	1	S	N	6
28	4	0	RF	ECRTS	304	34	3	60	52	28	4	S	N	5
29	4	0	LF	ECRTS	287	3	–	52	41	–	0		Y	4
30	4	0	LH	MTPJ	82	3	0	44	36	20	1	PS	N	3
31	–	0	LF	DFTS	12	4	3	51	30	28	1	PS	N	12
32	3	0	RF	ABCJ	23	9	–	28	38	–	2	PS	N	3
				MCJ	22	4	–	18	30	–				
33	–	0	LF	MCPJ	110	3	–	40	27	–	0		Y	–
34	2	0	LH	DFTS	61	10	–	42	34	–	1	S	N	–
35	4	0	RF	ECRTS	65	32	–	60	43	–	1	PS	N	3

Notes: Case number cases were numbered sequentially in order of presentation.

Lame: Degree of lameness (AAEP score) at presentation T0 and T120 hours post surgery prior to discharge from the hospital.

Limb: LF left fore, RF right fore, LH left hind, RH right hind.

Synovial site: MCPJ = metacarpophalangeal joint; MTPJ = metatarsophalangeal joint = MCJ mid carpal joint; ABCJ = Antebrachio-carpal joint; FPJ = femoropatella joint; DFTS = digital flexor tendon sheath; LDETS = lateral digital extensor tendon sheath; ECRTS = extensor carpi radialis tendon sheath.

TNCC: Total nucleated cell count of synovial fluid, at presentation T0, 48 and 120 hours after surgery.

Total Protein: Total protein g/L of synovial fluid at presentation T0, 48 and 120 hours after surgery.

Thorns: number of thorn fragments retrieved.

Site: Site of thorn fragments. **S** synovial, **PS** perisynovial.

Thorn: Debris thorn debris retrieved from the synovial retractor suction fluid. Obtained by filtering the fluid through a surgical swab and examining the any dark coloured material under a light microscope¹ to confirm the appearance of wood fibres. Y yes, N no.

In work (weeks): Number of weeks to return to full work, as reported by the owners/trainers by telephone.

ligament. In extensor tendon sheaths, 8 of 12 cases had intra-synovial thorn material located; in two cases this was free, in three intra-tendinous and in a further three they were in the synovial reflection. Intra-tendinous thorn injuries of the extensor tendons were not excluded along with the cases that had significant concurrent soft tissue injuries, as the tendon damage appeared to be minor and was considered to be unlikely to be of clinical significance.

Mean synovial fluid TP and TNCC at presentation, 2 and 5 days post-surgery were 47.6 g/L (range 18–66) and 176×10^9 cells/L (range 12–312); 33 g/L (range 16–52) and 13×10^9 cells/L (range 1–35) and 23 g/L (range 12–28) and 5×10^9 cells/L (range 1–12), respectively. In seven cases, synoviocentesis did not yield a suitable volume of fluid (<0.5 mL) for analysis at 2 days post-surgery. All synovial fluid cultures yielded no growth (Table 1).

Most horses were less lame on the morning of surgery than on admission the previous day. Twenty-eight (80%) were sound at 5 days post-operatively, the remaining 7 (20%) horses were sound in walk but not evaluated in trot. All incisions were reported to have healed without complication by 14 days post-operatively. All horses successfully returned to full work and the mean time-period until full work resumed was 8 weeks (range 3–48). No period for the return to work was available for seven cases but they were reported to have returned to work prior to 8 weeks. In 2 cases the return to work was delayed for 26 and 48 weeks, due to owner preference rather than lameness (Table 1).

Discussion

This is the first published study of the clinical presentation, diagnosis and treatment of plant thorn injury and synovitis in the horse. All cases had a history of jumping hedges containing blackthorn, and plant material retrieved prior to and/or at surgery was dark in colour and therefore assumed to be blackthorn. The 35 cases described in this prospective study demonstrate that a range of different synovial structures can be affected, the distribution of which is generally consistent with regions of the limbs passing through the hedge as the horse jumps over/through it. The mechanism for penetration of the digital flexor tendon sheath is more difficult to explain. In the author's experience, these cases frequently have substantial longitudinal injury to the superficial and/or deep digital flexor tendons, perhaps because they result from the limb loading onto a thorn as the fetlock hyperextends. The onset and severity of lameness caused by blackthorn synovitis is more rapid than would be expected for a foreign body reaction to other plant material, contamination or the trauma from thorn penetration (McIlwraith *et al.* 2015). This study demonstrates that blackthorn material may be found at surgery in the majority (80%) of cases, and in many cases (49%) is in the synovial cavity. The prognosis for return to athletic function of blackthorn plant thorn synovitis (with no flexor tendon injury) treated by the two-stage surgical procedure described herein is excellent. This is despite increased TP and TNCC levels pre- and post-operatively, that would be suggestive of sepsis. The average post-operative time-period to return to work was 8 weeks.

In contrast to typical bacterial synovial infection (Walmsley *et al.* 2011; Milner *et al.* 2014), all 35 cases in this case series made a full return to work. Although this may be expected in

cases of synovitis caused by other nonseptic processes, such as uncontaminated lacerations, inert foreign body penetrations, intra-articular medications and surgical interventions, in the author's experience, none of these processes produce such an acute profound lameness and increase in synovial TNCC and total protein. However, all cases in this study presented soon after the injury, therefore a positive outcome could have been expected for other causes of joint contamination or infection. In this study, no evidence of bacterial colonisation was clearly identified in any of the cases, suggesting a thorn induced synovitis, rather than infective synovitis. There is considerable cross over between synovial fluid TNCC and protein levels seen in nonseptic and septic synovitis. The levels in this case series all exceed the author's cut-off values for synovitis of $\text{TNCC} > 5 \times 10^9$ cells/L, and total protein level > 30 g/L; however, the majority also fulfil the criteria for synovial sepsis $> 30 \times 10^9$ cells/L and > 40 g/L (McIlwraith *et al.* 2015). In previous studies of confirmed synovial sepsis, approximately 25%–32% yielded positive bacterial cultures (Taylor *et al.* 2010; Robinson *et al.* 2016), therefore around 12 cases would be expected to yield positive cultures in this series. The culture technique utilised in the current study used synovial samples obtained by aseptic technique prior to antibiotic administration, and on average 0.5–1.0 mL of synovial fluid was available for enrichment media culture. All cases yielded no growth after incubation at 37 degrees for 8 days. Kratz *et al.* (2003) suggest that *Pantoea agglomerans* may be responsible for sepsis in plant thorn injuries even when bacterial culture is negative. This is because it is the species most commonly (although infrequently) isolated; they propose that inappropriate growth media and inaccurate identification methods could be the reason for negative culture results. De Champs *et al.* (2000) reported two cases of septic arthritis from plant thorn injury where *Pantoea agglomerans* was isolated from paediatric blood culture media (BACTEC Peds Plus), but not conventional agar plates; this enrichment media is similar but not the same as that used in our study. It is therefore possible that isolation was unsuccessful due to the media used; in future cases, culture in alternative enrichment media should be attempted. In the author's hospital, using the same technique, positive culture rates are around 30% in synovial sepsis cases (similar to previous studies). The majority of horses referred with synovial sepsis secondary to a wound have been administered antimicrobials by the referring veterinarian. Administration of an antibiotic drug before aspiration of synovial fluid has been postulated to decrease the likelihood of obtaining a positive bacterial culture (Ince *et al.* 2004), therefore as part of the study design all cases that received antibiotics prior to referral were excluded, resulting in the loss of eight cases. Inclusion of these cases may have compromised the study in terms of affecting the clinical presentation, the results of bacteriology cultures and outcome data. However, Taylor *et al.* (2010) and Ghanem *et al.* (2007) found that preoperative antibiotics did not interfere with isolation of bacteria from synovial samples collected during surgery, in horses or human patients. Fourteen cases were excluded due to flexor tendon laceration; this was because the injury will result in longer convalescence and poorer outcome than thorn penetration alone (Fraser and Bladon 2004), although the outcome of such cases from blackthorn injury warrants further investigation.

There are a limited number of case series of blackthorn injury in humans (Blake *et al.* 1981; Goupille *et al.* 1990;

Sharma and Meredith 2004; Baskar *et al.* 2006). These conclude that conservative treatment is usually unsuccessful, and that surgical management to remove the thorn fragments is curative (Goupille *et al.* 1990; Baskar *et al.* 2006). These findings are consistent with this study in the horse, and in the author's experience untreated cases also carry a poor prognosis in the horse. Reports of plant thorn synovitis in people describe septic synovitis caused by *Pantoea agglomerans* bacteria (Sugarman *et al.* 1977; Kratz *et al.* 2003; Joris and Duerinckx 2008; Jain *et al.* 2012; Fianyo *et al.* 2015). *Pantoea agglomerans* infection has been associated with a variety of thorn types in different parts of the world (Dutkiewicz *et al.* 2016), but not with blackthorn species. The latter thorns contain a higher concentration of phenolic compounds than many other fruiting plants, hence the dark colour (Guimarães *et al.* 2013). Strömqvist *et al.* (1985) suggest that alkaloids present in the thorns may be responsible for the intense inflammatory reactions. A possible explanation for the severity of the synovitis following blackthorn penetration is a nonseptic, immune mediated response to the large concentration of phenolic and/or alkaloid compounds. The acute response then appears to reduce to a more moderate synovitis consistent with a foreign body reaction to the plant material. A similar moderate synovitis is reported in man from various plant thorns (Baskar *et al.* 2006). Further work is required to determine whether a chemical synovitis is responsible for the clinical presentation seen in the horse.

Recent literature suggests that the outcome for synovial sepsis is comparable if surgery is delayed until normal working hours (Milner *et al.* 2014). Horses in this series were operated the day following presentation. At admission, these horses were at the end of a prolonged period of hard, fast work, they were fatigued and thus an increased risk for anaesthetic complications (Hubbell *et al.* 2000; Johnston *et al.* 2002; Taylor *et al.* 2010).

Twenty-five of 35 cases presented with severe lameness (AAEP score 4 or 5); all were given nonsteroidal anti-inflammatory medication but no antimicrobials, and were hospitalised over-night before surgery, and most horses were considerably more comfortable when they were evaluated the following day prior to surgery. In contrast to previous reports of synovial sepsis (Taylor *et al.* 2010; Walmsley *et al.* 2011; Milner *et al.* 2014), these cases had a positive outcome despite high pre- and post-operative synovial fluid TNCC and TP concentrations. This prospective study was designed to investigate whether synovial sepsis was the cause of blackthorn synovitis. Based on the primary author's experience, it is likely that keeping horses with blackthorn synovitis overnight without any antibiotic treatment would not affect the outcome. Cases considered at risk of synovitis from other causes were administered antibiotics and excluded from the study. Antibiotic treatment prior to referral for cases of synovitis of uncertain origin remains recommended. Topical antibiotic treatment, although widely recommended, was not used in this study. It has been suggested that its use may reduce excessive granulation tissue formation (Harmen *et al.* 2017); however, all wounds in the study were reported to heal by first intention.

These findings suggest that blackthorn synovial penetration creates a severe synovitis and has a different clinical progression than synovitis originating from sepsis. Unfortunately, further analysis of synovial samples such as

differential cell count; SAA, glucose, lactate levels and cytological evaluation were not available for this study. Further analysis would enable better definition of the type of synovitis. It remains possible that blackthorn synovitis results from bacterial infection; further investigations required include synovial fluid culture in other enrichment media and potentially PCR analysis.

The use of a high-resolution ultrasound-guided technique for identification of extra synovial thorn fragments is described. This was developed from techniques used in humans (Tung *et al.* 2007; Callegari *et al.* 2009) that have not been previously described in the horse, enabling accurate identification and removal of deep extra-articular thorn fragments with minimal surgical trauma. It is important to carry out this procedure before endoscopy as any air introduced into the tissue will obscure the ultrasonographic view of the thorn material. In cases with multiple thorn fragments in close proximity, needles are placed on each fragment before any incisions are made, this prevents air introduced by the incision obscuring ultrasound guidance. Only thorn material that could be imaged in two perpendicular planes was judged to be significant and required removal. All thorn material identified ultrasonographically was successfully retrieved at surgery. In the author's experience, regions of fall out only identifiable in one plane may be edge artefacts caused by normal structures such as blood vessels or air artefacts from thorn entry/exit sites. Alternatively, they may be very small thorn fragments, and our experience and the results of this study suggest that if they are thorn fragments that they are not large enough to be clinically significant. It is important to appreciate that thorns that are in a plane perpendicular to the skin are likely to be much larger than predicted by ultrasound. Electro-surgery, although more traumatic than sharp surgery, was necessary to provide a bloodless field. Although the brown charred tissue can reduce contrast from the thorn material, it can easily be removed with a swab stick and can be differentiated from the very black thorn material. The arthroscopic/tenoscopic techniques used in this study, combined with partial synovectomy at thorn entry sites enabled successful removal of thorn debris from the affected synovial sites. Blake *et al.* (1981) confirmed the diagnosis of blackthorn synovitis by histological examination of a synovial fluid sample, revealing birefringent vegetable material. In the author's experience with chronic cases, thorn debris can be easily identified from the material in the suction bottle connected to the synovial resector. The fluid is filtered through a gauze swab, and dark material is readily identified grossly, and confirmed to be of plant origin by microscopic examination. Focal synovectomy was performed to reveal thorn entry sites and identify thorn material, with no detrimental effect on the outcome. Consistent with findings in man (Sharma and Meredith 2004) and the author's experience prior to this study, if fragments are not removed, the prognosis is poor. Examination and probing of any suspected thorn entry sites, facilitated by local synovectomy, should be considered essential for successful treatment.

This prospective study has relatively low numbers as it took place at one referral hospital over a 2-year period. Although a multicentre study would increase the case numbers, it would also introduce other variables, such as surgeon experience. The author has experience of over 250 cases of blackthorn synovitis over 15 years prior to this study which led

to the development of the two-stage technique described and the use of standardised techniques.

This study illustrates several important aspects of plant thorn synovitis in horses. Firstly, high-resolution ultrasound is recommended to identify thorn fragments, as described in humans (Tung *et al.* 2007) and facilitate their accurate removal with minimal trauma. Secondly, arthroscopic/tenoscopic evaluation of synovial structure is essential to remove foreign material and rapidly restore function. In addition, many of the thorn fragments are very small (<0.5 mm) and may not be visible with a low-resolution arthroscopy system. Thirdly, the convalescent time in some cases was as little as 21 days, this is likely to be because with blackthorn synovitis, no structural compromise to the tissues was present, and removal of foreign material and inflammatory mediators allows the synovial environment to return to normal quickly. Lastly, it is important to differentiate blackthorn synovitis from typical synovial sepsis. Despite a similar presentation and persistent abnormal synovial fluid cytology post-operatively, an appropriate single surgical treatment of blackthorn synovitis yields an excellent prognosis to return to previous performance. These findings suggest that blackthorn synovitis is characterised by severe synovitis secondary to thorn phenolic compounds and not caused by bacterial infection. Antimicrobial treatment for future cases could be confined to the perioperative period, in line with good antimicrobial stewardship. Further, this suggests that antimicrobial medication, as for elective arthroscopic procedures is adequate for these cases. This protocol (procaine penicillin 22,000 iu/kg bwt q.12 h for 36 h) has now been adopted in our hospital.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This study was approved by the ethics committee of Nottingham University Veterinary School.

Source of funding

None.

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References

Baskar, S., Mann, J.S., Thomas, A.P. and Newton, P. (2006) Plant thorn tenosynovitis. *J. Clin. Rheumatol.* **12**, 137-138.

BEVA (2016) Protect Me Guidelines. www.beva.org.uk/_uploads/documents/1beva-antimicrobial-policy-template-distributed.pdf.

Blake, D.R., Bacon, P.A., Scott, C.A. and Potter, A.R. (1981) Monoarthritis from blackthorn injury: a novel means of diagnosis. *Br. Med. J.* **282**, 36.

Callegari, L., Leonardi, A., Bini, A., Sabato, C., Nicotera, P., Spano, E., Mariani, D., Genovese, E.A. and Fugazzola, C. (2009) Ultrasound-guided removal of foreign bodies: personal experience. *Eur. Radiol.* **19**, 1273-1279.

De Champs, B., Le Seaux, S., Dubost, J.J., Boisgard, S., Sauvezie, B. and Sirot, J. (2000) Isolation of *Pantoea agglomerans* in two cases of septic monoarthritis after plant thorn and wood sliver injuries. *J. Clin. Microbiol.* **38**, 460-461.

Dory, M.A. and Wantelet, M.J. (1985) Arthroscopy in septic arthritis. Lidocaine- and iodine-containing contrast media are bacteriostatic. *Arthritis Rheum.* **28**, 198-203.

Dutkiewicz, J., Mackiewicz, B., Kinga Lemieszek, M., Golec, M. and Milanowski, J. (2016) *Pantoea agglomerans*: a mysterious bacterium of evil and good. Part III. Deleterious effects: infections of humans, animals and plants. *Ann. Agric. Environ. Med.* **23**, 197-205.

Fianyo, E., Guignard, S., Economu, A., Thellier, N., Davidowicz, K. and Chevalier, X. (2015) Thorn synovitis: report of 2 cases. *Rev. Med. Interne* **36**, 426-429.

Fraser, B.S. and Bladon, B.M. (2004) Tenoscopic surgery for treatment of lacerations of the digital flexor tendon sheath. *Equine Vet. J.* **36**, 528-531.

Ghanem, E., Parvizi, J., Clohisy, J., Burnett, S., Sharkey, P.F. and Barrack, R. (2007) Perioperative antibiotics should not be withheld in proven cases of periprosthetic infection. *Clin. Orthop.* **461**, 44-47.

Goupille, P., Fouquet, B., Favard, L., Burdin, P. and Valat, J.P. (1990) Two cases of plant thorn synovitis. Difficulties in diagnosis and treatment. *J. Rheumatol.* **17**, 252-254.

Guimarães, R., Barros, L., Dueñas, M., Carvalho, A.M., Queiroz, M.J., Santos-Buelga, C. and Ferreira, I.C. (2013) Characterization of phenolic compounds in wild fruits from Northeastern Portugal. *Food Chem.* **141**, 3721-3730.

Harmen, C.C.G., Hawkins, J.F., Li, J., Connell, S., Miller, M., Saenger, M. and Freeman, L.J. (2017) Effects of topical application of silver sulfadiazine cream, triple antimicrobial ointment, or hyperosmolar nanoemulsion on wound healing, bacterial load, and exuberant granulation tissue formation in bandaged full-thickness equine skin wounds. *Am. J. Vet. Res.* **78**, 638-646.

Hubbell, J.A., Hinchcliff, K.W., Schmall, L.M., Muir, W.W., Robertson, J.T. and Sams, R.A. (2000) Anesthetic, cardiorespiratory, and metabolic effects of four intravenous anesthetic regimens induced in horses immediately after maximal exercise. *Am. J. Vet. Res.* **61**, 1545-1552.

Ince, A., Rupp, J., Frommelt, L., Katzer, A., Gille, J. and Lohr, J.F. (2004) Is 'aseptic' loosening of the prosthetic cup after total hip replacement due to nonculturable bacterial pathogens in patients with low grade infection? *Clin. Infect. Dis.* **39**, 1599-1603.

Jackson, R.W. (1985) The septic knee-arthroscopic treatment. *Arthroscopy* **1**, 194-197.

Jain, S., Bohra, I., Mahajan, R., Jain, S. and Chugh, T.D. (2012) *Pantoea agglomerans* infection behaving like a tumor after plant thorn injury: an unusual presentation. *Indian J. Pathol. Microbiol.* **55**, 386-388.

Johnston, G.M., Eastment, J.K., Wood, J. and Taylor, P.M. (2002) Confidential enquiry of perioperative equine fatalities (CEPEF): mortality results of Phases 1 and 2. *Vet Anaesth. Analg.* **29**, 159-170.

Joris, F.H. and Duerinckx, M.D. (2008) Case report: subacute synovitis of the knee after a rose thorn injury: unusual clinical picture. *Clin. Orthop. Relat. Res.* **466**, 3138-3142.

Kratz, A., Greenberg, D., Barki, Y., Cohen, E. and Lifshitz, M. (2003) *Pantoea agglomerans* as a cause of septic arthritis after palm tree thorn injury: case report and literature review. *Arch. Dis. Child.* **88**, 542-544.

Kuo, C.L., Chang, J.H., Wu, C.C., Shen, P.H., Wand, C.C., Lin, L.C., Shen, H.S. and Lee, C.H. (2011) Treatment of septic knee arthritis: comparison of arthroscopic debridement alone or combined with continuous closed irrigation-suction system. *J. Trauma* **71**, 454-459.

- McIlwraith, C.W. (2002) Diseases of joints tendons ligaments and related structures. In: *Adams' Lameness in Horses*, 5th edn., Ed: T.S. Stashak. Lippincott, Williams and Wilkins, Philadelphia. p 578.
- McIlwraith, C.W., Nixon, A.J. and Wright, I.M. (2015) *Diagnostic and Surgical Arthroscopy in the Horse*, 4th edn., Ed: C.W. McIlwraith, Elsevier, London.
- Milner, P.I., Bardell, D.A., Warner, L., Packer, M.J., Senior, J.M., Singer, E.R. and Archer, D.C. (2014) Factors associated with survival to hospital discharge following endoscopic treatment for synovial sepsis in 214 horses. *Equine Vet. J.* **46**, 701-705.
- Nwawka, O.K., Kabutey, N.K., Locke, C.M., Castro-Aragon, I. and Kim, D. (2014) Ultrasound-guided needle localization to aid foreign body removal in pediatric patients. *J. Foot Ankle Surg.* **53**, 67-70.
- Parisien, J.S. and Shaffer, B. (1990) Arthroscopic management of pyarthrosis. *Clin. Orthop. Relat. Res.* **275**, 243-246.
- Robinson, S., Timofte, D., Singer, R., Rimmington, L. and Rubio-Martinez, L.M. (2016) Prevalence and antimicrobial susceptibility of bacterial isolates from horses with synovial sepsis: Across-sectional study of 95 cases. *Vet. J.* **216**, 17-21.
- Robinson, S., Singer, R., Piviani, M. and Rubio-Martinez, L.M. (2017) Are serum amyloid A or D-lactate useful to diagnose synovial contamination or sepsis in horses? *Vet. Rec.* **21**, 425.
- Sharma, H. and Meredith, A.D. (2004) A report of 18 blackthorn injuries of the upper limb. *Injury* **35**, 930-935.
- Strömqvist, B., Edlund, E. and Lidgren, L. (1985) A case of blackthorn synovitis. *Acta Orthop. Scand.* **56**, 342-343.
- Sugarman, M., Stobie, D.G., Quismorio, F.P., Terry, R. and Hanson, V. (1977) Plant thorn synovitis. *Arthritis Rheum.* **20**, 1125-1128.
- Swanson, T.D. (1984) *Guide for Veterinary Service and Judging of Equestrian Events*, 3rd edn., American Association of Equine Practitioners, Golden, CO.
- Taylor, A.H., Mair, T.S., Smith, L.J. and Perkins, J.D. 2010. Bacterial culture of septic synovial structures of horses: does a positive bacterial culture influence prognosis? *Equine Vet. J.* **42**: 213-218.
- Tiwari, S. and Beriha, S.S. (2015) Pantoea species causing early onset neonatal sepsis: a case report. *J. Med. Case Rep.* **4**, 188.
- Tung, C.H., Chen, Y.H., Lan, H.H., Hsieh, T.Y., Chen, D.Y. and Lan, J.L. (2007) Diagnosis of plant-thorn synovitis by high-resolution ultrasonography: a case report and literature review. *Clin. Rheumatol.* **26**, 849-851.
- Walmsley, E.A., Anderson, G.A., Muurlink, M.A. and Whitton, R.C. (2011) Retrospective investigation of prognostic indicators for adult horses with infection of a synovial structure. *Aust. Vet. J.* **89**, 226-231.

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Original Article

Thoracoscopic pericardiectomy: A feasibility study and impact on cardiac volumetry in healthy horses

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Keywords: horse; echocardiography; preload; volumetric variables

Summary

This study was conceived to evaluate the feasibility of a thoracoscopic technique intended for partial pericardiectomy in horses and how cardiac volumes are influenced by such procedure in an immediate and mid-term perspective. Thoracoscopic pericardiectomy, which is known as a minimally invasive technique, was performed in six healthy horses. Echocardiographic evaluation was performed in every horse at different times, before and after the procedure. According to the area-length method, the following parameters were evaluated: maximum left atrial volume, minimum left atrial volume, left ventricular volume in systole and left ventricular volume in diastole. These variables were used to calculate the ejection fraction of the left atrium and left ventricle. After 28 days, repeated thoracoscopy was performed to inspect the thoracic cavity. Pericardiectomy was successfully performed in all horses, with post-operative complication documented in only one animal. After 28 days, adhesion was observed in two animals, located between the epicardium and the thoracic wall, without however impairing cardiac function. Pericardial window was broad and well delimited in all horses, without impairing cardiac function. The thoracoscopic pericardiectomy was feasible in all horses. Although a mild reduction in cardiac volumes was documented in the first 72 h after surgery, the procedure did not impair cardiac filling and emptying in the mid-term perspective. Future studies are warranted to investigate how this technique performs in horses with pericardial diseases.

Introduction

Echocardiography is the gold standard method for noninvasive assessment of dimensions, structure and function of the cardiac chambers in horses (Prada and Yamaki 2012; Decloedt *et al.* 2017). In cardiac activity, ventricular function is generally considered more important than atrial function. However, atrial contraction contributes significantly to cardiac output, especially in athletic horses (Marr and Bowen 2010a).

The ventricle is in charge of systolic and diastolic function, which is the ability to contract and eject blood, and the ability to relax, allowing blood to flow from the atrium to the ventricular chamber, respectively (Marr and Bowen 2010b). During diastole, ventricular filling may be affected by venous inflow, atrioventricular valve function, atrial function, pericardial compliance, heart rate, myocardial relaxation and cardiac compliance, the previous two being the most important (Sousa 2006; Marr and Bowen 2010a).

Compliance is the term that defines the ease with which the ventricular walls stretch to accommodate the blood during diastole. In the presence of decreased compliance, a higher filling pressure is required to reach the final diastolic volume, which occurs in cases of left ventricular (LV) lumen reduction, pathological hypertrophy, myocardial fibrosis, infiltrative diseases, pericardial tamponade and right ventricular dilation, resulting in diastolic dysfunction. In such cases, a larger preload is required to obtain normal end-diastolic ventricular volume. Diastolic function can also be affected by myocardial relaxation which, when impaired, reduces the primary rate of ventricular filling. This may occur in cases of myocardial hypertrophy, fibrosis, ischaemic heart disease and pericarditis (Marr and Bowen 2010b). Horses with pericardial effusion are frequently presented with nonspecific signs, such as tachycardia, tachypnoea, inappetence and lethargy. Diminished or inaudible cardiac sounds may also be evident on auscultation. In cases where intrapericardial pressure exceeds right atrial and ventricular pressures, cardiac tamponade is installed, and may lead to right-sided congestive heart failure. In these cases, echocardiographic findings include diastolic collapse of the right atrial and ventricular walls. Heart chambers may also appear smaller, due to reduced filling from increased intrapericardial pressure. With disease progression, life-threatening left-sided output failure may ensue.

Pericardiectomy or pericardiocentesis are the treatments indicated to eliminate the risk of cardiac tamponade in cases of recurrent pericardial effusions (Brunner *et al.* 1995; Marr and Bowen 2010c). The pericardiectomy can be realised by two different procedures: thoracotomy or thoracoscopy. When compared to thoracotomy, thoracoscopy improves the visualisation of the thoracic organs, decreases acute and chronic post-operative pain (Latham and Dullye 2011), reduces surgical trauma, low mortality and rapid recovery (Teixeira *et al.* 2015).

Studies have shown a significant increase in systolic volume after pericardiectomy in anaesthetised dogs (Hoit *et al.* 1991). Similarly, right and left ventricular filling is influenced by the presence of the pericardium (Brunner *et al.* 1995). In dogs with pulmonary hypertension, pericardiectomy resulted in rapid haemodynamic improvement, with an increase in LV systolic volume by one-third (Belenkie *et al.* 2004). In pigs submitted to maximal exercise after pericardiectomy, there was an increase in cardiac output, oxygen consumption and LV mass and size (Hammond *et al.* 1992). These aspects have not yet been studied and confirmed in horses and, therefore, the goal of this study was to evaluate the impact of thoracoscopic partial

pericardiectomy on left atrial and ventricular volumes in this species.

Materials and methods

After physical examination, where heart rate (HR), respiratory rate (RR), weight, capillary filling time, rectal temperature, frequency of caecal movements, degree of hydration and mucosal staining were evaluated, six horses (four males and two females) were selected for a prospective longitudinal study. Bodyweight and age of the selected animals ranged from 460 to 552 kg (516 ± 39), and from 3 to 26 years (13 ± 8) respectively. Laboratory tests such as blood count, creatine kinase (CK), aspartate aminotransferase (AST), gamma glutamyl transferase (GGT), urea and creatinine were performed. The inclusion criteria applied in this study were the absence of abnormalities in clinical and laboratorial examinations. All selected horses were considered fit for the procedure.

The animals were kept in a horse stock, in a quiet environment and under low light (Voros *et al.* 1991) during transthoracic echocardiographic examination (ECO). The use of sedatives was not required. Examination was performed at four different time points: prior to the surgical procedure (M0); 24 h post procedure (M1); 72 h post procedure (M2) and 28 days post procedure (M3). To optimise echocardiographic image quality, trichotomy was performed in the right hemithorax, between the 4th and 5th intercostal spaces (ICS), and the right thoracic limb was tractioned and positioned slightly ahead of the contralateral limb.

The images were obtained with a MyLab 30 Gold ultrasound machine¹, equipped with a 2 MHz sector transducer and capable of performing Bidimensional (M), Time-motion (M) and Doppler modes. Through long-axis four chamber views, indices such as maximum left atrial volume (LAVmax), minimum left atrial volume (LAVmin), left ventricular volume in systole (LVVs) and left ventricular volume in diastole (LVVd) were calculated according to the area-length method. These indices were used to determine the left atrial ejection fraction ($EF_{LA}\%$) and left ventricular ejection fraction ($EF_{LV}\%$). After basal echocardiographic evaluations (M0), the animals were submitted to partial pericardiectomy by thoracoscopy.

Prior to the surgical procedures, water fasting of six and feeding fasting of 12 h were applied. All horses were submitted to general anaesthesia with monopulmonary intubation of the right lung and placed in left lateral recumbency on the surgical table for the performing of partial pericardiectomy by thoracoscopy. Access to the thoracic cavity was obtained by means of a skin incision of approximately 2 cm in the 5th left intercostal space for the first three procedures, and in the 6th intercostal space for the last three, aligned with the scapulohumeral joint. Then, incision and blunt divulsion of the musculature were performed and, with the use of a Cocker hemostat, the incision was deepened until the parietal pleura was perforated, resulting in pneumothorax. Through the opening, a 11 mm cannula with endotip was introduced, along with a 10 mm optic coupled to a micro camera. The pneumothorax was established with carbon dioxide and adjusted to a maximum pressure of 4 mmHg. The placement of two more portals was performed for the introduction of the instruments in the first three procedures, under direct inspection. For the last three procedures, only two portals were

applied, one for the introduction of the optics and the second for the placement of the instruments.

After the auxiliary instruments were inserted, the pericardium was pulled with the Hook forceps towards the ribs in a way to hold the myocardium avoiding lesions by contact with the surgical instrument, then an incision was made from cardiac base to apex, exposing the left atrial appendage. Pericardiectomy was then initiated with a small incision of approximately one centimetre and, from this opening, the pericardium was drawn, facilitating the enlargement of the opening, to approximately 30 cm. In the first three procedures, seizing forceps and scissors were used for the incision, while in the following three procedures, only the Hook forceps was used, which has an internal cutting face.

By the end of every procedure, the portals were removed, the musculature was approximated and muscle and skin sutures were performed with a nonabsorbable no 2 polypropylene thread, in standard Wolf stitches, and the pneumothorax was resolved with a surgical aspirator.

After 28 days of the surgical procedure, a second thoracoscopy was performed to inspect the thoracic cavity and the pericardial window. During the transoperative period, the animals were monitored by electrocardiography, heart rate evaluation, invasive blood pressure, rectal temperature, respiratory rate and capnography. Post-operative care of both thorascopies consisted of clinical evaluation of the animals three times a day and daily dressings at the incision site, including thorough evaluation of the surgical wound.

The animals received 20,000 IU of procaine benzylpenicillin associated with dihydrostreptomycin and procaine hydrochloride intramuscularly for 7 days and intravenous flunixin meglumine at 1.1 mg/kg bwt intravenously for 3 days after each surgical procedure. Animals that still presented pain after the administration of anti-inflammatory drugs also received an intramuscular dose of 0.1 mg/kg bwt of methadone. Skin sutures were removed after 10 days.

All variables were submitted to analysis of variance followed by Dunnett's test, considering $P < 0.05$.

Results

At baseline physical and echocardiographic examination, the animals did not present abnormalities. Thoracic hair was clipped for the echocardiographic examinations, although this procedure was not imperative (Bonomo *et al.* 2014). This information is important due to the fact that the maintenance of the hair is aesthetically desirable in competing horse athletes.

The echocardiographic values obtained at all four different moments are shown in **Tables 1 and 2**.

There was a decrease in $EF_{LA}\%$ in M1 (44.4 ± 12.8), but in M2 (50.9 ± 10.8) and M3 (52.6 ± 5.4) the values went up again. The same thing happened with LAVmax and LAVmin, but this difference was not statistically significant.

There was no statistically significant difference in left atrial volumes obtained by B-mode (**Fig 1**).

In further echocardiographic evaluations, no evidence of increased preload after thoracoscopic pericardiectomy was documented.

There was no statistical difference between LVVs, LVVd and $EF_{LV}\%$ in the different moments.

TABLE 1: Mean values and standard deviations of LAVmax, LAVmin and EF_{LA}% measurements, evaluated by echocardiography at moments M0, M1, M2 and M3, in horses submitted to thoracoscopic pericardiectomy, where *P<0.05.

Variables	M0	M1	M2	M3
LAVmax	902.4 ± 213.9	808 ± 314.7	782.7 ± 235.7	952.9 ± 198.1
LAVmin	593.4 ± 223.7	585.6 ± 332.6	537.8 ± 176.6	565.2 ± 175.2
EF _{LA} %	35.8 ± 11	29.7 ± 18.8	31.6 ± 3.4	41.5 ± 10.2

EF_{LA}%, ejection fraction of the left atrium; LAVmax, maximum left atrial volume; LAVmin, minimal left atrium volume.

TABLE 2: Mean values and standard deviations of LVVs, LVVd and EF_{LV}% of horses submitted to thoracoscopic pericardiectomy at moments M0, M1, M2 and M3, where *P<0.05.

Variables	M0	M1	M2	M3
LVVs	822.9 ± 398.3	749 ± 292.8	754.9 ± 296.1	793.9 ± 212.5
LVVd	1731.4 ± 392.7	1328 ± 326.7	1506.2 ± 384.8	1687.1 ± 511
EF _{LV} %	54.5 ± 11.5	44.4 ± 12.8	50.9 ± 10.8	52.6 ± 5.4

EF_{LV}%, left ventricular ejection fraction; LVVs, left ventricular volume in systole; LVVd, left ventricular volume in diastole.

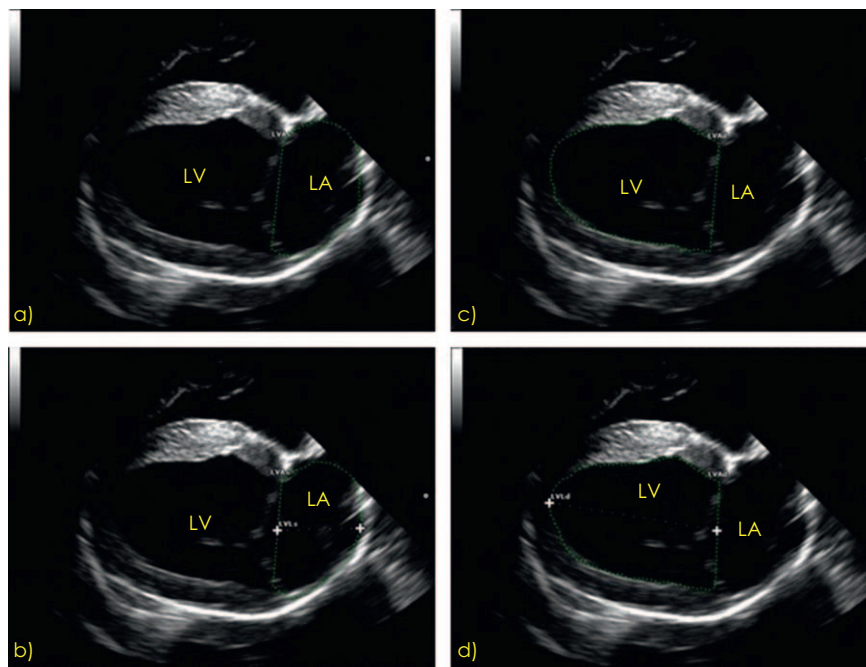


Fig 1: B-mode long-axis echocardiographic view, exemplifying the measurements of: a and b) LAVmin; c and d) LVVd. It is possible to observe in a) delimitation of the minimal planimetric area of the left atrium; b) determination of the minimum length of the left atrium from the mitral annulus to the cardiac base; c) delimitation of the planimetric area of the left ventricle in diastole; d) determination of left ventricular length in diastole from the cardiac apex to the mitral annulus.

Discussion

The decrease in EF_{LA} probably reflects impaired filling and decreased relaxation of the LV, affecting its compliance (Bonomo *et al.* 2014). This temporary dysfunction was probably caused by the acute inflammation resulting from the surgical procedure (Voros *et al.* 1991). Physiologically, the acute increase of inflammatory cytokines leads to decreased cardiac contractility, diastolic dysfunction and increased capillary permeability.

The mean values of LVVs and LVVd of the horses in this study are higher than those documented by Bonomo *et al.* (2014), who found mean values of 242.08 and 711.04 mL

respectively. This difference may be related to the lower mean weight of the horses used by the authors above (470 kg [516 ± 39]). According to Hoit *et al.* (1991), left and right ventricular filling is restricted by the pericardium, and an increase in ventricular volume is observed in dogs submitted to pericardiectomy. However, this fact was not observed in the animals of the present study.

The mean EF_{LV}% of the animals in this study is below the values documented by Giannico *et al.* (2015) of 64.63%, Michima (2003) of 66.38%, Mirian (2014) of 67.22% and Bello *et al.* (2011) of 73.78%. This difference is probably due to the fact that the horses used in this study were not athletes. Mirian (2014) observed that the ejection fraction is increased

in horses under training. When comparing the baseline $EF_{LV}\%$ of the horses of this study with the values obtained in M1, a significant reduction can be observed, but in M3 the values increase again, nearly approaching the baseline. This alteration may be related to the presence of post-operative local inflammation; however, as stated by Li *et al.* (2013), myocardial dysfunction induced by inflammation is a temporary compensatory mechanism. In other words, temporary-reduced cardiac function in the face of acute inflammation is advantageous in preventing stress-induced cardiac injury.

Although there was no statistically significant difference in left atrial volumes obtained by B-mode (**Fig 1a** and **b**), there was a variation between the different time points. LAVmax and LAVmin decreased in the periods of 24 and 72 h after the surgical procedure and increased again at M3. Such reductions may reflect a lower preload, probably related to reduced venous return, attributed to peripheral vasodilation, resulting from surgical inflammation.

The ventricular volumes obtained by B-mode (**Fig 1c** and **d**) were not statistically different between the different time points, but a tendency towards volume reduction was observed as of M1. It is suspected that this decrease was also due to the decrease in preload and post-operative local inflammation, but this alteration was temporary, and no impairment was seen in cardiac function. It is possible that the decrease in LVVd is related to the surgical procedure, since an increase in final diastolic ventricular pressure may occur in dogs submitted to pericardiectomy (Hoit *et al.* 1991). Diastolic phase begins with the closing of the semilunar valves, followed by active ventricular relaxation, passive ventricular filling and atrial contraction (Sousa 2006). When there is an increase in final diastolic ventricular pressure, the amount of blood reaching the ventricle is lower, as it encounters greater resistance when entering this chamber (Sousa 2006).

In further echocardiographic evaluations, no evidence of increased preload after thoracoscopic pericardiectomy was documented. In fact, a decrease was observed in the first post-operative hours. This possibly occurred in response to a decreased venous return, attributed to peripheral vasodilation, resulting from surgical inflammation, because the inflammation can generate cytokine and lead to poor systolic function (Marr and Bowen 2010d). At 28 days, the previously observed alterations were not present anymore.

Although the findings of this study are significant, more research should be performed to verify what occurs in horse athletes after undergoing pericardiectomy. Besides, this work presents some limitations, such as the small number of animals used in the procedures, the short evaluation time after surgery and the nonstandardisation of breed and age.

Conclusion

Echocardiography allowed the evaluation of maximum and minimum left atrial volume, left ventricular volume in systole and diastole, atrial ejection fraction and ventricular ejection fraction, showing that pericardiectomy interfered in these variables in a transient way for a maximum of 72 h.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Study protocol approved by the Committee of Ethics in the Use of Animals (CEUA) of the Department of Agrarian Sciences – Federal University of Paraná – Brazil, in a meeting held December 17th, 2015, under protocol number 081/2015.

Source of funding

None.

Authorship

J. Silave-Meirelles, M. Sousa and P. Dornbusch contributed to study design, study execution, data analysis and interpretation and preparation of the manuscript. G. Meirelles contributed to study design, study execution and preparation of the manuscript. B. Brüler contributed to study execution and preparation of the manuscript. R. Vilane contributed to study design, study execution and data analysis and interpretation. R. Guedes and A. Souto contributed to study execution. All authors gave their final approval of the manuscript.

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References

- Belenkie, I., Sas, R., Mitchell, J., Smith, E.R. and Tyberg, J.V. (2004) Opening the pericardium during pulmonary artery constriction improves cardiac function. *J. Appl. Physiol.* **96**, 917-922.
- Bello, C.A.O., Lima, E.M.M., Silva, C.E.V., Godoy, R.F. and Teixeira Neto, A.R. (2011) Estabelecimento de índices ecocardiográficos de cavalos de polo. *Pesquisa* **31**, 495-498.
- Bonomo, C.C.M., Michima, L.E.S. and Miyashiro, P. (2014) Avaliação ecocardiográfica do desenvolvimento cardíaco de cavalos atletas: comparação entre atividades físicas distintas. *Pesqui. Vet. Bras.* **34**, 923-927.
- Brunner, M., Moeslinger, T. and Spieckermann, P.G. (1995) Echocardiography for teaching cardiac physiology in practical student courses. *Adv. Physiol. Educ.* **13**, 2-9.
- Declodt, A., De Clercq, D., Vem Sofie, S., Van Der Vekens, N., Sys, S., Broux, B. and van Loon, G. (2017) Echocardiographic measurements of right heart size and function in healthy horses. *Equine Vet. J.* **49**, 58-64.
- Giannico, A.T., Dornbusch, P.T., Montiani-Ferreira, F., Barros-Filho, I.R., Deconto, I. and Oliveira, S.T. (2015) Echocardiographic measurement of cart horses in the metropolitan region of Curitiba-PR. *Semin. Ciênc. Agrár.* **36**, 827-838.
- Hammond, H.K., White, F.C., Bhargava, V. and Shabetai, R. (1992) Heart size and maximal cardiac output are limited by the pericardium. *Am. J. Physiol.* **263**, H1675-H1681.
- Hoit, B.D., Dalton, N., Bhargava, V. and Shabetai, R. (1991) Pericardial influences on right and left ventricular filling dynamics. *Circ. Res.* **68**, 197-208.
- Latham, P. and Dullye, K.K. (2011) Complications of thoracoscopy. *Anesthesiol. Clin. North Am.* **19**, 187-200.
- Li, Y., Ge, S., Peng, Y. and Chen, X. (2013) Inflammation and cardiac dysfunction during sepsis, muscular dystrophy, and myocarditis. *Burn. Trauma* **1**, 109-121.
- Marr, C.M. and Bowen, M. (2010a) Introduction to cardiac anatomy and physiology. In: *Cardiology of the Horse*, 2nd edn., Ed: C.M. Marr and I.M. Bowen, Saunders Limited, Philadelphia. pp 11-13.
- Marr, C.M. and Bowen, M. (2010b) Introduction to cardiac anatomy and physiology. In: *Cardiology of the Horse*, 2nd edn., Ed: C.M. Marr and I.M. Bowen, Saunders Limited, Philadelphia. pp 10-11.

- Marr, C.M. and Bowen, M. (2010c) Fever: endocarditis and pericarditis. In: *Cardiology of the Horse*, 2nd edn., Ed: C.M. Marr and I.M. Bowen, Saunders Limited, Philadelphia. pp 222-223.
- Marr, C.M. and Bowen, M. (2010d) Neuroendocrine control of cardiovascular function: physiology and pharmacology. In: *Cardiology of the Horse*, 2nd edn., Ed: C.M. Marr and I.M. Bowen, Saunders Limited, Philadelphia. pp 29.
- Michima, L.E.S. (2003) *Avaliação das dimensões e índices cardíacos obtidos por ecocardiograma em equinos de enduro criados no estado de São Paulo*.
- Mirian, M. (2014) *Avaliação comparativa do grau de esforço e condição cardíaca em cavalos árabes e mestiços árabes submetidos a treinamento de resistência, avaliados através de teste de esforço máximo em esteira*.
- Prada, D.G. and Yamaki, F.L. (2012) Avaliação ecocardiográfica do átrio esquerdo de cães saudáveis por meio do modo-M convencional e do modo bidimensional. *Arq. Bras. Med. Veterinária e Zootec.* **64**, 585-592.
- Sousa, A.C.S. (2006) Volume atrial esquerdo como índice de função diastólica. *Arq. Bras. Cardiol.* **87**, e27-e33.
- Teixeira, P.P.M., Coutinho, L.N. and Silva, M.A.M. (2015) Cirurgia toracoscópica videoassistida. In: *Videocirurgia em pequenos animais*, 1st edn., Ed: Guanabara Koogan Ltda, Guanabara Koogan Ltda, Rio de Janeiro. pp 333.
- Voros, K., Holmes, J.R. and Gibbs, C. (1991) Measurement of cardiac dimensions with two-dimensional echocardiography in the living horse. *Equine Vet. J.* **23**, 461-465.

Zimeta™ (dipyrone injection)

500mg/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.

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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.

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 Dehydro- genase (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 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 500mg/mL solution in a 100mL, multi-dose vial.

Approved by FDA under NADA # 141-513 NDC 86078-245-01

Manufactured for:
Kindred Biosciences, Inc.
1555 Bayshore Hwy, Suite 200,
Burlingame, CA 94010

To report adverse reactions call
Kindred Biosciences, Inc. at
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**When administered according to label directions.*

Zimeta is indicated for the control of pyrexia in horses

Important Safety Information

Zimeta™ (dipyrone injection) should not be used more frequently than every 12 hours. For use in horses only. Do not use in horses with a hypersensitivity to dipyrone, horses intended for human consumption or any food producing animals, including lactating dairy animals. Not for use in humans, avoid contact with skin and keep out of reach of children. Take care to avoid accidental self-injection and use routine precautions when handling and using loaded syringes. Prior to use, horses should undergo a thorough history and physical examination. Monitor for clinical signs of coagulopathy and use caution in horses at risk for hemorrhage. Concomitant use with other NSAIDs, corticosteroids and nephrotoxic drugs, should be avoided. As a class, NSAIDs may be associated with gastrointestinal, renal, and hepatic toxicity. The most common adverse reactions observed during clinical trials were Elevated Serum Sorbitol Dehydrogenase (SDH), Hypoalbuminemia and Gastric Ulcers. **For additional information, see brief summary of prescribing information on the following page.**

References: 1. Zimeta™ (dipyrone injection). [Full Prescribing Information], Kindred Biosciences, Inc. (Burlingame, CA). Revised: 03/2019. 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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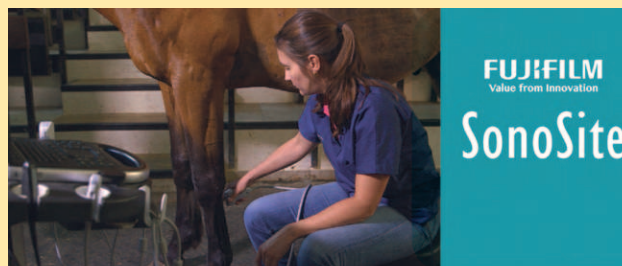
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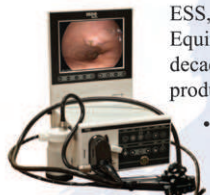
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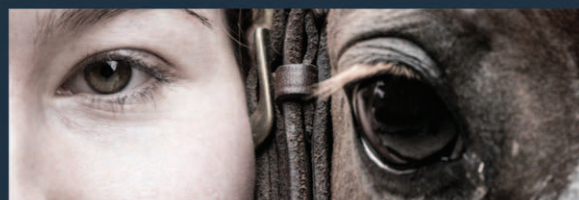

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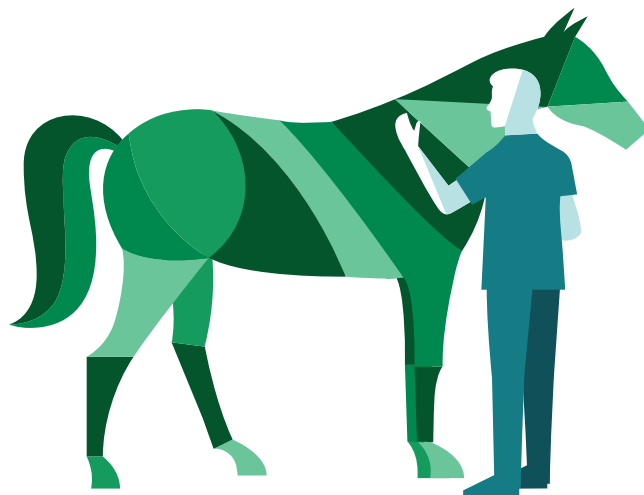
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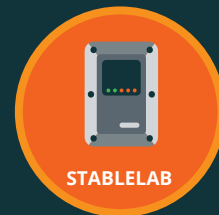




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¹ Oertly, et al. The accuracy of Serum Amyloid A in determining early inflammation in horses following long-distance transportation by air. AAEP Proceedings, 2017 460-461.

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