EQUINE VETERINARY EDUCATION/AMERICAN EDITION

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DECEMBER 2021

AAEP®

EQUINE VETERINARY EDUCATION

American Edition | December 2021

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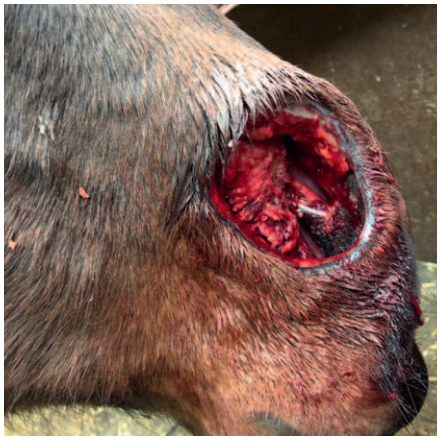

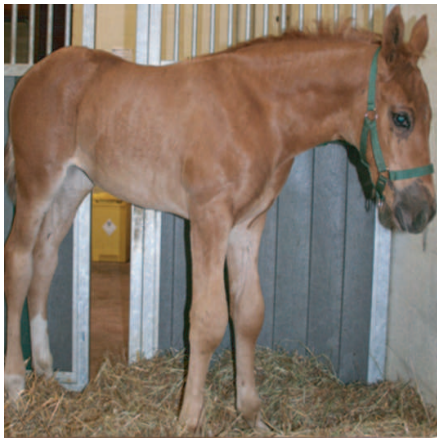

AAEP NEWS In this issue

American Association of Equine Practitioners
4033 Iron Works Parkway
Lexington, KY 40511
TEL (800) 443-0177 • (859) 233-0147
FAX (859) 233-1968
EMAIL aaepoffice@aaep.org
aaep.org

To access our website, go to aaep.org, select LOGIN, then enter your email and password. If you have difficulty logging in or have forgotten your password, please call or email the office.

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(859) 233-0147 / dkirkland@aaep.org

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

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From the president: Laying the groundwork for continued progress

By Scott Hay, DVM

Dr. Scott Hay

As we come to the end of 2021, I reflect on the year that I have served as president of the AAEP. I sincerely thank each of you for the opportunity to serve this organization that I truly love. It has been an honor and a privilege, and I hope that I have been able to help make the organization just a little bit better moving forward.

We have all dealt with significant changes in this last year. Experiencing the pandemic and the adjustments in how we deal with the world in general has been stressful for all of us. Many things have changed in our lives but, as true adapters, veterinarians have found ways to take advantage of these changes. Whether it is seeing clients in a different way, having staff work remotely, acquiring continuing education remotely, or endless Zoom meetings, veterinarians have found ways to take away the positives from these forced adaptations. I applaud each of you for finding ways to make the best of a challenging situation.

> The changes may not come easy, but they will be necessary to turn this situation around. The responsibility is on all of us.

The AAEP has remained in excellent shape through the pandemic. I won't say there was never a concern, but successful implementation of remote continuing education for the 2020 convention as well as other meetings held before and after has provided members with a convenient source of practical CE and kept the AAEP in a solid financial condition. While expansion into remote learning has helped overcome some of the challenges of the past two years, the recent return to an in-person convention was an absolute joy. I look forward to more in-person meetings moving forward, as the one-on-one interaction among colleagues is a true benefit of this organization.

Among the major initiatives the AAEP has been working on over the last year is the retention and recruitment of equine veterinarians for our future. The subject has been mentioned before in this column and been a major topic of discussion on the General Discussion listserv. The AAEP Retention Task Force has been working diligently to identify the key factors affecting this problem and will continue its work in 2022. The findings of the task force were highlighted at our convention. Those issues will certainly put a focus on things that we can change to affect the problem. The changes may not come easy, but they will be necessary to turn this situation around. The responsibility is on all of us.

As was announced at the convention, The Foundation for The Horse has moved into the public phase of its 3-year comprehensive campaign. We're nearly 70% of the way toward reaching our $10 million goal, and your assistance is needed to help put us over the top. Contributing on your own is certainly needed and greatly appreciated, but sharing the story of The Foundation with clients, friends and others and inviting them to support the cause can multiply your impact. Achievement of the goal will enable greater support for students, equine research and horses at risk. On behalf of The Foundation, I thank you in advance for your support!

In closing I want to thank my fellow officers and board members. It has been great working with you the last year, and I look forward to more to come.

I also want to thank the membership for always being engaged. Whether it is in your volunteer service, being active on the listservs or any of the other ways of being involved in the AAEP, your participation is greatly valued. It is your association. Continue to make it so.

Finally, I would like to thank the AAEP staff. I know it has been said before, but the staff members of this organization are second to none. Their hard work and dedication to our membership is what makes the AAEP the organization it is today.

Thank you!

The recent return to in-person convention provided the one-on-one interaction among colleagues that is a true benefit of AAEP.

AAEP supports federal legislation banning the sale of ejiao

The AAEP has announced its support of the Ejiao Act (H.R. 5203), legislation introduced in the U.S. House of Representatives on September 10 by Rep. Don Beyer (VA-08) that would prohibit the sale or transport of any ejiao products made from donkey skins.

Ejiao is a gelatin used in Chinese beauty products and traditional medicines that is made by boiling donkey skins. According to Brooke, an international charity focused on the welfare of working equines, demand is estimated to be 4.8 million skins each year, a rate that would wipe out half the world's donkey population within 5 years. The United States is the world's third largest importer of ejiao, with $12 million worth of imports each year.

The AAEP in 2018 joined with international equine welfare organizations in denouncing the inhumane transport and killing of donkeys to satisfy the escalating global trade of donkey skins. Beyond welfare concerns for the animals' treatment, the issue is especially devastating in developing countries where donkeys are essential to the livelihoods of millions of the world's poorest people. Families lose their income overnight because of donkey theft. The loss of a donkey also jeopardizes the transport of children to school and limits the growth of women in community-related roles.

"The trade in donkey skins has created immense suffering for the animals and those affected by their loss," said AAEP President Dr. Scott Hay. "The AAEP is proud to support both the Ejiao Act and the ongoing work of equine welfare organizations to end the inhumane treatment of donkeys affected by the trade in skins."

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

Contagious Equine Metritis Guidelines published

Comprehensive guidelines to assist practitioners with identification, diagnosis and control of Contagious Equine Metritis (CEM), a non-systemic venereal disease of equines that causes short-term infertility in mares and rare abortion, are now available on the AAEP website and Publications app.

Six outbreaks of CEM have occurred in the U.S. in the past 15 years, including a significant outbreak in 2008-2010 in which over 1,000 exposed horses in 48 states were required to be tested, resulting in 23 contaminated stallions and five infected mares ultimately identified and treated.

"Outbreaks in the U.S. have demonstrated the risk of incursions and the need for surveillance in the active breeding population to identify cases early and limit disease spread," said guidelines co-author Dr. Abby Sage, Richmond staff veterinarian for the Virginia Department of Agriculture and Consumer Services. "Several of these outbreaks also demonstrated significant stallion-to-stallion spread of *Taylor equigenitalis* via fomites and inadequate biosecurity during semen collection and stallion handling."

Dr. Sage and co-author Dr. Peter Timoney, the Frederick Van Lennep Chair in Equine Veterinary Science at the University of Kentucky's Gluck Equine Research Center, advise equine practitioners and stallion owners/managers to follow stringent biosecurity protocols when collecting and handling stallions and consider implementation of annual testing of active breeding stallions prior to breeding season as ongoing assurance of disease freedom.

The CEM Guidelines were reviewed and approved by the AAEP's Infectious Disease Committee and board of directors. View the guidelines or save them to your mobile device for future reference at aaep.org/document/contagious-equine-metritis.

Besides CEM, AAEP guidelines for 22 additional equine infectious diseases are available at aaep.org/guidelines/infectious-disease-control/using-guidelines. Three foreign animal disease guidelines can be found at aaep.org/infectious-disease-control/foreign-animal-disease-guidelines.

All AAEP guidelines are also accessible on the free Publications App. Search "AAEP Publications" at your app store to download.

5 things to know about AAEP this month

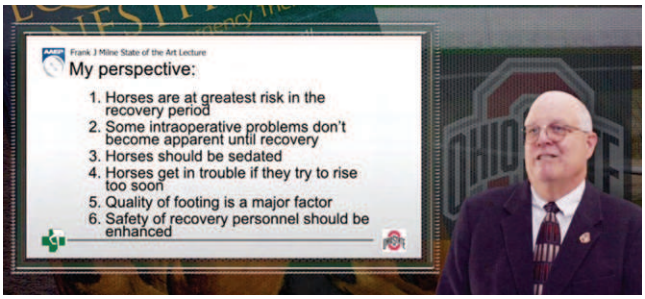
1. Register for the AAEP Virtual Convention at convention.aaep.org and earn CE through on-demand access to all educational sessions from the four main session rooms through March 31, 2022.
2. Download AAEP's new Contagious Equine Metritis Guidelines at aaep.org/document/contagious-equine-metritis or view on the Publications App.
3. Enjoy free access until Feb. 28 to all the *EVE* and *EVJ* articles highlighted during the Kester News Hour and cited in the Milne Lecture at https://tinyurl.com/4vx2pn7t.
4. Help The Foundation achieve its $10 million campaign goal by inviting clients, friends and others to join with us. Learn more at foundationforthehorse.org.
5. Annual Convention *Proceedings* books were mailed in mid-December to members who did not attend the convention. *Proceedings* papers can also be found on the Convention App.

Nominate a distinguished researcher for the 2023 AAEP Milne Lecture

Deadline to nominate is January 31

The Frank J. Milne State-of-the-Art Lecture is a traditional highlight of each year's annual convention, and you can help determine the 2023 honoree by nominating an accomplished researcher.

The Milne Lecture was created in 1997 to recognize an individual with a distinguished career in research and discovery, and who has presented and published their findings in a specific area of equine health. The lecture is intended to honor the accomplishments of the presenter and provide a meaningful learning experience to the AAEP membership. The lecture is a perspective on the state-of-the-art in the presenter's area of expertise.



Dr. John Hubbell delivers the 2020 Milne Lecture virtually on the topic of equine anesthesia.

The award recipient will be determined by a subcommittee of the AAEP Educational Programs Committee in February 2022 and will then be presented to the board of directors for approval. The selected individual will deliver their lecture and receive their award at the AAEP's 2023 Annual Convention in San Diego, Calif.

Nominees should be an expert in their field with a track record of accomplishment and the ability to relate the topic to the audience. A nomination form must be completed and include qualifications and accomplishments of the nominee.

A Milne Lecture nomination form may be requested from Carey Ross, scientific publications coordinator, at cross@aaep.org. Completed forms must be returned to her by Jan. 31, 2022.

Help equine rescue and retirement facilities apply for free vaccines

2022 UHVRC application deadline is February 1

AAEP members affiliated with 501(c)(3) equine rescue and rehabilitation facilities in the United States should work with those facilities now to complete the application for complimentary vaccines from the Unwanted Horse Veterinary Relief Campaign (UHVRC) by the Feb. 1 deadline.

The UHVRC is a non-profit partnership between Merck Animal Health and the AAEP to safeguard the health and facilitate the adoption of rescue horses. Since its inception in 2008, the UHVRC has provided more than 46,000 doses of core vaccines to protect horses in need.

The UHVRC provides qualifying equine facilities with Merck Animal Health vaccines to protect against Eastern and Western equine encephalomyelitis, equine herpesvirus (EHV-1 and EHV-4), West Nile virus, equine influenza and tetanus. Eligible facilities must coordinate an application with an AAEP-member veterinarian and adhere to the AAEP Care Guidelines for Equine Rescue and Retirement Facilities.

Visit aaep.org/horse-owners/unwanted-horse-veterinary-relief-campaign to download the application and equine vaccine order form.

MERCK Animal Health

UHVRC Unwanted Horse Veterinary Relief Campaign

ASSOCIATION

Intern, two students named case study contest winners

The AAEP's Educational Programs Committee recently selected three winners of the 2021 case study contest: Dr. Chelsea Folmar, an intern at the Equine Medical Center of Ocala and 2021 graduate of Texas A&M University; Kaitlin Frei, a fourth-year student at University of Pennsylvania; and Katherine Miley, a fourth-year student at Louisiana State University.

Their case studies, listed below, are available as educational resources at aaep.org/case-studies.

- Dr. Folmar: "Hemilaminectomy in a 4-Week-Old Clydesdale Foal"
- Frei: "Limbal Hemangiosarcoma and Inflammatory Bowel Disease in an Appaloosa Mare"
- Miley: "Surgical Management of Septic Pedal Osteitis"

Dr. Chelsea Folmar

Kaitlin Frei

Katherine Miley

As winners of the contest, which was open to veterinary students and first-year graduates, each received complimentary registration for the AAEP's 67th Annual Convention in Nashville, Tenn., and $500 to support travel to the meeting.

FOUNDATION

Foundation unveils $10 million comprehensive campaign

Nearly $7 million already committed toward goal

The Foundation for the Horse has embarked upon an ambitious effort to raise $10 million over a three-year period. Begun quietly in January 2020, "Taking the Lead – The Campaign for the Horse" already has confirmed commitments of more than $6.7 million despite the challenges of a global pandemic throughout most of 2020 and into 2021.

Foundation Advisory Council Chair Dr. Rick Mitchell, Campaign Cabinet Chair Dr. Monty McInturff and Campaign Regional Chair Dr. Margo Macpherson publicly launched the campaign Dec. 5 during the Opening Session at the AAEP's 67th Annual Convention in Nashville, Tenn. Every dollar given, every pledge made and every estate plan documented is applied toward the goal.

"This campaign is about doing more for the horse," said Dr. McInturff. "It is about securing the future: a future with more relief for horses at risk of abandonment or neglect; a future with more resources to help horses in the wake of natural disasters; a future with more research in pursuit of treatments and cures; and a future in which more students pursue and stay active in equine veterinary medicine. Let's all work together to take the lead!"

The Campaign Cabinet of volunteers comprises John Chalk, Dr. Doug Corey, Dr. Rob Franklin, Jeannie Jeffery, Dr. Margo Macpherson, Dr. Monty McInturff, Dr. Rick Mitchell and Melanie S. Taylor.

From modest beginnings 27 years ago, The Foundation has evolved into a dynamic organization that, for the first time in its history, distributed more than $1 million in grants in 2021 in support of programs and projects that improve the health and well-being of horses. The generosity of campaign contributors will help ramp up support of The Foundation's mission and further expand its impact around the world.

"I ask each of you to share your passion for the horse with those in your sphere of influence," said Dr. Mitchell. "Tell your story about why you care and give. Wave your AAEP and Foundation flag. Help us inspire others to join us in this mission and help us secure the future."

Will you accept the challenge and help The Foundation achieve its $10 million goal by making a gift and inviting clients, associates, and friends to join with us? Support the cause and make the world a better place for horses by donating online at foundationforthehorse.org/give-now. To assist with the campaign, contact Dr. Paul Ransdell, senior development officer, at (859) 705-0430 or pransdell@foundationforthehorse.org.

Integrative therapies you need to know

By Rosemary LoGiudice, DVM, DACVSMR, CVSMT, CVA, CCRT, FCoAC

Dr. Rosemary LoGiudice

Horse owners and trainers often use integrative—or even their own—therapies to try to maintain their horses' wellbeing and/or improve performance. Many times, they do so without input from or the knowledge of their primary care veterinarian. These therapies can include a multitude of oral, manual, and even injectable entities, some of which can truly be classified as complementary, alternative, and integrative veterinary medicine (CAVM) therapies.

The AVMA 2019 Model Veterinary Practice Act (MVPA) defines CAVM therapies as: "a heterogeneous group of preventive, diagnostic, and therapeutic philosophies and practices that are not considered part of conventional (Western) medicine as practiced by most veterinarians and veterinary technicians/technologists. These therapies include, but are not limited to, veterinary acupuncture, acutherapy, and acupressure; veterinary homeopathy; veterinary manual or manipulative therapy (i.e., therapies based on techniques practiced in osteopathy and chiropractic medicine); veterinary nutraceutical therapy; and veterinary phytotherapy."

Integrative/complementary therapies are popular with horse owners, but as was reported in the July 9, 2021, post in *The Horse* by Christa Leste-Lasserre, MA, regarding Dr. Annelies Decloedt's survey of more than 1,500 horse owners, 25% of the survey respondents who use CAVM do not mention to their veterinarians that they are utilizing these therapies. This survey also revealed that of the 1,532 respondents, 73% had used CAVM, of which 65% were manual therapies and approximately 55% herbals, 50% homeopathy and 33% therapies such as water treadmills and/or acupuncture. (Read the post at thehorse.com/1101725/complementary-therapies-popular-but-sometimes-lack-veterinary-collaboration).

The article, "A Survey Examining Attitudes Towards Equine Complementary Therapies for the Treatment of Musculoskeletal Injuries" (Thirkell, J; Hyland,R; *Journal of Equine Veterinary Science*, Vol. 59, Dec. 2017, p 82-87) reported similar percentages, with 81% of the respondents reporting that they would try therapies without consulting their primary care veterinarian. To me, this behavior could reflect that owners may not be aware how integrative therapies may actually interact with the overall health care of a horse and that veterinarians are commonly aware of and trained in integrative therapies.

The primary care veterinarian is the appropriate person to coordinate health care practices for their horse, but he/she needs to know all the therapies being employed.

Oftentimes, unknown to the people using these integrative therapies, if not employed properly and by properly trained professionals, there can be side effects and even interactions with conventional therapies that can be detrimental to the horse. Owners often begin integrative therapies for an issue before seeking veterinary advice or intervention which, if inappropriate to be used, may cause the condition being addressed to worsen and delay appropriate treatment and therapy. Therefore, it is very important for the horse's primary care veterinarian to be aware of all therapies being used. This is another example of the importance of having a robust veterinarian-client-patient relationship. Communication and history-taking should include having the horse's owner, trainer or caretaker reveal all therapies being used or administered so that the veterinarian can evaluate fully how to proceed and treat.

As veterinarians, we all have been trained in conventional (Western) veterinary medical practices. Some of us have also sought additional training in integrative therapies. Personally, I prefer to use the term "integrative" rather than "complementary" (spell it wrong and it means free) or "alternative." I don't believe these therapies are necessarily an alternative to or that they replace our traditional, conventional veterinary therapies, but rather can be integrated appropriately with conventional therapies to add to the care we can provide as indicated.

Most veterinary practice acts include integrative therapies in the definition of the practice of veterinary medicine. According to the AVMA 2019 MVPA, the "Practice of veterinary medicine" means: To diagnose, prognose, treat, correct, change, alleviate, or prevent animal disease, illness, pain, deformity, defect, injury, or other physical, dental, or mental conditions by any method or mode; including the: … use of complementary, alternative, and integrative therapies,…" As such, it is then the responsibility and duty of the primary care veterinarian to be able to provide or properly recommend appropriate integrative therapies, especially when the client is inquiring about such therapies; or when gathering patient history, the veterinarian discovers that integrative therapies are being used.

While not every veterinarian chooses or may be able to be trained in integrative therapies, it is important that all veterinarians be familiar with the therapies available. This way, when clients are searching for additional possible treatments or preventative care, the primary care

continued on next page

AAEP ETHICAL PRACTICE Every Day-Every Time

Dr. LoGiudice owns Animal Rehabilitation, Therapy, & Sports Medicine in Yorkville, Ill., and is a senior instructor at Healing Oasis Wellness Center in Sturtevant, Wisc. She is a member of the AAEP's Professional Conduct and Ethics Committee.

Enjoy sun, sand and science at Resort Symposium in Hawai'i

Registration for tropical CE meeting extended to Jan. 17

Pack your Hawaiian shirt for a midwinter getaway that will recharge your mind and body when the AAEP's 23rd Annual Resort Symposium heads to the Mauna Lani Resort on the Kohala Coast of Hawai'i.

The meeting will offer 15 CE hours over the course of three half-day educational sessions. Days 1 and 2 will help you manage and resolve afflictions of pregnant and post-partum mares and of newborn foals. Day 3 will instill diagnostic and management strategies for orthopedic issues in sport horses.

After sessions, relax under blue skies on the beach or at the pool; or set off to discover the island's rich natural beauty.

The registration deadline for this unique educational opportunity is Jan. 17. Register for the meeting, book your hotel room and view the educational program at aaep.org/meeting/resort-symposium.

Please note: Travelers entering Hawai'i from the U.S. and its Territories who have been fully vaccinated in the U.S. (including its Territories) may bypass quarantine without a pre-travel test. The vaccination record document must be uploaded to Safe Travels and printed out prior to departure and the traveler must have a hard copy in hand when arriving in Hawai'i. Learn more at hawaiicovid19.com/travel.

Thanks to Zoetis for their sponsorship of the 23rd Annual Resort Symposium.

Integrative therapies, continued

veterinarian will be able to either provide those services or refer their client to a properly trained professional. It is extremely important for the primary care veterinarian to know the rules of the state or jurisdiction in which he/she practices to understand what services are allowed to be performed by appropriately trained professionals if they are not veterinarians, and if not veterinarians, what supervision the primary care veterinarian needs to provide. Checking with the state's practice act is the first source of information; another source for general information is avma.org/resources-tools/avma-policies/complementary-alternative-and-integrative-veterinary-medicine.

The bottom line is that we as veterinarians need to do everything possible to ensure that our clients are comfortable sharing all information about treatments their horses are receiving and that clients understand that only when their primary care veterinarian is aware of all treatments or therapies being used or desired, including integrative therapies, that appropriate equine health care can be provided.

Share your research at the 2022 convention in San Antonio

After celebrating the return of in-person learning at AAEP's recently concluded convention in Nashville, it's time to prepare for 2022 by submitting papers to be considered for presentation during the 68th Annual Convention in San Antonio, Texas, Nov. 18–22. The presenting author of selected papers will receive complimentary registration and an honorarium.

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

Submit papers by March 15 at https://s3.goeshow.com/aaep/annual/2022/AAEP_paper_submission.cfm. Authors should visit the site in advance to set up a profile and provide paper and author information before uploading the paper when it is finished. Complete considerations and ethical guidelines are available in the General Instructions area of the site.

As an aid to private practitioners, first-time authors or members seeking guidance with their submission, AAEP offers a mentorship program in which experienced presenters are available to provide advice and direction. However, mentors are not responsible for rewriting or selecting material. Contact Carey Ross, scientific publications coordinator, at cross@aaep.org for a list of available mentors or with questions concerning educational paper submission.

Recent grads: Learn new techniques at labs-focused CE event

If you graduated between 2017–2021, give yourself the gift of a diversified skill set this holiday season by registering for the AAEP's New Practitioners Symposium, a wet labs-focused CE event being held Feb. 19–20 at the University of Florida.

With attendance limited to only 60, you'll acquire plenty of hands-on training in key areas that will help you improve patient care and expand professional possibilities.

You'll rotate through the following 90-minute wet labs each afternoon:

Feb. 19 Wet Labs

Flash Colic Ultrasound
Ultrasound of the Metacarpus/Metatarsus
Radiology of the Skulls (Sinus & Teeth)

Feb. 20 Wet Labs

Podiatry: Films and Common Conditions
Ophthalmology (Exams, Diagnostics)
Ultrasound of the Stifle

Mornings will feature lectures on pertinent medical and non-medical topics as well as a business round table session offering expert advice on subjects important to early-career practitioners. The meeting will offer 10 CE credits and utilize a flipped classroom model in which registrants complete relevant instructional material online at home prior to on-site training.

Visit aaep.org/meetings for more information or to register. The registration rate is $400. If you need assistance or have questions, contact Kristin Walker at kwalker@aaep.org or (859) 233-0147.

Members in the News

Dr. Howard Ketover

Dr. Howard Ketover assumes role of Wisconsin VMA president

Dr. Howard Ketover, founding partner of Irongate Equine Clinic in Madison, Wisc., was installed as president of the Wisconsin Veterinary Medical Association on Oct. 21.

A 2002 veterinary graduate of Colorado State University, Dr. Ketover is also the director and lead for Wisconsin Large Animal Emergency Response, a 501(c)(3) organization that trains veterinarians and first responders to manage large animals safely in emergency and disaster scenarios.

Dr. Ben Espy

Professional Rodeo Cowboys Association honors Dr. Ben Espy

Dr. Ben Espy, the head of veterinary services at the San Antonio Stock Show and Rodeo for the past 25 years, has been named 2021 PRCA/Zoetis Veterinarian of the Year for his commitment to the health and welfare of rodeo livestock. The ceremony took place Dec. 1 in Las Vegas, Nev.

Dr. Espy, who received his veterinary degree from Texas A&M University in 1996, has been a consultant on the PRCA's Animal Care and Welfare Committee since 2011. In addition, he served on the AAEP board of directors from 2011–2013, as chair of the Owner Education Committee, and as a member of the Educational Programs and Scientific Review & Editorial committees.

AAEP mourns the loss of two members

Dr. Lee Cyphers

Dr. Lee Cyphers

Dr. Lee Cyphers, association veterinarian for Oaklawn Park in Hot Springs, Ark., for more than 30 years, passed away Sept. 5 at the age of 66.

Dr. Cyphers received his veterinary degree from Louisiana State University in 1985. Two years later with his then wife and fellow classmate Viki, the couple opened Cyphers Veterinary Hospital in Hot Springs, which they owned and operated until selling the practice in 2011. Dr Cyphers tenure as association veterinarian at Oaklawn spanned from 1990 until his death.

Dr. Jay Dee Fox

Dr. Jay Dee Fox

Dr. Jay Dee Fox, longtime veterinarian for Cheyenne Frontier Days in Wyoming, died Sept. 28 at age 77.

A rodeo team member during his pre-vet studies, Dr. Fox earned his veterinary degree from Colorado State University in 1969. The Nebraska native settled in Cheyenne and began working for Dr. Cliff Bishop's large animal practice before eventually taking over the practice, caring for his human, equine and bovine clients until his final days.

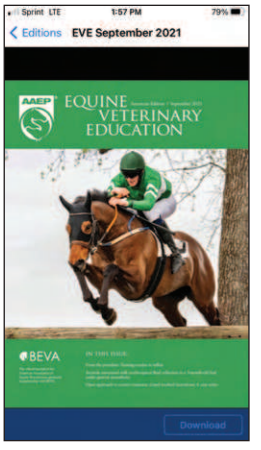
Benefit: Keep up with AAEP and The Foundation using the Publications App

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*, Spur, Leadership Resource Guide, white papers and guidelines. You can also listen to the Practice Life podcast and read 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 arriving 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.

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



2022 Resort Symposium

Hawai'i

January 19-21

Mauna Lani Resort
Island of Hawai'i

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Highlights of recent clinically relevant papers

Cryptorchidectomy through an umbilical portal

This retrospective case series by US-based Connie Finley and Andrew Fischer aimed to describe a surgical technique for the removal of cryptorchid testes through an enlarged umbilical portal following laparoscopic intra-abdominal castration in dorsal recumbency.

Seventy-nine horses presented for a laparoscopic cryptorchidectomy were included in the study of which 68 horses were unilaterally cryptorchid (38 left, 30 right) and 11 horses were bilaterally cryptorchid. Cryptorchid testes were castrated by ligating loop application and/or electrosurgery. The umbilical portal incision was extended along the linea alba for testes removal. All descended testes were removed by routine closed castration with the scrotal incision left to heal by second intention. Perianaesthetic laboratory values, surgical procedure descriptions, surgery and anaesthesia times, and in-hospital perioperative complications were recorded.

Five horses (6%) had intra-operative complications; three required an additional haemostatic technique; one developed intra-abdominal haemorrhage from the left parainguinal incision which resolved spontaneously, and one sustained a perforation of the large colon requiring conversion to a laparotomy. Thirteen horses (15%) developed post-operative complications; two were anorexic and mildly pyrexic; four developed colic signs responsive to medical management; four horses developed a haemoabdomen, of which two resolved without treatment, one resolved with medical treatment, and one required standing laparoscopic electrocautery of the right spermatic cord; two horses developed an umbilical portal incisional infection, of which one resolved without treatment and one required opening and cleaning of the wound to resolve; and one horse was euthanised due to an inability to stand following anaesthesia.

The extended umbilical portal incision offers a comparable and successful alternative to extending the parainguinal incision for removal of the testis following laparoscopic castration and may avoid potential trauma to the surrounding musculature or vasculature of parainguinal incisions.

Features of lumbosacral region pain

This descriptive post-mortem case series by Laura Quiney and co-workers in the UK aimed to describe the gross variations of osseous and soft tissues, and histopathological features of nerve tissue in the lumbosacral region of affected and control horses.

All horses subjected to euthanasia, for which a definitive diagnosis for poor performance or lameness had been made were included in the study. Horses with a substantial response to infiltration of local anaesthetic solution around the sacroiliac joint regions were included in the affected group (n = 27). Horses for which the source(s) of pain was confirmed by diagnostic anaesthesia to be distant to the lumbosacral region were included in the control group (n = 5). Of the affected horses, 24 (89%) had concurrent hindlimb lameness, 13 (48%) had concurrent forelimb lameness, 6 (22%) had neurological gait deficits and 2 (7%) had axial skeleton pathology. Of the unaffected horses, 3 (60%) had concurrent hindlimb lameness, 3 (60%) had concurrent forelimb lameness and 2 (40%) had axial skeleton pathology. The pelvic regions were isolated, and the soft tissues were assessed grossly. Sections of the lumbosacral plexus and cranial gluteal, sciatic and obturator nerves were examined histologically. The osseous specimens were evaluated for anatomical variants and abnormalities.

Gross discoloration of the sciatic or obturator nerves was observed in 7 (26%) affected and no control horses. Grade 3/3 histological abnormality scores were assigned in 22% of nerve sections from affected horses compared with 3% from control horses. Several osseous variants (bifid sacral spinous processes, straight-shaped sacroiliac joint surface, short arrow-shaped sacral alae, left-right asymmetry of sacral alae, sacral curvature, absence of the fourth to fifth and ankylosis of the fifth to sixth lumbar articular process joints, left-right asymmetry of caudocranial position of the fourth to fifth and lumbar-sacral articular process joints) and abnormalities (sacroiliac enthesopathy, extra ventral sacroiliac joint surface, lumbosacral symphyseal periarticular modelling, lumbosacral intertransverse joint pitting lesions) were more frequently observed in affected horses.

Lumbosacral region pain may reflect the presence of several pathological changes. Neural pain may play an important role in some horses.

MRI of the proximal metacarpal region

This retrospective study by Elisabeth van Veggel and co-workers in the Netherlands, USA, UK and Belgium evaluated the distribution and severity of bone and soft tissue lesions in the proximal metacarpal region of 62 Warmblood horses in lame and control groups (36 lame and 26 control limbs; the control group included 7 contralateral limbs). Correlation between lesions and ability to return to work was evaluated in the lame group.

Proximal suspensory ligament (PSL) size was not different between the lame and control groups. Hyperintensity seen on T1W/T2*W GRE images within the dorsal collagenous part of the PSL and hyperintense short-T1 inversion recovery (STIR) signal within the dorsal collagenous part of the PSL or within the McIII were only present within the lame group. Palmar cortical McIII resorption and dorsal margin irregularity of the PSL and McIII sclerosis were more severe within the lame limbs, but mild gradations were also seen in control limbs. Intermediate gradings for a subset of lesions were commonly seen in the non-lame contralateral to lame limbs. Return to work in the lame group was not statistically different for any measured observation(s), and 19/33 of the lame horses returned to work at similar or higher levels.

In this group of Warmblood horses, 58% returned to work within a variable time frame. The majority (81%) of lame limbs showed bone and soft tissue abnormalities, but no enlargement of the PSL was noted in lame horses, and no correlation was seen between the severity or type of lesions and the ability to return to work. The presence of STIR hyperintensity within the proximal McIII or dorsal collagenous part of the PSL and hyperintensity within the dorsal

collagenous part of the PSL on T1W GRE and T2*W GRE images, as well as significant palmar cortical McIII resorption are considered clinically relevant lesions. Contralateral limbs may not truly represent the normal condition, showing nonclinical variations and adaptive remodelling.

Comparison of neonatal foals and crias

This comparative, retrospective cohort evaluation of two species (camelid and equine) by Daniela Bedenice and co-workers at Tufts University, USA aimed to elucidate similarities between disease manifestations and mortality risks of critically ill (CI) neonatal crias and foals admitted to the same referral centre.

Data relating to 246 CI neonatal crias and 356 neonatal foals under 4 weeks old admitted to a university hospital were compared between groups using univariate and multivariate analyses.

Female crias (142/246, 57.7%) were significantly overrepresented in comparison to fillies (132/352, 37.5%). Congenital defects and failure of transfer of passive immunity were more often observed in neonatal crias, while colic, diarrhoea, patent urachus, septic arthritis, and omphalitis were significantly more common in CI foals. Overall survival to discharge (excluding fatal congenital defects) was comparable between crias (174/224, 77.8%) and foals (287/347, 82.1%), while crias (26/48, 54.2%) were more likely than foals (21/60, 35%) to die naturally than undergo euthanasia. Lower respiratory disease and indications for oxygen or IV glucose support increased mortality in the multivariate outcome models of both species. Species-specific adaptations of paediatric diagnostic criteria for sepsis were significantly associated with mortality in the multivariate analysis of patients with complete haematological datasets. However, the diagnosis of systemic inflammatory response syndrome (SIRS) did not retain statistical significance as an independent outcome predictor.

Lower respiratory disease and oxygen or glucose dysregulation increased mortality irrespective of species. However, despite species-specific differences in disease prevalence, the success of intensive care management was comparable.

Group B rotavirus in foals

In this report Tirth Uprety and co-workers in the US identified ruminant origin group B rotavirus associated with diarrhoea outbreaks in foals.

Equine rotavirus group A (ERVA) is one of the most common causes of foal diarrhoea. In early 2021 there was an increase in the frequency of severe watery to haemorrhagic diarrhoea cases in neonatal foals in Central Kentucky. Diagnostic investigation of faecal samples failed to detect evidence of diarrhoea-causing pathogens including ERVA. Based on *Illumina*-based metagenomic sequencing, the authors identified a novel equine rotavirus group B (ERVB) in faecal specimens from the affected foals.

The protein sequence of all 11 segments had greater than 96% identity with group B rotaviruses previously found in ruminants. Furthermore, phylogenetic analysis demonstrated clustering of the ERVB with group B rotaviruses of caprine and bovine strains from the USA. Subsequent analysis of 33 foal diarrheic samples by RT-qPCR identified 23 rotavirus B-positive cases (69.69%). These observations suggest that the ERVB originated from ruminants and was associated with outbreaks of neonatal foal diarrhoea in the 2021 foaling season in Kentucky. Emergence of the ruminant-like group B rotavirus in foals warrants further investigation due to the significant impact of the disease in neonatal foals and its economic impact on the equine industry.

Lymphoma diagnosis

This study by Caitlin Moore and co-workers in the US reported the clinical performance of a commercially available thymidine kinase 1 (TK1) assay for diagnosis of lymphoma in horses.

Medical records of 42 hospitalised horses (14 with a definitive diagnosis of lymphoma, 4 with other neoplasia, and 24 with inflammatory disease) were reviewed and groups were compared via Kruskal-Wallis and Mann-Whitney tests, and logistic regression was performed.

Median (range) TK1 was 3 U/L (0.4-17.7 U/L) in horses with lymphoma and 3.9 U/L (0.8-94 U/L) in horses without lymphoma. There was no significant difference in total protein between horses with and without lymphoma (6.6 g/dL [5.5-8.3 g/dL] vs 6.6 g/dL [4.7-10.4 g/dL]). There was no significant difference in fibrinogen between horses with and without lymphoma (447 [100-1364] mg/dL vs 433 [291-2004] mg/dL). On logistic regression, serum TK1 activity was not associated with a diagnosis of lymphoma (odds ratio, 0.97; 95% confidence interval, 0.9-1.05).

Serum TK1 values were not predictive of lymphoma diagnosis in this cohort of horses.

S. WRIGHT
EVE Editorial Office

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Case Report

Salmonella enterica subsp. *arizonae*-associated abortion in a mare

K. K. Mayhew, L. Clarke* and E. W. Howerth

Department of Pathology, College of Veterinary Medicine, University of Georgia, Athens, Georgia, USA
**Corresponding author email: llclarke@wisc.edu*

K. K. Mayhew's present address: Covered Bridge Equine, Watkinsvlle, Georgia,USA
L. Clarke's present address: Wisconsin Veterinary Diagnostic Laboratory, University of Wisconsin, Madison, Wisconsin, USA

Keywords: horse; abortion; *Salmonella*; MALDI-TOF MS; pathology

Summary

Abortion in mares can be a financially devastating event to horse owners and the equine industry. In this case report, we describe the gross, histopathological and microbiological findings associated with an abortion caused by *Salmonella enterica* subsp. *arizonae*, which should be considered in cases of abortion and metritis. Gross and histopathological evaluation of fetal and placental tissue were consistent with ascending septic placentitis resulting in fetal septicaemia. *S. enterica* subsp. *arizonae* was isolated from the placenta, lung and fetal gastric contents. Diagnosis was confirmed by MALDI-TOF MS. To our knowledge, this subspecies of *S. enterica* has not been previously reported as an isolate in a case of late-term equine abortion. A retrospective search of abortion cases at our institution was done, and no similar cases were identified for comparison. This case demonstrates *S. enterica* subsp. *arizonae*, although not previously reported as a cause of abortion in pregnant mares and uncommonly isolated from equids in the literature, may cause late-term abortions in susceptible animals. This pathogen should be considered in cases of abortion outbreaks on a farm and merits investigation of the carrier status of mares within a herd (**Figs 1** and **2**).

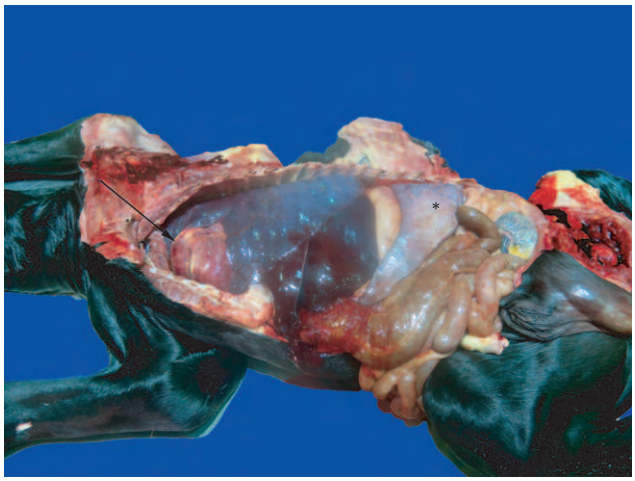


Fig 2: Image of foal following opening of body cavities. Note the epicardial haemorrhage (arrow) and splenic enlargement with a prominent follicular pattern (*).

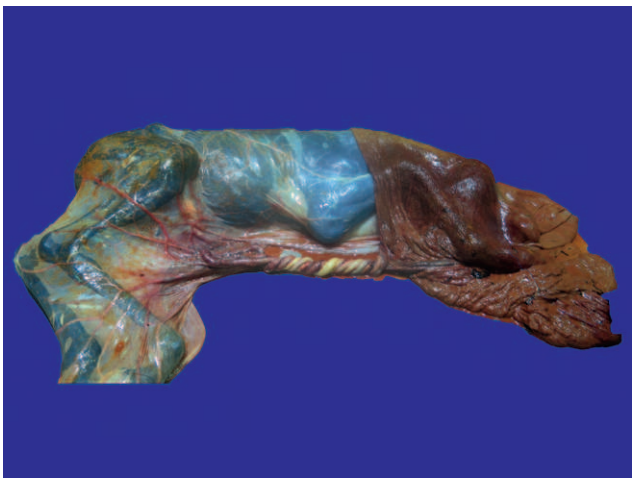
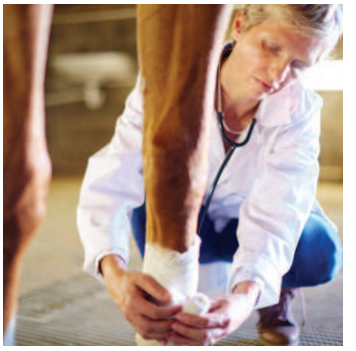


Fig 1: Image of foal as presented to necropsy with amnion intact and tearing of the placenta over the caudal aspect. The placenta is grossly thickened, oedematous and discoloured.

Key points

- The cause of abortion in mares is difficult to diagnose, but a thorough post-mortem examination done within 24 hours of death can help to elucidate novel infectious causes.
- *Salmonella enterica* subsp. *arizonae* has not previously been reported as a cause of abortion in mares but was the determined aetiology in this case. Investigation of the carrier status of breeding mares may be warranted as a further direction of study.
- Multiple diagnostic modalities, including histopathology, enriched culture and MALDI-TOF, are essential to identifying uncommon abortigenic agents such as *Salmonella enterica* subsp. *arizonae*.

Dr. Kami Vickerman, Pioneer Equine Animal Hospital, Oakdale, CA



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Case Report

Surgical repair and reconstruction of a nasal fistula following intra-lesional formalin injection

***H. Barnes*†*, *A. M. Gillen*†, *J. Brown*‡ and *D. C. Archer*†**

†*The Philip Leverhulme Equine Hospital, Institute of Veterinary Science, University of Liverpool, Neston; and* ‡*Tenby Vets, Wales, UK*
**Corresponding author email: hattieb@liverpool.ac.uk*

Keywords: horse; nasocutaneous fistula; skin graft; dermal scaffold; formalin

Summary

A 6-year-old Cleveland Bay mare was referred to the University of Liverpool Equine Hospital for repair of an iatrogenic nasocutaneous fistula. The fistula had developed following attempted ablation of an epidermal inclusion cyst located in the right nasal diverticulum with intra-lesional formalin 6 weeks previously. After removal of the cyst contents, 15 mL of neutral-buffered 10% formalin had been injected directly into the cyst via an external approach. Subsequent tissue necrosis resulted in the formation of a full-thickness defect in the overlying tissues and the creation of a 5 × 5 cm nasocutaneous fistula (**Fig 1**). Upon referral, surgical management was undertaken to repair the fistula under general anaesthesia in a single-stage procedure. The fistula was debrided and a commercial dermal regeneration mesh (Pelnac®) was applied to bridge the defect, acting as a tissue scaffold. The silicone-covered side of the mesh was placed towards the nasal passages, to physically reduce airflow to the overlying tissues and to reduce the degree of tissue desiccation. The edges of the mesh overlapped the fistula and were carefully secured using interrupted braided synthetic lactomer (Polysorb 3 Metric) sutures to the adjacent periosteum and subcutaneous tissues, avoiding placement of the sutures directly over the defect. The *levator labii superioris* muscle was used to cover the scaffold by transecting it close to its proximal origin and reflecting it rostrally. Due to the width of the defect, the muscle belly did not fully cover the mesh. The muscle was therefore sectioned in a frontal plane and then fanned over the mesh and secured to the adjacent subcutaneous tissues using braided synthetic lactomer. Finally, a transposition skin flap was created adjacent to the site and was rotated axially to cover the defect and secured in place. The adjacent sites were reconstructed using simple interrupted and horizontal mattress sutures in the skin using poliglecaprone 25 (Monocryl 3 Metric). The mare made an excellent recovery and subsequent dressing changes over the next 17 days showed good healing, with only a small area of granulation tissue forming at the rostral tip. Long-term follow-up confirmed complete healing of the surgical site with an excellent cosmetic outcome (**Fig 2**).

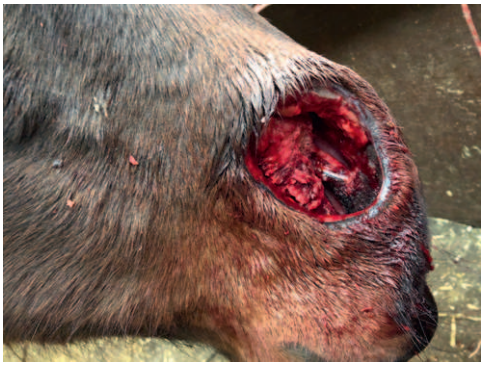

Fig 1: The nasocutaneous fistula following complete necrosis of the soft tissues at the site; the image was taken 6 weeks following formalin administration and 3 weeks prior to surgical repair being performed.

Fig 2: Image showing the completed surgical repair with caudal surgical site following retroflexion of* levator labii superiosis *muscle and rostral transposition flap overlying the muscle flap and Pelnac mesh.

Key points

- Extensive tissue necrosis should be considered as a significant complication of intra-lesional formalin administration as a nonsurgical option to ablate nasal atheromas.
- Commercial biological scaffolds can assist in fistula repair in areas of low tissue availability and reduced mobility.
- The *levator labii superioris* muscle should be considered as a candidate for muscle transposition to aid repair of rostral nasocutaneous fistulas.

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Case Report

Intravenous formalin for treatment of haemorrhage in horses

C. R. Moreno*, K. M. Delph and W. L. Beard

Department of Large Animal Clinical Sciences, Veterinary Health Center at Kansas State University, Manhattan, Kansas, USA
**Corresponding author email: moreno.209@osu.edu*

C. R. Moreno's present address: Department of Veterinary Clinical Sciences College of Veterinary Medicine, The Ohio State University, Columbus, Ohio, USA

Keywords: horse; intravenous; formalin; haemorrhage; treatment

Summary

Administration of intravenous formalin for the treatment of haemorrhage has been used with anecdotal success for decades. However, there is limited information in the literature regarding its use in clinical cases. This uncontrolled retrospective study describes 11 cases that were treated with intravenous formalin at the Veterinary Health Center at Kansas State University from 2009 to 2019. The objective of this study was to describe the signalment, clinical and laboratory findings, treatment and outcome of horses treated with intravenous formalin for potentially life-threatening haemorrhagic conditions. This study does not attempt to prove the efficacy of intravenous formalin, but rather to report its clinical use and the associated details of those cases. Horses ranged in age from 2 to 23-years-old. There were nine Quarter Horses, one Thoroughbred, and one Appaloosa. Treated conditions included haemoabdomen (4/11), uterine haemorrhage (1/11), epistaxis (3/11), haemorrhage secondary to a mandibular laceration (2/11) and haemothorax (1/11). All horses had an elevated heart rate (>42 beats/min) and seven horses had an elevated respiratory rate (>20 breaths/min) on initial physical examination. Six out of 11 horses had a prolonged capillary refill time, defined as ≥2 s. A complete blood count (CBC) was performed in nine of the 11 cases. A consistent finding on the CBC was anaemia (defined as an erythrocyte concentration <6 x 10^{12}/L and/or a spun haematocrit of <30%) which was present in all cases. A serum chemistry panel was performed in eight of the 11 cases. Hypercreatininemia (>152.5 μmol/L) was noted in five cases on admission. All of those horses survived to discharge and had a normal creatinine on a final chemistry panel. A coagulation profile was performed in four horses. Only one of four horses had a prolonged PT (14.2 s with normal being 10–12 s). All horses were treated with intravenous formalin of varying concentrations at least once. The most utilised dose was 0.476% formalin (50 mL 10% neutral buffered formalin diluted in 1 L of isotonic fluid). Some horses were also treated with aminocaproic acid, Yunnan Baiyao, whole blood transfusions and surgery. Ten out of the 11 horses survived to discharge with one horse reported by the owner to have died 2 weeks later of an unknown cause.

Key points

- The authors do not advocate the routine use of intravenous formalin for control of haemorrhage but realise its potential as a tool in selected cases.
- Intravenous use of formalin in actively bleeding horses does not appear to negatively affect survival to discharge (90.9%).
- While this retrospective study cannot establish efficacy due to differences in doses and adjunct therapies, there were no adverse reactions observed with the administration of neutral buffered intravenous formalin to actively bleeding hospitalised horses at the utilised doses.

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Case Report

Heterotopic polydontia as a cause for a cystic lesion in the paranasal sinus of a Thoroughbred filly

***A. Gardner*†*, *J. Lorbach*† *and H. Rice*‡**

†*The Ohio State University, Columbus, Ohio; and* ‡*Littleton Equine Medical Center, Littleton, Colorado, USA*
**Corresponding author email: gardner.300@osu.edu*

Keywords: horse; sinus cyst; dental abnormalities; sinusitis; facial surgery

Summary

A 1-year-old Thoroughbred filly with left bony facial distortion and unilateral narrowed nasal passage was diagnosed with a multilobar expansile mass within the caudal maxillary and frontal sinuses on computed tomography (CT). The Hounsfield unit (HU) assignation to the hyperdense interior of the mass was consistent with soft tissue (average 78HU). Typical findings associated with a sinus cyst, including expression of amber fluid from the mass and a thick lining that could be peeled from the sinus walls, were found on surgical exploration of the sinus under general anaesthesia via a left maxillary sinus flap. The cyst contained six hard structures surrounded by a gelatinous matrix. A diagnosis of heterotopic polydontia was made after histological examination of the hard structures confirmed the presence of all components of embryologically normal dental tissue. These immature dental structures, or denticles, were well organised, and each included a central dental papilla, odontogenic epithelium, dentin, enamel and an outer layer of enameloblasts. The filly recovered well and entered training to race as a 2-year-old, as remodelling of the bony distortion and narrowing of the nasal passage were sufficient for airflow. Previous reports of paranasal cystic lesions in horses suggest developmental abnormalities as a causative factor, especially in young horses. Furthermore, heterotopic polydontia is reported as the underlying aetiology in some human paranasal sinus cysts. While polydontia has been reported in the paranasal sinuses and nasal passages of horses, this is the first case report that finds them associated with a cystic lesion within the paranasal sinus. Heterotopic polydontia should be considered as a cause for paranasal sinus cystic lesions. Immature dental structures may have the appearance of soft tissue on CT imaging if not developed to the point of significant mineralisation (**Figs 1** and **2**).

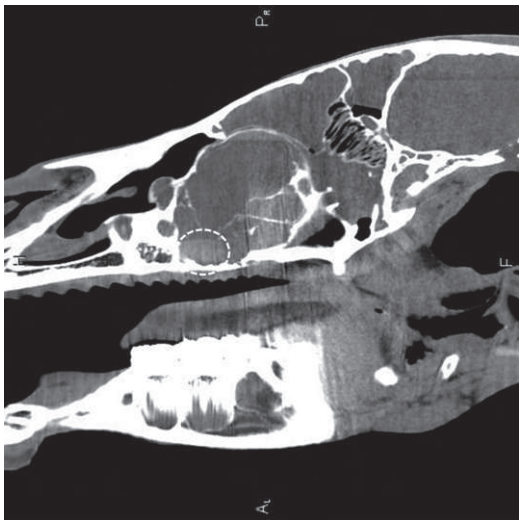

Fig 1: Computed tomographic image of the caudal maxillary and frontomaxillary mass. A faintly demarcated opacity later deemed to be the supernumerary dental structures is indicated (dashed circle).

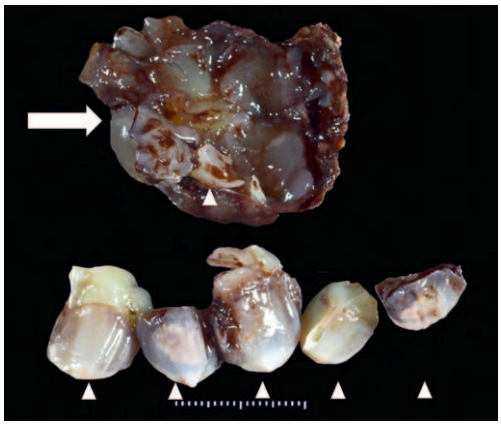

Fig 2: Extirpated cyst and contents. The cyst lining was found to be primitive mesenchyme (white arrow). Six hard, tooth-like structures interpreted as denticles (white arrowheads) were found within the cyst.

Key points

- Heterotopic polydontia has been suggested as a cause for paranasal sinus cysts in young horses and other animals.
- Three-dimensional imaging such as computed tomography (CT) may be useful in surgical planning but histological confirmation of dental structures is necessary for diagnosis of heterotopic polydontia if sufficient mineralisation of immature structures has not occurred.
- Prognosis after extirpation is good, and airflow may improve with remodelling.

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Case Report

Evaluation of the use of an endotracheal tube as a novel method of short-term haemostasis in post-operative paranasal sinus surgery in three horses

V. Melly* and P. Baia

B. W. Furlong and Associates, Califon, New Jersey, USA
**Corresponding author email: virginia.melly@ucdconnect.ie*

Keywords: horse; sinus cyst; progressive ethmoid haematoma; haemostasis; standing surgery

Summary

Haemorrhage is a clinically important short-term complication of equine paranasal sinus surgery, especially following damage to the nasal mucosa, ethmoturbinates or a progressive ethmoid haematoma (PEH). A cotton pressure dressing used to firmly pack the nasal cavity and/or sinus was first described for post-operative haemostasis and remains the current conventional treatment as a means of haemostasis. Despite reported complications, no alternative methods have been reported in equine sinus surgery.

A frontonasal bone flap was performed routinely in the three standing horses with paranasal sinus disease. Following mass or material removal, a sinonasal window was created or enlarged. In Case 1, the fistula was initially gauze packed, which controlled haemorrhage until concerns of gauze dislodgement necessitated removal 8 hours post-operatively. Severe haemorrhage ensued, requiring emergency passage of a 24-mm endotracheal tube (ETT) and cuff inflation for control. In Cases 2 and 3, a size 24-mm and 18-mm ETT, respectively, were used electively for post-operative haemostasis.

In each case, the ETT was introduced retrograde through the nasal passage of the affected side, and advanced using direct visual guidance via the sinusotomy site, until the cuff was positioned overlying the surgical site or site of active haemorrhage (**Fig 1**). The cuff was inflated with air until adequate pressure was achieved to provide haemostatic compression, and the end of the tube extending from the nostril were secured on the side of the face (**Fig 2**). Carefully monitored staged removal of the ETT, beginning with cuff deflation and gentle tube rotation before complete removal, occurred 24–48 h after placement. No haemorrhage was observed upon removal.

The ETT was easy to use in the standing horse and no discomfort or complications were recorded. It adequately controlled haemorrhage post-operatively by application of controlled pneumatic pressure against the mucosal vasculature. No short-term or long-term complications were observed.

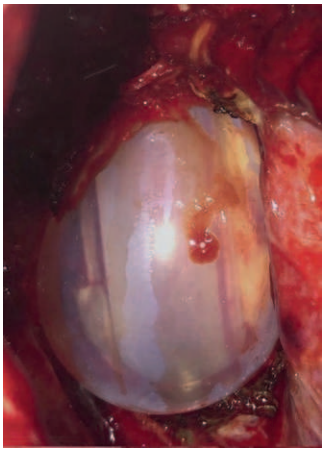

Fig 1: Inflated ETT cuff within the sinonasal fistula in Case 2. This image was observed via the sinusotomy site.

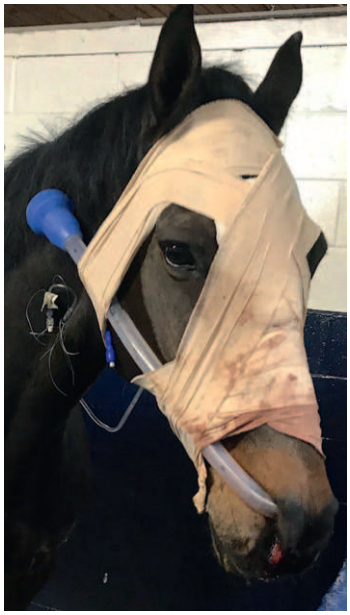

Fig 2: ETT in Case 1 exiting the right nostril and secured in place with Elastikon tape.

Key points

- ETT cuff placement may be indicated to control sinonasal haemorrhage in the short-term post-operative period following surgical sinonasal window creation.
- An ETT cuff may be superior to the conventional gauze packing, by providing reliable haemostasis without complications and improved patient comfort.

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Case Report

Medical management of a large intra-abdominal mass caused by *Rhodococcus equi* in a foal

***S. D. Shaw*[†], *L. G. Arroyo*[†]*, *A. zur Linden*[†], *C. Allen*[‡], *A. Giraldo*[†] and *N. D. Cohen*[§]**

[†]*Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, Ontario;* [‡]*Allen Equine Services, Etobicoke, Ontario, Canada; and* [§]*Department of Large Animal Clinical Sciences, College of Veterinary Medicine, Texas A&M University, College Station, Texas, USA*
**Corresponding author email: larroyo@uoguelph.ca*

Keywords: horse; *Rhodococcus*; diarrhoea; abscess; gallium; computed tomography

Summary

A 4-month-old Thoroughbred filly presented with pyrexia, inappetence and diarrhoea. Abdominal ultrasonography revealed a mass of mixed echogenicity extending from the right ventral flank across midline to the left. The mass measured 10 cm deep from ventral to dorsal and 17 cm from cranial to caudal. A second, homogenous and well-vascularised mass, measuring approximately 5 cm deep × 6 cm in length, was identified in the left ventral flank region. Thoracic ultrasonography revealed no abnormal findings of the pleural surface of either hemithorax. Computed tomography revealed an ill-defined, multilobulated, soft-tissue mass with central gas and fluid dense regions in the right ventral abdomen, consistent with marked caecal wall thickening (up to 4 cm) of both the body and the base of the caecum (**Fig 1**). The mass extended from the level of the 17th thoracic to 4th lumbar vertebra and crossed midline to the left and measured 18.1 × 12.9 × 22.2 cm.

Marked mesenteric lymphadenopathy was also present. In the left mid-abdomen, adjacent to the mesenteric vasculature, one enlarged mesenteric lymph node was identified, measuring 6.2 × 7.5 × 5.5 cm. Incidentally, within the dorsal aspect of the left caudal lung, adjacent to the aorta, an amorphous, multilobulated soft tissue dense mass that was 6.3 × 5 × 5.7 cm was identified, consistent with a pulmonary abscess. Percutaneous aspiration of the abdominal mass (**Fig 2**) yielded purulent material which was pure culture positive for *Rhodococcus equi*. Follow-up computed tomography revealed complete resolution of the abdominal mass and lymphadenopathy after treatment with clarithromycin, rifampin and gallium maltolate.

Extrapulmonary disorders associated with *R. equi* should be considered even when thoracic ultrasonography shows no evidence of pulmonary pathology. Although intra-abdominal abscesses have a grave prognosis, successful treatment was achieved in this case. Gallium maltolate can be safely administered to foals and may improve patient outcomes.

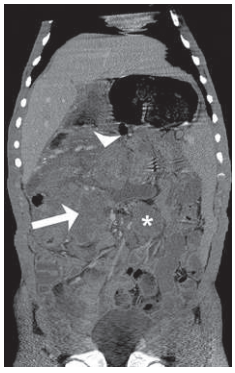

Fig 1: Computed tomography image from a foal performed on presentation. This image was taken after contrast medium administration and reformatted to 5 mm slice thickness. There was marked thickening of the caecal body (white arrowhead) and the base of the caecum (white arrow), as well as marked mesenteric lymphadenopathy (*).

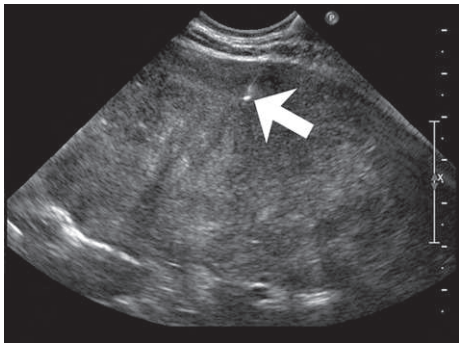

***Fig 2: Ultrasound-guided fine needle aspirates of the caecal thickening were performed percutaneously (5–8 MHz curvilinear probe) under general anaesthesia. Cytology revealed severe, suppurative, inflammation characterised by large numbers of markedly lytic neutrophils. Intracytoplasmic bacteria with coccoid to rod-shaped morphology (pleomorphic rods) were observed. Aerobic culture yielded pure heavy growth of* Rhodococcus equi.**

Key points

- Computed tomography was a valuable imaging modality for characterising and monitoring the extent and regression of an intra-abdominal *R. equi* abscess in a foal.
- Gallium maltolate was safe to use and may improve patient outcomes of extrapulmonary *R. equi* affections in foals.
- Extrapulmonary *R. equi*-associated disorders are associated with a poor prognosis and should be considered despite no evidence of pulmonary pathology.

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Clinical Commentary

Medical management of *Rhodococcus equi* infections: A clinical epidemiology perspective

L. Huber

Institute of Environmental Decisions, Health Geography and Policy Group, ETH Zürich, Zürich, Switzerland
Corresponding author email: laura.huber@usys.ethz.ch or laura.huber16@hotmail.com

Keywords: horse; Rhococcus equi; epidemiology

Summary

***Rhodococcus equi* infections cause severe pulmonary disease in foals, affecting animal welfare and increasing production costs in horse-breeding farms. Extra-pulmonary disorders (EPD) are relatively common and can occur independently of pulmonary disease; foals with EPD have a more guarded prognosis. The accompanying paper by Shaw *et al*. (2021) reports the successful diagnosis and medical treatment of a large abdominal abscess caused by *R. equi* infection. The authors report on the benefits of using gallium maltolate, a semimetal compound with antimicrobial activity, in combination with traditional *R. equi* infection antimicrobial treatment (combination of a macrolide and rifampicin). Experimental studies are needed to understand further the benefits of this combined therapy, to evaluate the synergistic effects and if it improves the concentration of antimicrobial drugs into infected tissues. The publication of this case report in *Equine Veterinary Education* is of clinical importance to equine practitioners when diagnosing and treating *R. equi* infected foals with or without EPD.**

Rhodococcus equi, a Gram-positive bacterium, is a soil saprophyte and facultative intracellular pathogen infecting humans and animals. *R. equi* infections continue to be highly prevalent at horse-breeding farms, and one of the most important causes of morbidity and mortality in foals despite efforts to prevent the disease. Foals are gradually exposed to *R. equi* in the farm environment through aspiration of aerosolised bacteria or by consumption. Upon infection, *R. equi* causes pyogranulomatous pneumonia, being manifested as subclinical to severe clinical pulmonary disease. While most subclinically affected foals recover spontaneously without the need for treatment, antimicrobial chemotherapy is warranted upon clinical signs of the disease. Extra-pulmonary disorders (EPD) can occur concomitantly or independently of pneumonia. Cases with EPD show higher mortality and poorer response to treatment. The accompanying paper by Shaw and collaborators reports a case of a 4-month-old foal with severe abdominal disease caused by *R. equi* without evident past or present clinical signs of respiratory disease. Upon admission to the clinic, the foal presented with pyrexia, inappetence and diarrhoea. As cited in the accompanying paper, differential diagnosis for this patient's initial clinical signs included several infectious diseases (e.g. caused by *Salmonella*, rotavirus, coronavirus), endoparasites or diet changes, among others. In the reported case, the isolation of a pure *R. equi* culture from a large abdominal abscess, identified by computer tomography scanning, led to the definitive diagnosis of *R. equi* infection. In this patient, EPD caused by *R. equi* occurred without concomitant clinical signs of pulmonary disease. This finding raises awareness for clinicians to include *R. equi* infections in their differential diagnosis even when no respiratory clinical signs suggestive of rhodococcosis are evident.

Extra-pulmonary disorders, such as polysynovitis and uveitis, were traditionally attributed to immune-mediated disorders caused by *R. equi* infections. However, recent studies cultured virulent *R. equi* from synovial and uveal fluid samples from foals with polysynovitis and uveitis after being experimentally challenged with *R. equi* intratracheally (Huber *et al*. 2018a). This suggests that septic polysynovitis and uveitis occurred as a result of *R. equi* systemic infection. In the accompanying paper (Shaw *et al*. 2021), the evidence of a small pulmonary abscess suggests possible septic spread of *R. equi* either from the lungs to the abdomen or vice versa. In this report, no other signs suggestive of EPD were detected. Previous studies have showed that foals with polysynovitis and uveitis did not show evident clinical signs, and these complications can be easily missed without thorough ocular examination and palpation of joints. Therefore, because of the lack of sufficient clinical evidence, it is likely that no additional diagnostics, such as blood culture, were performed to rule out sepsis. More studies are needed to understand the pathogenesis of multiple body site infections caused by *R. equi* through genotype identification of isolated strains. These studies should explore: (i) genomic differences indicative of body site tropism and (ii) the occurrence and the effect of multi-strain infections on the prognosis and response to treatment.

Antimicrobial resistance is a major threat to human and animal health. Animal productions are thought to contribute to the emergence of antimicrobial resistance because 73% of all antimicrobials sold globally are destined for the use in animals (Van Boeckel *et al*. 2017). Equine production systems are no exception. Recently, the practice of prophylactic use of macrolides and rifampicin was linked to the emergence of multidrug resistance in *R. equi* in foals (Huber *et al*. 2018b) and from the environment of horse-breeding farms (Huber *et al*. 2019). To prevent further selection of resistant *R. equi*, attempts to reduce antimicrobial use have been explored. These attempts include prevention of the disease, by the development of vaccines, and the reduction of antimicrobials use in subclinically affected foals. Moreover, alternatives to the use of antimicrobials have been explored as a way to mitigate antimicrobial resistance. Gallium maltolate, a semimetal compound with antimicrobial activity, has been explored as an alternative therapy. Its effectiveness as an antimicrobial agent is due to its similarity with iron,

leading bacteria to uptake gallium instead of iron. This results in impaired bacterial iron-dependent biological processes, such as enzyme synthesis. Of importance, gallium maltolate was shown to be effective against multidrug-resistant ESKAPE (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* species) organisms (Hijazi *et al*. 2018). Thus, gallium maltolate can be considered as a last-resort compound to treat patients infected with multidrug-resistant pathogens, that could not be otherwise treated (Hijazi *et al*. 2018). Gallium maltolate is safe for use in foals, and its efficacy is comparable to traditional antimicrobial therapy to treat presumed *R. equi* pneumonia in naturally infected foals (Cohen *et al*. 2015). However, evidence is still lacking regarding the synergistic effect of gallium maltolate used in combination with other antimicrobials, such as macrolides and rifampicin. In the accompanying paper by Shaw *et al*. (2021), the use of gallium maltolate in combination with clarithromycin and rifampicin did not cause overt adverse effects and was efficient in treating a severely affected patient. In this case, the rationale to use gallium in combination with traditional therapy was to enhance antimicrobial concentration in the inflamed tissue. This effect, however, has not been shown experimentally. In the Shaw *et al*. (2021) report, the use of gallium maltolate seemed promising and successful. However, more studies are needed to evaluate: (i) the impact of electing gallium maltolate alone or in combination with other drugs on the recovery time of the patient; and (ii) the synergistic mechanism of these drug combinations on the penetration of the inflamed tissue. Nonetheless, the use of gallium maltolate at farms to treat subclinically and clinically affected foals contributes greatly to reducing antimicrobial selective pressure and the emergence of antimicrobial resistance in *R. equi* and other bacteria that can harm human and animal health.

In summary, this case report highlights important information on the diagnosis of the atypical clinical presentation of *R. equi* infection in a foal. It is important to highlight the use of alternative therapies to antimicrobials in naturally and severely affected foals to guide future treatment decisions in similar cases. However, more studies are needed to understand the further the effects of gallium maltolate in combination with other drugs. The publication of this case report in *Equine Veterinary Education* is of clinical importance to equine practitioners when diagnosing and treating *R. equi* infected foals with or without EPD.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this clinical commentary.

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Case Report

Equine conidiobolomycosis: A review and case study

S. Zetterström, R. Hanson, A. Velloso Alvarez, F. Caldwell, L. Boone and J. Schumacher

Department of Clinical Sciences, J T Vaughan Teaching Hospital, College of Veterinary Medicine, Auburn University, Auburn, Alabama, USA
**Corresponding author email: hansorr@auburn.edu*

Keywords: horse; conidiobolomycosis; conidiobolus coronatus; fluconazole

Summary

Conidiobolus coronatus is the one of most commonly identified upper respiratory fungal pathogens in horses. This article includes a review of clinical signs, diagnostics, treatment and outcomes in previously reported cases of equine conidiobolomycosis, and six additional cases seen at our hospital. Each of the six horses presented with a complaint of serosanguinous or haemorrhagic nasal discharge and conidiobolomycosis was confirmed by histopathology and a fungal culture. Additional complaints included increased respiratory noise (n = 4), weight loss (n = 2) and exercise intolerance (n = 1). One horse with extensive bilateral nasal lesions had a history of coughing and respiratory distress. Granulomas were seen in the external nares (**Fig 1**) and/or, by using endoscopic examination, were seen in a single nasal passage (n = 2), both nasal passages, or bilaterally affecting the nasal septum (n = 4; **Fig 2**). Five horses were treated medically with orally administered fluconazole (14 mg/kg bwt loading dose followed by 5 mg/kg bwt, per os, q. 24 h) alone (n = 2) or fluconazole in combination with oral iodides (1–2 mg/kg bwt for one week, then 0.5–1.0 mg/kg bwt, per os, q. 24 h; n = 3). Three of these horses also had surgical treatment that involved aggressive debulking of nasal and septal masses in two horses and nasal septum resection in one horse. Medical treatment ranged from 3 weeks to 4 months. Three horses had reoccurrence of granulomatous nasal tissue developing months to years after the initial admission. In these, the infection resolved after retreating with fluconazole and organic iodide (n = 2) or after nasal septum resection combined with fluconazole and organic iodide treatment (n = 1). One horse was subjected to euthanasia without treatment because of the extent of the disease. For the horses in our small study, oral fluconazole appeared to be the most effective treatment of conidiobolomycosis. If surgical treatment is undertaken, simultaneous administration of fluconazole may improve the chance of resolution. The results of this study also emphasise the importance of periodic re-evaluations of horses with nasal conidiobolomycosis to avoid prematurely ending medical treatment and to identify signs of reoccurrence.

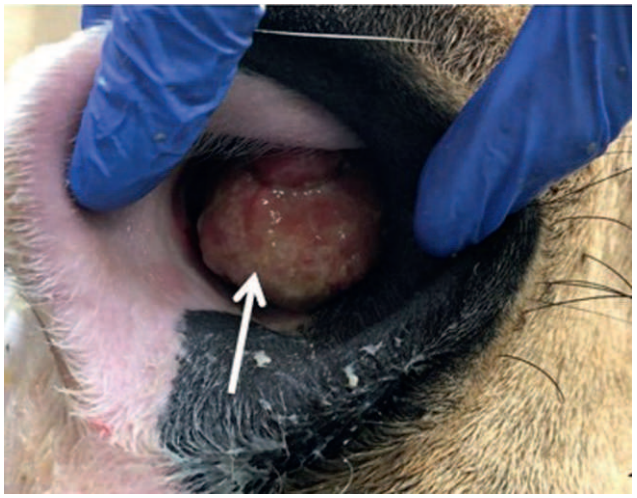

Fig 1: Photograph of the left nostril illustrating a rostral granuloma (arrow) originating from the nasal septum.

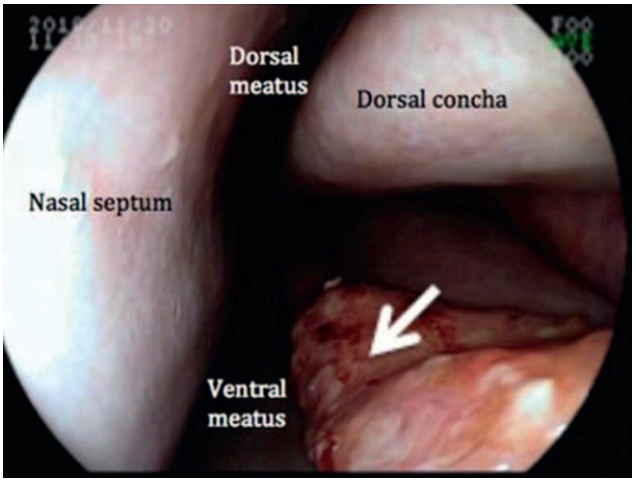

Fig 2: Endoscopy image of the left nasal passages. A fungal granuloma is affecting the left ventral meatus (arrow).

Key points

- Conidiobolomycosis is a rare, chronic, granulomatous disorder of the upper respiratory tract in horses caused by *Conidiobolus coronatus,* a saprophytic fungus found in soil and decaying plant debris, primarily in tropical or subtropical areas.
- Clinical signs often include serosanguinous or haemorrhagic nasal discharge.
- Oral fluconazole appears to be an effective drug for treatment of conidiobolomycosis, although prolonged treatment is typically required for resolution and to prevent reoccurrence of the infection.

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Clinical Commentary

Beyond conidiobolomycosis – the other 'zygomycoses'

P. J. Johnson**, K. S. Townsend and L. M. Martin

Department of Veterinary Medicine and Surgery, University of Missouri College of Veterinary Medicine, Columbia, Missouri, USA
**Corresponding author email: johnsonpj@missouri.edu*

Keywords: horse; zygomycosis; conidiobolomycosis; basidiobolomycosis

Summary

Disease resulting from infection by Zygomycetes fungi (including two groups of coenocytic fungal pathogens: the Mucormycota and the Entomophthoramycota) has been collectively referred to as zygomycosis. Clinical disease associated with both the Mucormycota and the Entomophthoramycota is rarely encountered in horses. Potentially life-threatening, mucormycosis is an angioinvasive disease that principally affects immunocompromised individuals. The order of Entomophthorales include two genera: Conidiobolus and Basidiobolus. The most common of these, *Conidiobolus coronatus*, typically causes chronic necrohaemorrhagic tumefactions in the nostrils, nasal passages and nasopharyngeal walls of immunocompetent equine hosts, most commonly seen in the south-eastern USA and parts of Australia. Infection by *Basidiobolus ranarum* is reported less frequently and usually causes solitary ulcerative skin lesions with pruritus. This short commentary intends to complement the accompanying review of conidiobolomycosis by summarising reported cases of mucormycosis and basidiobolomycosis in horses. Moreover, some new information regarding taxonomic challenges to traditional 'Zygomycosis' classification is presented.

Introduction

Fungal species in the class Zygomycota (Zygomycetes) have traditionally been divided into two orders, Mucorales (Mucormycota) and Entomophthorales (Entomophthoramycota) (Quinn *et al*. 1994; Grooters 2014; Kontoyiannis and Lewis 2015; Naranjo-Ortiz and Gabaldón 2019). Disease resulting from Zygomycetes fungal infection has been collectively referred to as zygomycosis. Interestingly, it has recently been suggested that the disease category known as 'zygomycosis' should be abolished because phylogenetic analysis has revealed that the 'Zygomycota' are a polyphyletic group (meaning that constituent species are derived from more than one common evolutionary ancestor and therefore not suitable for classification within the same taxon) (Kwon-Chung 2012; Vilela and Mendoza 2018; Naranjo-Ortiz and Gabaldón 2019). Controversially, the finding that *Basidiobolus* spp. (historically classified in the Entomophthorales group) share phylogenetic features with monoflagellated chytrid fungi resulted in the proposal to eliminate the *Basidiobolus* genus from the Entomophthorales group (Gryganskyi *et al*. 2012; Humber 2012; Kwon-Chung 2012; Spatafora *et al*. 2016; Vilela and Mendoza 2018; Naranjo-Ortiz and Gabaldón 2019). However, it has also been suggested that the term 'zygomycosis' should be retained to collectively name infections caused by both groups of coenocytic fungal pathogens: the Mucormycota and the Entomophthoramycota. In spite of these controversies, placement of the genus *Basidiobolus* with the entomophthoralean fungi is still broadly supported by many experts in the field (Gryganskyi *et al*. 2012; Humber 2012; Spatafora *et al*. 2016).

The Mucorales fungi ('pin moulds') have a world-wide distribution and are constituted by 12–13 families, 56 genera, and approximately 300 species, including *Absidia* spp., *Mucor* spp., *Rhizopus* spp., and *Saksenaea* spp (Walther *et al*. 2019). Most Mucorales fungi are saprotrophic, growing on organic substrates (such as soil, fruit, plant debris and faecal residues). Some Mucorales fungal species (also known as coenocytic [sparsely septate] fungi) are opportunistically parasitic to animals, plants and other fungi (Walther *et al*. 2019). Infection by Mucorales fungi is referred to as mucormycosis and typically results in rapidly progressive disease in immunocompromised or otherwise debilitated people. The usual route of contamination is through inhalation of a large number of fungal spores.

Mucormycosis has been infrequently reported to cause disease in horses and resulting lesions may be disseminated or restricted to a specific organ (Carrasco *et al*. 1997; Guillot *et al*. 1997). True mucormycosis is extremely rare in horses. Rosmini (1982) reported systemically disseminated mucormycosis in a 4-year-old stallion in which nodular fungal granulomata were identified in the spleen, liver, kidneys, aorta and bones during post-mortem examination. In another report, mucormycosis resulting from *Absidia corymbifera* infection caused an intensely pruritic ulcerative granulating lesion with draining tracts in the forelimb of a 5-year-old Spanish Thoroughbred broodmare (López-Sanromán *et al*. 2000). Treatment with both systemic and topically administered amphotericin B was attempted but improvement in the lesion did not occur. The mare eventually aborted, developed anorexia, episodes of fever and loss of bodily condition, leading to euthanasia (López-Sanromán *et al*. 2000). In that case, there was no evidence of mycosis in internal organs at post-mortem examination.

In another case, disseminated internal infection by both *Aspergillus fumigatus* and *A. corymbifera* led to a rapidly fatal clinical course in a 6-year-old pony mare with clinical signs that included hyperthermia and pulmonary abnormalities (Thirion-Delalande *et al*. 2005). Post-mortem examination of that pony revealed severe necrohaemorrhagic colitis, splenitis, encephalitis and pneumonia. The fungal pathogens were not uniformly distributed throughout affected organs; there was acute invasive concomitant aspergillosis and mucormycosis of the colon and lungs, whereas the brain and spleen were affected solely by mucormycosis. Extensive petechial and ecchymotic haemorrhage throughout the internal organs

resulted from generalised fibrinoid vasculitis and thrombosis with fungal hyphae both within and around vessels (Thirion-Delalande *et al*. 2005). Dual mycotic infections are exceptionally rare (Carrasco) and that report emphasised the value of immunohistochemistry in order to differentiate the fungal pathogens and to confirm the mixed fungal infection (Thirion-Delalande *et al*. 2005). In other reports of dual fungal infection with both aspergillosis and mucormycosis, the patterns of infection were different (gastric aspergillosis associated with disseminated mucormycosis and concomitant pulmonary aspergillosis and mucormycosis) (Carrasco *et al*. 1997; Guillot *et al*. 2000).

Whereas most clinical cases of mucormycosis in both human and equine individuals are sporadic, and reports refer to single cases, Guillot *et al*. (2000) reported an outbreak of mucormycosis resulting from infection by *A. corymbifera* in a group of 15 French ponies aged between 1 and 6 years. Infection was presumed to have been from an environmental source (and not contagious). Of that group, four affected ponies died within a few days of onset of disease. Clinical signs in infected ponies included fever (39–42°C), diarrhoea and neurological signs (circling, seizures). One of the surviving ponies developed cutaneous ulcers at the muzzle, nostrils and lips. Microbiological culturing of biopsied skin lesions failed to grow *A. corymbifera*, and fungal pathogen identification was ascertained by immunohistochemistry.

Grossly visible mucormycotic lesions identified during post-mortem examination consisted of focal nodular areas of necrosis (10–60 mm in diameter) with a red line of demarcation throughout the lining of the gastrointestinal tract with subjacent submucosal oedema (Guillot *et al*. 2000). Focal necrotic nodules were also present in the pharyngeal mucosa. Vascular lesions were extensive and led to thrombi and infarction with haemorrhage in the lungs and in the brain. Hyphal elements were observed microscopically in affected tissues using periodic acid-Schiff and haematoxylin and eosin (H&E) staining and were morphologically characterised as thin-walled hyphae (10–20 μm) lacking regular septation or branching, consistent with mucormycosis. Although immunohistochemical studies confirmed that the intestinal, pulmonary and cerebral lesions resulted from infection by *A. corymbifera* (microbiological culturing yielded negative results), fungal hyphae in the gastric lesions were only positive for *A. fumigatus*. Subsequent reappraisal of the histopathological appearance of hyphae in gastric lesions determined that their histomorphology (narrow, septate, regular-branching hyphae of consistent width) was more consistent with *A. fumigatus*.

Other descriptions of likely equine mucormycosis cases have been based not on microbiological culturing or immunohistochemical confirmation but have depended on histomorphological features of observed hyphae (Austin 1976; Peet *et al*. 1981; Muttini 1982; Whitton and Kannegieter 1996). In those reports, mucormycosis was suspected because numerous, broad, irregularly branching, nonseptate hyphae were recognised in the wall of thrombosed blood vessels and in adjacent necrotic tissues. In most of those cases, fungal lesions typically involved several organs including the lungs, heart, kidneys, spleen, liver, stomach, large and small intestine, bones or brain. Grossly evident lesions were commonly described as either small white nodules (5–10 mm) or large infarcted areas. Cutaneous manifestations of mucormycosis, as described by Guillot *et al*. (2000) are clearly extremely rare (López-Sanromán *et al*. 2000).

Identified risk factors for mucormycosis in people have included poorly controlled diabetes mellitus, immunosuppression, excessive use of antimicrobials, corticosteroids and intravenous drug abuse (Ellis 1998). Corticosteroid treatment and accommodation in a heavily contaminated environment have been suggested to be risk factors in some equine cases (Austin 1976; Peet *et al*. 1981; Moore *et al*. 1993; Carrasco *et al*. 1997).

Necrotising mycotic vasculitis and systemic aspergillosis represent an uncommon complication of ulcerative enterocolitis in horses (Slocombe and Slauson 1988; Rosenstein and Mullaney 1996; Sweeney and Habecker 1999; Tunev *et al*. 1999; Alves *et al*. 2018). In these cases, it is likely that systemic mycotic dissemination originates from ulcerated areas of the gastrointestinal tract in patients that are immunocompromised (leukopenia, immunoparalysis, hypoproteinaemia) as a result of sepsis/endotoxaemia. Although aspergillosis has been implicated in most of these cases (Slocombe and Slauson 1988; Rosenstein and Mullaney 1996; Sweeney and Habecker 1999; Tunev *et al*. 1999; Alves *et al*. 2018), mucormycosis (associated with disseminated *A. corymbifera*) or dual mucormycosis/aspergillosis infections have also been reported in some cases of colitis (Carrasco *et al*. 1997; Guillot *et al*. 2000; Thirion-Delalande *et al*. 2005).

As recognised in the accompanying report regarding conidiobolomycosis (Zetterstrom *et al*. 2021), mucormycotic infections (and other Zygomycoses) in horses have also occasionally been historically misattributed to and confused with *Pythium insidiosum* (pythiosis or 'swamp cancer'), an oomycete (Austwick and Copland 1974). Cutaneous lesions associated with both pythiosis and zygomycosis (usually *Basidiobolus ranarum*) are characterised by pyogranulomatous and eosinophilic inflammation with broad, sparsely septate hyphae. Therefore, cutaneous lesions resulting from pythiosis and zygomycosis have been previously referred to collectively as phycomycosis (Grooters 2014). In light of the fact that the epidemiology, treatment and prognosis differ between the two types of infection, the diagnostician should employ microbiological culturing and immunohistochemical approaches in order to establish a definitive aetiology in these cases.

The order of Entomophthorales includes two genera: *Basidiobolus* and *Conidiobolus*. Disease associated with the Entomophthorales fungi (*Conidiobolus coronatus*, *Conidiobolus incongruus*, *Conidiobolus lamprauges* and *B. ranarum*) has been more commonly reported in the equine species than for the Mucorales. In contrast to the Mucorales, Entomophthorales fungi cause disease in immunocompetent individuals (Vilela and Mendoza 2018). Entomophthorales fungi tend to cause chronic localised infections and the formation of solid tumefactions in integumentary subcutaneous tissue (basidiobolomycosis) or in the lining of the nasal passages and nasopharynx of horses (conidiobolomycosis).

Most human cases of zygomycosis associated with Entomophthorales fungi are seen in people living in tropical and subtropical parts of the world, especially in Africa and Asia. Cases of basidiobolomycosis and conidiobolomycosis are most commonly encountered in horses in the south-eastern parts of the United States and along the eastern and northern coastline areas of Australia (Miller 1983; Zetterstrom

et al. 2021). Entomophthorales fungi are widely distributed saprophytic species that are found in soil, decaying plant matter and contaminated water. *Basidiobolus* spp. are also found in insects and in both reptilian and amphibian faecal material (Vilela and Mendoza 2018). Host infection likely occurs as a result of the transfer of soil-derived spores through minor trauma or insect bites (basidiobolomycosis) or the inhalation or ingestion of spores (Grooters 2014).

Conidiobolomycosis is also known as rhinoentomophthoromycosis (or rhino-facial conidiobolomycosis) in the human medical field, where it is encountered as a rare, grossly disfiguring disease due to infection by entomophthoralean fungi (Blumentrath *et al*. 2015; Vilela and Mendoza 2018). In horses, reports of disease associated with conidiobolomycosis indicate that it is restricted to the nasal passages and nasopharynx (**Fig 1**). The accompanying article provides a comprehensive review of conidiobolomycosis in horses (Zetterstrom *et al*. 2021).

Although *B. ranarum* (formerly *B. haptosporus*) infection usually results in cutaneous or subcutaneous lesions that resemble those of pythiosis, they are more commonly identified at the lateral aspects of the head, neck, thorax or abdominal wall. Pythiosis lesions are more commonly found at the distal aspects of limbs, the ventral aspect of the abdomen or thorax, or on the face (Grooters 2014). The lateral position of lesion location likely results from infection via ground contact during recumbency. *Basidiobolus ranarum* lesions are usually singular, somewhat circular, ulcerative, granulomatous masses with an oedematous and serosanguineous surface. Like pythiosis, lesions are also often pruritic and become aggravated by self-trauma. *Basidiobolus* lesions may have kunkers but they tend to be smaller (<2 mm) than those associated with pythiosis (Grooters 2014). In rare instances, internally invasive infections by *B. ranarum* have led to gastrointestinal and retroperitoneal lesions in some affected people (Nazir *et al*. 1997; Yusuf *et al*. 2003; Mathew *et al*. 2005). Internal infection by *B. ranarum* has not been reported in horses to our knowledge.

As described in the accompanying article, one of the identifying histopathological features of entomophthoralean fungi (but not Mucorales) in healthy (immunocompetent) mammalian hosts is the genesis of the Splendore-Höeppli phenomenon, an eosinophilic inflammatory response (as seen microscopically using H&E and periodic acid-Schiff staining) that surrounds invading coenocytic hyphae (Vilela and Mendoza 2018). The Splendore-Höeppli phenomenon is also identified in the context of inflammatory reactions to Oomycota pathogens (*P. insidiosum*, *Lagenidium* spp, *Paralagenidium* spp.), other fungi, invading parasites and bacteria, and with inert structures such as silk sutures (Vilela and Mendoza 2018). The Splendore-Höeppli phenomenon results from the accumulation and degranulation of eosinophils (and other inflammatory cells) at the hyphal-host interface; localised tissue damage is attributed to the result of the release of proteases and other enzymes by hyphae and

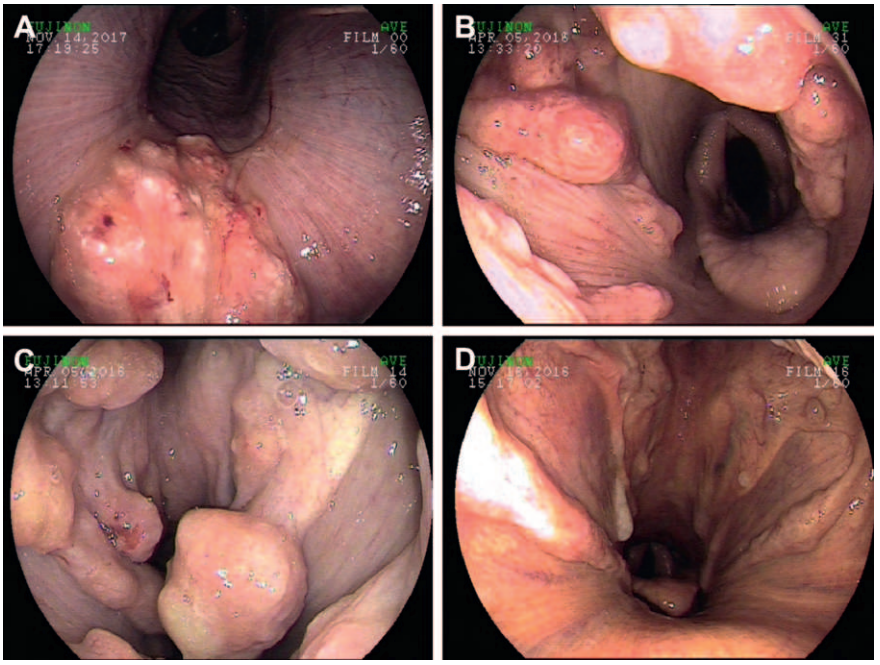

Fig 1: Representative endoscopic images of nasal/nasopharyngeal conidiobolomycosis obtained from two resident Missouri horses. An ulcerative, haemorrhagic, tumefaction at the ventral aspect of the nasal passage (and rostral to the soft palate) is depicted from a 15-year-old American Quarter Horse gelding that had been presented with chronic serosanguineous nasal discharge (A). Extensive nasopharyngeal tumefactions are depicted from a 13-year-old Arabian mare, presented with both chronic serosanguineous nasal discharge, sonorous breathing and exercise intolerance (B, C). The appearance of the nasopharynx of the Arabian mare is depicted following treatment with a combination of sodium iodide and potassium iodide over the period of 7 months (D). It can be seen that, along with clinical remission of nasal discharge and improved stamina, tumefactions have been significantly lessened by treatment (although the endoscopic appearance of the nasopharynx is still abnormal).

the release of cytotoxic compounds by granulocytic cells, creating an eosinophilic blanket. It has been suggested that the phenomenon represents an evolutionary strategy by some pathogens to shield important antigens from the host's immune system, thus facilitating survival in infected hosts (Mendoza and Newton 2005).

Incidents of disease and outcomes of treatment of horses infected with *Basidiobolus ranarum* have been rarely reported in the literature. Potassium iodide has been the traditional treatment approach for *Basidiobolus* skin lesions in people. In one report of two horses, cutaneous phycomycosis attributed to *B. ranarum* infection was successfully treated using a combination of potassium iodide and surgical excision (Owens *et al*. 1985). As noted by Zetterstrom *et al*. (2021) in the accompanying article, surgical resection alone is not reliably effective for the management of infections caused by entomophthoralean fungal pathogens (*Basidiobolus* or *Conidiobolus* spp.). Although treatment relies on a combination of surgery and traditional antifungal drugs (potassium iodide, amphotericin B, itraconazole and ketoconazole), the relative infrequency of entomophthoralean fungal infections has precluded the establishment of well-defined drug recommendations (dosage, duration and the best antifungal drug selection) in both the equine and human medical fields. It should be emphasised that Entomophthoralean fungi are often intrinsically resistant to some of the available antifungal drugs, necessitating some therapeutic experimentation with different drugs or combinations of drugs (Vilela and Mendoza 2018).

Review of recent literature shows that, from the human perspective, chronic, persistent or progressing cases of entomophthoramycosis respond unfavourably to currently available monotherapies (Blumentrath *et al*. 2015; Shaikh *et al*. 2016; Vilela and Mendoza 2018). However, the prognosis is improved if infection is treated early in the course of disease using antifungals, iodine, hyperbaric oxygen, surgery or a combination of those approaches (Blumentrath *et al*. 2015; Shaikh *et al*. 2016).

Pathogenic entomophthoralean fungi (*B. ranarum* and *Conidiobolus* spp.) are regarded as neglected pathogens in the human medical field (Shaikh *et al*. 2016; Vilela and Mendoza 2018). An evident lack of interest in developing new treatments for entomophthoralean fungal infections by the scientific community, the pharmaceutical industry, and funding agencies is likely attributable to the fact that these infections are frequently diagnosed in poor populations of the world, usually as solitary cases (rather than epidemics) (Vilela and Mendoza 2018). The potential efficacy of newer azole antifungals, such as posaconazole, remains to be ascertained.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Each author contributed to the writing of the manuscript. The manuscript has been approved by all authors.

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Case Report

Interleukin 31 and targeted vaccination in a case series of six horses with chronic pruritus

V. Fettelschoss[†‡§,1], F. Olomski[‡§,1], K. Birkmann[§], T. M. Kündig[§¶], K. Bergvall[††] and A. Fettelschoss-Gabriel[†‡§]*

[†]Department of Dermatology, University Hospital Zurich, Schlieren; [‡]Faculty of Medicine, University of Zurich, Zurich; [§]Evax AG, Münchwilen; [¶]Department of Dermatology, University Hospital Zurich, Zurich, Switzerland; and [††]Department of Clinical Sciences, Swedish University of Agriculture, Uppsala, Sweden
**Corresponding author email: antonia.gabriel@usz.ch*

Keywords: horse; pruritus; CPUO (chronic pruritus of unknown origin); IL-31; TSLP

Summary

Chronic pruritus is defined as a skin condition that is associated with clinical signs of itching lasting longer than 6 weeks. Numerous different causes such as hypersensitivity reactions to insect bites, environmental, food or contact allergens may lead to the development of chronic allergic pruritus in horses. The treatment of chronic pruritus is a serious challenge and depends on its cause. Often the causative allergen is unknown, making chronic pruritus of unknown origin (CPUO) difficult to treat. As such a treatment independent of the pruritic allergic trigger is well desirable. Interleukin-31 (IL-31) is a common player in allergic pruritus across species and has been previously associated with pruritus in horses with insect bite hypersensitivity (IBH).

This case series included six client-owned horses with a long history of CPUO that could not be explained by IBH. For all horses, treatment attempts so far remained unrewarding and CPUO progressed. Lesional and nonlesional skin biopsies were taken from three CPUO horses, and levels of IL-31, thymic stromal lymphopoietin (TSLP) and monocyte chemoattractant protein 1 (MCP-1) were quantified. Levels of IL-31, TSLP and MCP-1 were upregulated in all pruritic, alopecic skin lesions when compared to healthy skin of the same horse. Of note, IL-31 and TSLP were not detectable in healthy skin at all. Upon confirmation of IL-31 expression in CPUO lesions, four CPUO horses were subsequently included into a clinical trial using a virus-like particle (VLP)-based therapeutic vaccine eIL-31-CuMV$_{TT}$ targeting IL-31. All vaccinated horses developed anti-IL-31 IgG antibody titres. Clinical signs and pruritic behaviour improved in all four horses upon vaccination with the eIL-31-CuMV$_{TT}$ vaccine (**Fig 1**, representative illustration of case study 2). The vaccine was well tolerated without safety concerns throughout the study. Despite the small patient number and lack of a placebo control group, we propose the anti-IL-31 therapy by active immunisation might be applied as an allergen-independent treatment option for horses with CPUO overcoming the challenges of identifying the allergic trigger.

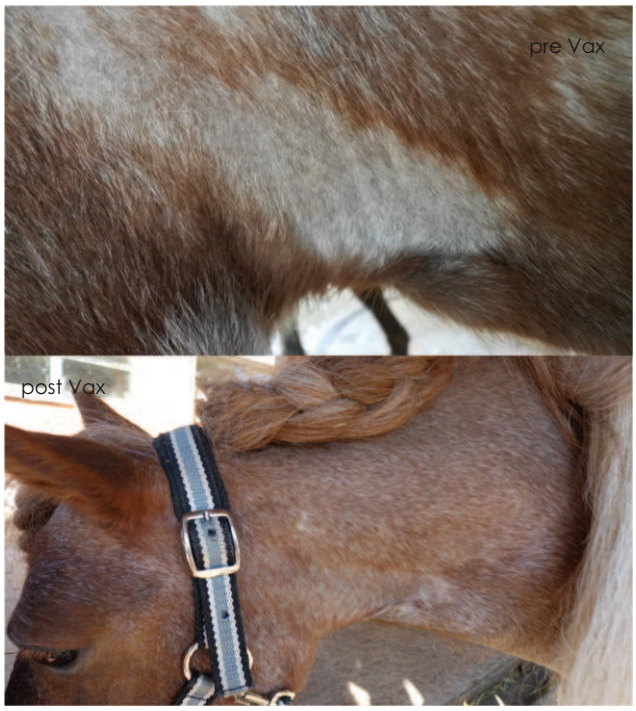

Fig 1: Pruritic skin lesions before and after vaccination, Horse 2. Skin photographs of pruritic site at neck from day of first vaccination (pre-Vax) and from 4 weeks post second vaccination (post-Vax).

Key points

- There is increased expression of IL-31, TSLP and MCP-1 mRNA in lesions from CPUO horses, compared to being not detectable (IL-31, TSLP) or reduced (MCP-1) in nonlesional autologous skin biopsies.
- Therapeutic vaccination using eIL-31-CuMV$_{TT}$ induced anti-IL-31 IgG antibody titres in horses with CPUO.
- Vaccinated CPUO horses showed reduced levels of pruritus and subsequently improvement of skin lesions.

[†]Equal contributions of authors.

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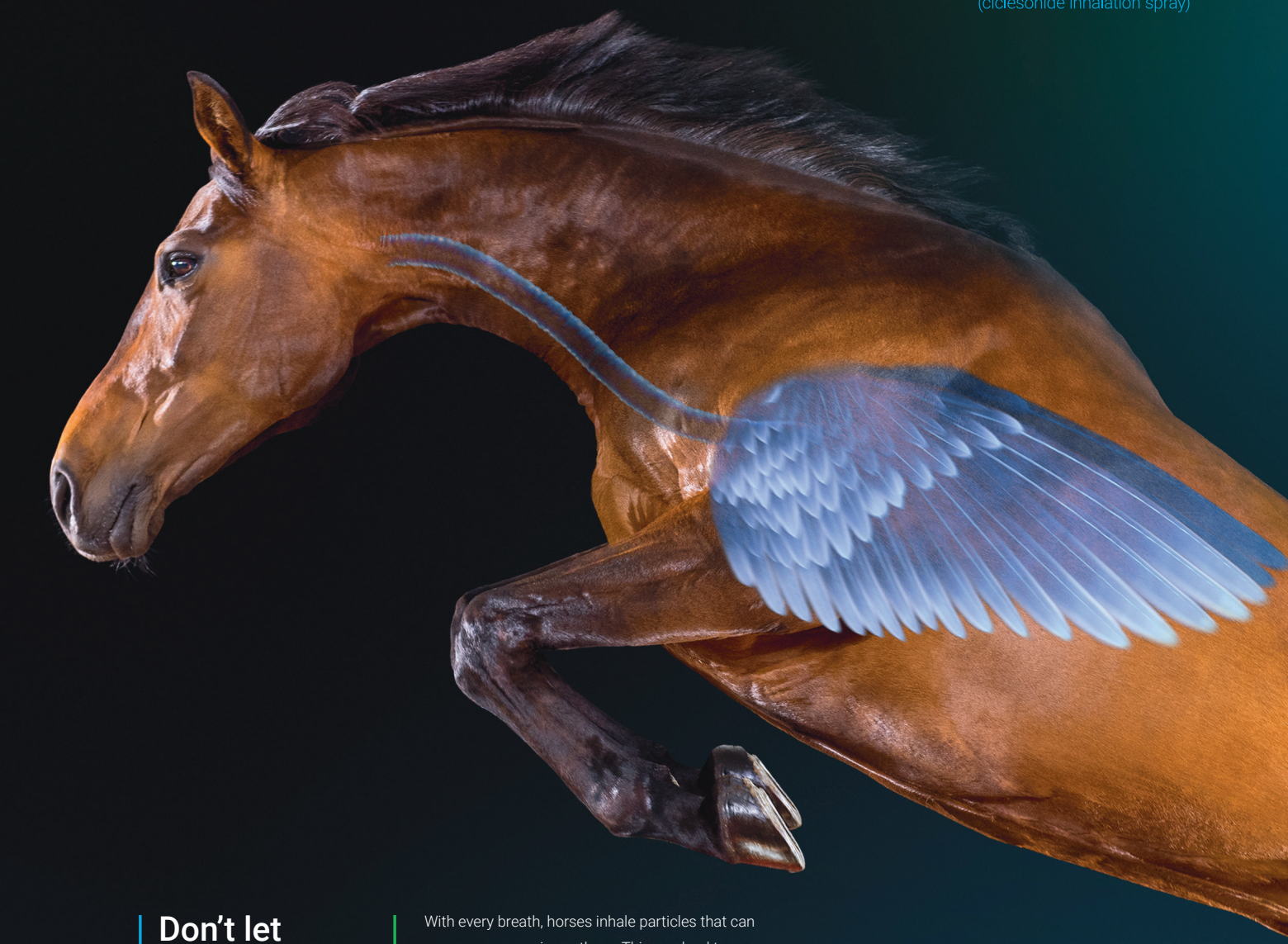

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Clinical Commentary

Control of chronic allergic pruritus in horses

S. L. White

Department of Large Animal Medicine, College of Veterinary Medicine, University of Georgia, Athens, Georgia, USA
Corresponding author email: slwhite@uga.edu

Chronic pruritus (CP) in horses is one of the most frustrating conditions for veterinarians and owners to manage. The sensation of itch leads to self-inflicted trauma, alopecia, crusting and moderate-to-severe secondary skin lesions that adversely affect the horse's comfort, results in visual disfiguration and may affect the horse's ability to work. Ectoparasites (biting flies and midges, lice, trombiculides and ticks), infections (bacterial or fungal), immune-mediated diseases (pemphigus or cutaneous vasculitis), contact allergies, drug reactions, atopy and rarely food allergies may all result in CP (White 2015). Many causes of pruritus are readily diagnosed and treatable; however, there are horses with pruritus in which the inciting agent(s) or disease process is difficult to identify and hard to control.

Horses with sustained pruritus that exhibit seasonal exacerbation of clinical signs are most often hypersensitive to the salivary proteins of haematophagous *Culicoides* spp. The distribution of biting *Culicoides* spp is worldwide (except for Iceland) and the incidence of insect bite hypersensitivity (IBH) within horse populations varies from 3 to 60% (Schaffaritz *et al*. 2012). Most cases of IBH resolve with the change in season, although clinical signs may be present throughout the year in long-standing cases of IBH. Other horses with sustained pruritus, as in the cases presented by Fettelschoss and coworkers (2021) in this issue, may show clinical signs of pruritus and subsequent secondary skin lesions that are not due to biting insects, continue throughout the year and or show initial clinical signs of pruritus during the winter months in which an aetiology cannot be determined.

Atopy is the second most common reason for CP in horses and is similar to that found in man and dogs (Fadok 2013; Marsella 2013). Allergic reactions in atopic individuals develop to common environmental antigens; no new substances need to be introduced to initiate the clinical disease. Horses with IBH and atopic individuals have a dysregulation of the immune system characterised by a strong Th2 response, a relative overproduction of cytokines IL-4, IL-5, IL-6, IL-13 and IL-31 and subsequent production of IgE. The allergic reaction is characterised by both an immediate and late phase type I reaction and, in chronic IBH, with type IVb. Lack of suppression of the Th2 response by T-regulatory cells further enhances the immune response (Schaffaritz *et al*. 2012; Fadok 2013).

Other than identification of offending allergens by removal and challenge, the diagnosis of CP in horses is imprecise. IBH is diagnosed by the presence of *Culicoides* spp, seasonality of clinical signs and the distribution of lesions. Atopy is diagnosed by exclusion of other known disease entities. Identification of offending allergens is currently done by serologic testing for the presence of specific IgE antibodies or the tissue response to intradermal injection of allergens. Serologic testing by ELISA determines the presence of circulating IgE to specific antigens and, in the case of IBH, does not indicate if the antibodies are responsible for the skin reaction and subsequent pruritus (Peters *et al*. 2013; Meulenbroeks *et al*. 2015). Intradermal skin testing (IDT) determines the presence of specific IgE in the skin; however, positive reactions occur in horses without IBH or atopy (Wagner *et al*. 2009). Both tests depend on the use of regionally appropriate antigens (Sloet van Oldruitenborgh-Oosterbaan *et al*. 2009). Intradermal testing also depends on the purity and concentration of the antigens used and the experience of the person performing the test (Baxter and Vogelnest 2008). To date, there is no standardisation for either serologic or intradermal tests and results are variable. Both tests are used to identify antigens to use in allergen-specific immune therapy (ASIT) and not for diagnosis. Many horses appropriately tested and treated with ASIT improve; however, treatment time to effect is prolonged and the subsequent development of an allergic response to solutions with multiple antigens is possible (Stepnik *et al*. 2012; Ginel *et al*. 2013; Radwanski *et al*. 2019).

The best management of allergic dermatitis is the avoidance of allergen exposure and depends on the identification of the allergen(s). Even with the best of farm and horse management, complete avoidance is often not possible. In other cases of CP, the offending allergens cannot be identified. Thus, current treatment is symptomatic consisting of topical and systemic medications used to reduce the sensation of itch and decrease the immune response (Marsella 2013; White 2015). Systemic medications to diminish the immune response and pruritus are dosed by weight and must be given frequently. Furthermore, possible adverse side effects, particularly with corticosteroids, may limit their long-term use.

In horses with IBH and atopy infiltration of affected skin with eosinophils is a hallmark of the allergic response (Brosnahan 2020). IL-5 recruits, activates and sustains eosinophils which in turn secrete IL-5 and which help maintain the eosinophil infiltrate, perpetuating the immune response and contributing to tissue damage (Bagci and Ruzicka 2018). Recently, Fettelschoss-Gabriel and coworkers (2018) developed a vaccine linking equine IL-5 to a virus like particle derived from a cucumber mosaic virus with a tetanus toxoid epitope (eIL-5CMV$_{TT}$). In an initial clinical trial, 34 Icelandic horses with IBH were either immunised 5 times with the eIL-5CMVtt or placebo. The year prior to vaccination all horses were untreated and clinical lesion scores were determined periodically throughout the insect season. Blood samples were obtained to determine the concentration of eosinophils and IgE levels to *Culicodes* spp by a commercially available test. Skin lesion scores were recorded as before. Forty-seven per cent of vaccinated horses had an improvement in clinical scores by 50% and 21% improved by 75%, whereas 13% of control horses improved by 50%. IgG

antibody titres to CVM_{TT} were measured to indicate vaccine response. No adverse reactions occurred.

In a follow-up study, horses previously given the eIL-5CMV_{TT} vaccine were given a booster prior to the beginning of the insect season (n = 17) and the former control horses (n = 13) were vaccinated at 0, 4 and 19 weeks (Fettelschoss-Gabriel *et al*. 2019). Skin lesion scores, concentration of blood eosinophils and antibodies to CVM_{TT} were determined as before. Horses vaccinated for the second year had a later onset of skin lesions and improved skin lesion scores compared with the previous year. Improvement in skin lesion scores in horses vaccinated for the first year indicated a less intense vaccination regimen produced significant improvement in skin lesion score. A longitudinal safety study of vaccinated horses had no general adverse effects of the vaccine and a strong B cell response with the production of IgG to IL-5 and CMVtt without the production of IL-5 specific T cell responses (Jonsdottir *et al*. 2020).

The sensation of itch is transmitted by unmyelinated peripheral C fibres in the epidermis and dermal–epidermal junction. A minority of the fibres are sensitive to histamine, other fibres, termed cowhage-sensitive fibres, are activated by IL-31. IL-31 is released by Th2 cells, mast cells, eosinophils, basophils and keratinocytes (Peters *et al*. 2013; Morin and Misery 2019). A complex interaction of inflammatory cells and keratinocytes post-IL-31 binding and subsequent mediator release is thought to prolong the itch-scratch cycle and tissue damage (Bagci and Ruzicka 2018; Wang and Kim 2020). Interleukin-31 binds to the cell body of nociceptive C fibres in the dorsal root ganglion directly linking the immune response to the neurological system (Morin and Misery 2019). In human medicine and dogs, monoclonal antibodies to IL-31 have been shown to reduce the sensation of itch in pruritogenic dermatologic diseases. Passive immunisation with monoclonal antibodies for therapeutic use in the horse would require frequent administration of a weight dependent dose. Thus, they are unlikely to be financially practical in horses.

Olomski and coworkers (2020) have demonstrated the presence of IL-31 in peripheral blood mononuclear cells and in biopsies of affected skin in horses with IBH.

A vaccine against equine IL-31 produced by the same technology as the eIL-5CMV_{TT} vaccine was used in a double-blind placebo-controlled trial (n = 18) in Icelandic horses with IBH. Skin lesions were documented periodically by photography and pruritic behaviour were scores kept by owners. A significant reduction in pruritic behaviour and skin lesion scores was seen in vaccinated horses; no adverse side effects occurred. In this issue, Fettelschoss and coworkers (2021) demonstrated the presence of IL-31 in skin biopsies in horses with chronic pruritic allergic dermatitis not due to IBH. Four horses of different breeds with year-round CP of unknown origin were vaccinated similarly to the horses with IBH. All horses responded with improved skin lesion scores and a reduction of pruritic behaviour.

From the results of the studies cited here, the use of the IL-5 and IL-31 vaccines provides control of the inflammatory response in the skin and reduction of pruritus in horses with allergic dermatitis without the need for specific allergen identification. It is important to note that skin lesion scores and pruritus in the majority of the Icelandic horses with IBH in the clinical trials using IL-5 and IL-31 vaccination improved but did not completely resolve (Fettelschoss-Gabriel *et al*. 2018; 2019; Olomski *et al*. 2020). Part of the improvement in clinical signs may have been due to a decrease in the degree and length of exposure to offending allergen(s) due to environmental or management factors. Similar results were seen in the four horses of different breeds with CP of unknown origin indicating the vaccine against IL-31 may be useful in horses with a variety of conditions resulting in pruritus. Thus, larger controlled clinical trials in multiple breeds are needed to further determine vaccine efficacy. Nevertheless, partial improvement in pruritus and skin lesions in horses with allergic dermatitis would allow a decrease in the need for medications currently used that require frequent administration of weight based doses, may result in adverse side effects and or are prohibited in horses in competition. Use of these vaccines will not replace the need to search for the inciting cause nor negate the necessity of management to decrease allergen exposure. Their use, however, would be a substantial step forward in providing horse comfort and minimising chronic skin lesions.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this clinical commentary.

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Original Article

Freehand magnetic needle guidance technology for intra-articular cervical injection in horses

P. Crecente [†]* ***, D. Argüelles*** [‡] ***and M. Cifuentes*** [§]

[†]*Hospital Equinum, Brexo-Lema, Cambre, Spain;* [‡]*Hospital Clínico Veterinario de Córdoba, Universidad de Córdoba, Córdoba, Spain; and* [§]*Department of Anatomy, Animal Production and Clinical Veterinary Sciences, University Santiago de Compostela, Lugo, Spain*
**Corresponding author email: info@hospitalequinum.com*

Keywords: horse; ultrasound-guided; navigation technique; cervical facet injection; magnetic

Summary

The use of ultrasound-guided injections is a widely known and well-established procedure in equine medicine not only for intra-articular procedures but also for treating injuries affecting soft tissues. The aim of this study was to compare the conventional ultrasound-guided technique (CUGT) with a modified ultrasound-guided magnetic navigation technique (MUGT) in the articular process joints spaces of the cervical vertebrae. The aforementioned techniques were compared by measuring the degree of difficulty, the time employed and the success of the procedure (injecting blue methylene into the articular process joints spaces of cadavers to allow us to know whether the procedure was successful). Neck specimens from 11 cadavers were used to conduct this study. To compare the two different techniques, the articular process joints spaces of 11 specimens were injected bilaterally using ultrasound guidance, using one technique on each side. One millilitre of methylene blue was injected into the C2-C3, C3-C4, C4-C5 and C5-C6 articular process joints; then, these joints were dissected to verify the success rate of the injections. The results were similar regarding the success rate of the procedure; however, there were differences in the time employed (25.0 s median runtime for MUGT vs. 32.1 s median runtime for CUGT) and the degree of difficulty (1.3 attempts on average for MUGT vs. 2.4 attempts on average for CUGT). According to the results of this study, MUGT involved less difficulty and slightly less time employed to inject the cervical articular processes joints than CUGT; however, further studies in live horses are needed to assess the efficiency of this method, and studies in other joints or soft tissues are needed to validate the method. This new technique could also improve other equine ultrasound-guided procedures, such as nerve blocks, ultrasound-guided tendon/joints treatments or other articular injections.

Introduction

Several studies have demonstrated various benefits of ultrasound-guided regional anaesthesia, and its success rates and cost-effectiveness have increased, thus improving post-operative analgesia and recovery (Hadzic *et al*. 2005), and intraneural and intravascular puncture and injection are avoided. Out-of-plane needle penetration using the magnetic guidance system take into account these important aspects of patient safety.

The magnetic ultrasound-guided technique, or MUGT, created for human anaesthesiology purposes, can be applied easily to many equine veterinary procedures.

The treatment and diagnostic analgesia of cervical articular process joints can be challenging due to the complex palpation and identification of the articular facets (Berg *et al*. 2003). Approximately 50% of clinically normal horses may have degenerative changes of the articular process joints at C6-C7 (Mattoon *et al*. 2004). Diseases of the cervical articular process joints (APJ) including osteoarthritis, osteochondrosis or fractures are a significant source of morbidity in horses (Rooney 1969; Stewart *et al*. 1991; Powers *et al*. 1992; Ricardi and Dyson 1993).

Therefore, ultrasound-guided injections, whether periarticular or intra-articular, are the most common treatment for the aforementioned problems (Ross and Dyson 2003). However, this technique is somewhat limited as it is not easy to see the needle in the axial plane of the ultrasound beam.

Ultrasound-guided procedures, such as cervical articular process injections, require the precise placement of the needle tip within a finite 3D space with little margin for error. Novices, and even expert clinicians, are liable to misjudge the position of the needle tip using the standard technique. This is even more so in live horses due to small movements that may occur (e.g. reaction to needle penetration, skin pain during penetration) when using an ultrasound-guided injection, which could mean not seeing the needle in the screen of the ultrasound, leading to the potential for serious injury such as inadvertent penetration of the spinal cord parenchyma.

The ultrasound-guided approaches of the injection of the cervical articular process joints described above can be performed using a linear or convex transducer probe. The articular processes are the most dorsolateral structures and form a characteristic echogenic interface. This is referred to as the 'chair' sign (Mattoon *et al*. 2004). The joint space is located at the junction of the cranial and caudal processes, identified as an anechoic gap between the two articular processes, and the needle can be inserted cranial or caudal to the probe.

We used two techniques in the current study: a traditional one using a conventional microconvex probe and a new technique using a freehand magnetic needle navigation probe. The new modified ultrasound-guided magnetic navigation technique presented (MUGT) was compared with the conventional ultrasound-guided technique (CUGT) for validation.

The authors hypothesised that MUGT would improve the success rate and reduce the procedure time and difficulty for performing cervical articular process joints injections

compared with conventional ultrasound-guided technique (CUGT).

Our hypothesiswas that, due to this novel guidance technology, the visualisation and projection of the needle tip could be potentially simplified using real-time navigation because operators do not need to constantly check whether the needle is in the axial plane of the ultrasound beam and to check whether the angle of penetration is the right one to reach the articular joint.

Cervical articular process joints are formed by the caudal articular process and the cranial articular process of two vertebrae. The transverse process of the first cervical vertebra is easily palpated. Using the width of a hand, similar to the length of one cervical vertebra, as a reference, the approximate area of a specific articulation can be located. The transverse process is palpated, and the probe placed on it, and the probe slided 5–7 cm along the dorsal part of the vertebrae.

The joint space is found by sliding the probe from caudal to cranial in this position, and it is in a different location depending on which cervical vertebrae is being imaged.

There is a cranial recess just below the most cranial part of the joint running in a ventral direction. Synovial fluid from the joint is not always obtained, mainly because of the presence of a synovial fold between the articular processes in 94% of the horses. Moving the probe cranially to the joint space, the area appears to be bigger; however, it is possible to insert the needle outside the joint, and moving it too caudally, the space is smaller and consequently more difficult to penetrate. The middle point is where it is easiest to see the articular surface including the dorsal part and, in some cases, the spinal cord.

Materials and methods

Eleven cadaveric specimens, employed for anatomic dissection lessons of the university (USC-Spain), were used in this study. The eleven cadavers were injected under ultrasound guidance in the C2-C3, C3-C4, C4-C5 and C5-C6 joint spaces on each side. C6-C7 were not included in this study because the MUGT system uses a linear probe with only 5.5 cm of maximum penetration.

One side was injected using CUGT (Esaote MyLab 30 gold with a 3.5–7.5 Mhz microconvex probe[1]), whereas on the other side MUGT was used (eZono 4000 with a 6–12 MHz linear probe with a magnetic navigation system[2]). The sides of the neck were alternatively changed for CUGT and MUGT from one horse to another, as it could theoretically affect the success rates (outcomes) for one treatment over another. A 0.9 × 75 mm spinal needle (Becton Dickinson[3]) was used for both techniques. Methylene blue was injected in each joint space (1 mL)[4]. The injections were performed by one operator who used the left hand for the probe and the right hand for the needle.

Each horse neck was placed over a dissection table in a horizontal position, clipped with a number 40 blade and then washed. The transverse processes of the vertebrae were located by palpation. From that position, the probe was slid slightly dorsally until the articular joint with the cranial and caudal articular processes and an anechoic area created by the joint space in the middle were found.

In the MUGT method, the eZono 4000 was built around a proprietary needle navigation technology (termed 'eZGuide') that allows the clinician to manipulate the needle in any plane and receive real-time, colour-coded feedback on its position relative to the transducer shown in the ultrasound image. The technology involves the use of magnetic sensors that are used in a sterile environment, in the transducer, and requires the clinician to magnetise the needle immediately before commencing the procedure using a sterile magnetiser.

The needle is inserted into the centre of the magnetiser cup (under sterile conditions), so that the tip touches the rubber surface at the bottom, is held for 1–2 s and is then withdrawn. In this manner, the first longitudinal 3.5 cm of the needle will become magnetised and exhibit magnetic polarity (**Fig 1**). It is important that the needle tip is inserted all the way to the bottom of the cup so that a magnetic signature of consistent length is achieved.

The range is 35 mm from needle tip to the plane of the ultrasound image. Based on the real-time information of needle orientation and position, the software is able to extrapolate the trajectory through the tissue and indicate it to the user (Nichols and Sobrino 2016).

The positioning information is communicated back to the clinician using colour-coded lines and graphics on the ultrasound screen. The extent of the needle penetration along that trajectory is marked by a dotted line bounded by a set of two solid parallel lines. These lines represent the outside confidence limits for the position of the needle, whereas it is likely that the needle is very close to the midpoint between these two; even if not seen, the needle is between the lines. The distance between these lines is always the same because the length of the magnetic needle is fixed at 3.5 cm. At the same time, a representation of the needle and its position with respect to the transducer is shown on the left side of the image (**Fig 2**). The remainder of the on-screen graphics will change according to the orientation of the needle with respect to the transducer. If the needle is inserted in-plane, a square box appears on the screen at the distal end of the solid parallel lines to indicate the needle tip position (**Fig 3**).

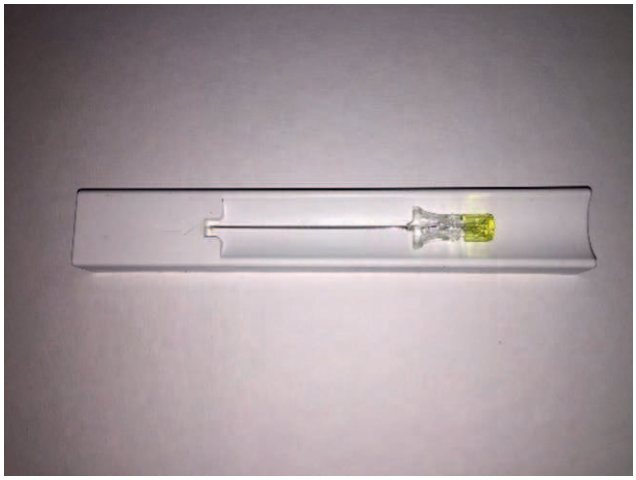

Fig 1: Device used to apply a fix magnetic field to the long needles. The needle is introduced into the magnetising device from the top as shown in the picture, advanced until the tip touches the end of the cavity and removed from the cavity after a couple of seconds. Following this procedure, the needle becomes a magnet that will be detected by the MUGT system.

The eZGuide feature on the eZono 4000 is designed to allow reliable guiding of the needle from any angle with respect to the transducer, not just 0° and 90°. The ability to insert the needle from various oblique angles may be especially advantageous when the target is best visualised in a specific 2D ultrasound plane but when in-plane or 90° out-of-plane insertion may not be desirable for any number of reasons. These include poor ergonomics, the need to access difficult-to-reach spaces and the identification of vulnerable structures such as blood vessels or nerves that lie along the traditional needle trajectory. eZono has termed this functionality 'Free Plane Navigation', alluding to the concept that the needle can approach the transducer in a full 360-degree arch. For this study, average range from 30° to 40° angle to the longitudinal plane of the probe was used. For every injection in the C2-C3, C3-C4, C4-C5 and C5-C6 joint spaces made with both ultrasound-guided methods (CUGT and MUGT), the runtime was measured, the success of the technique was determined, and the degree of difficulty was estimated.

The degree of difficulty was estimated by taking into account the number of attempts needed for each injection until being successful. Every failed attempt means taking out the needle and reorienting it because the needle was out of the joint. It was considered as easy when the goal was achieved in 1–2 attempts or difficult when more than two attempts were needed.

The accuracy of both techniques was classified as failed when injections ended up in periarticular (methylene blue outside the articular capsule) or extra-articular (methylene blue in the fibrous capsule) locations and as successful when the injections ended up in intra-articular locations (methylene blue inside the articular cavity contacting the articular cartilage) (**Fig 4**).

For each ultrasound-guided method and for each articular joint, the number of failed and successful injections was recorded.

Data on the runtime, number of attempts, and technical accuracy (estimated as the number of successful injections per technique) were subjected initially to a two-way ANOVA, with the ultrasound guidance technique and articular joint as factors. As no significant differences were found due to the factor 'articular joint', data from the injections in the different articular joints for each ultrasound guidance technique were pooled, and then, comparisons between CUGT and MUGT data were made by using Student's t test.

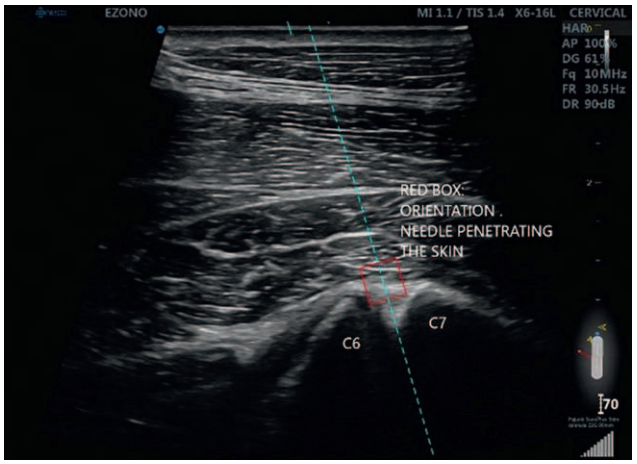

Fig 2: MUGT system: Ultrasound picture before injection of C6-C7 joint, the tip of the needle is in the skin, depicted as two small blue lines in the near field. The dotted blue line shows the trajectory of the needle before penetrating the tissues, and the red box shows the place where the needle is directed to. Left is cranial and right is caudal. Ezono 5000 ultrasound system.

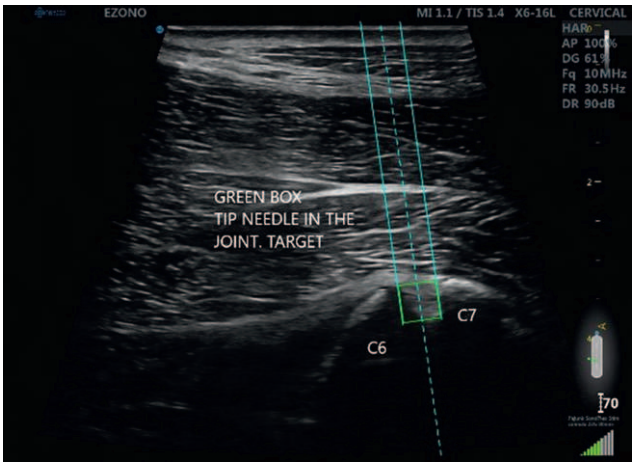

Fig 3: MUGT system: Ultrasound picture showing the tip of the needle in C6-C7 joint (green box). Left is cranial and right is caudal. Parallel blue lines indicate the deepness of the tip needle, when the tip needle gets to the expected area (red box) this turns from red to green. Left is cranial, and right is caudal. Ezono 5000 ultrasound system.

Results

Eighty-eight cervical joints were injected in this study, with 44 used for each technique (MUGT and CUGT) from the C2 to C5 joints (11 in each joint per technique).

Methylene blue was injected in all joints of the eleven cadaveric specimens with the aim of visualising the success of injections. The results are those referring to the parameter 'technical accuracy', and they are provided in **Table 1**.

The average injection time needed using MUGT as the ultrasound guidance method was 25 s in all articular process joints. This time was lower than that required for the injections using CUGT (32.1 s). This was related to the mean number of attempts needed to perform the injections: one attempt

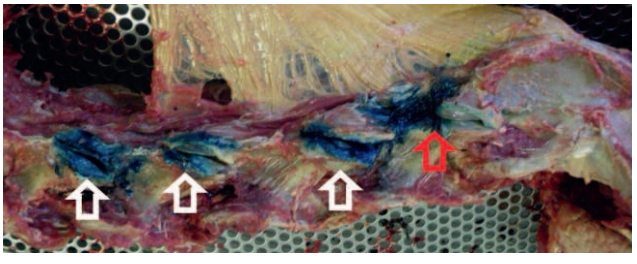

Fig 4: Cervical articular process joints with methylene blue during the necropsy, showing three (white arrows) successful attempts and one (red arrow) failed attempt. Left is cranial and right is caudal.

when using MUGT and two with CUGT (**Table 1**). Within each ultrasound guidance method, there were no differences in the mean number of attempts among articular joints.

The two ultrasound-guided techniques had the same high accuracy, with 8–9 injections ending up in intra-articular locations (**Table 1**).

Discussion

Injection of the cervical articular process joints is widely used to treat joint diseases (Denoix and Dyson 2003). The next step to increase sensitivity and successful treatments in equine medicine is the use of echo-guided injections (Nielsen *et al*. 2003).

Injections of the cervical articular process joints can be easily performed with traditional ultrasound equipment with linear or convex probes by an experienced operator, but for some other practitioners this technique can be challenging.

The use of a standard microconvex or a convex probe offers a wide field and, as a result, more structures can be identified such as both contours of the cranial and caudal facets, part of the lateral process of the vertebrae as well as the intertransversus, multifidus and longissimus muscles. With the linear probe, the window can be smaller (the linear probe is not used in a trapezoidal mode because Ezono 4000 has no trapezoidal mode), allowing identification of both articular margins of the articular joint processes, but there are less reference anatomical structures than with the microconvex probe.

The eZGuide feature on the eZono 4000 facilitates this technique; however, using a linear probe has the inconvenience of having a narrower field and thus having fewer anatomical references. Another handicap is the depth of penetration of the Ezono 4000 transducer, only 5.5 cm, which in some cases is insufficient depending on how fat or big the horse is and what cervical joint is being injected (C6-C7 is placed deeper in some horses and for this reason they were excluded from this study), and consequently on the thickness of the neck. This is solved in the Ezono 5000 (**Fig 5**) that can penetrate 10 cm using MUGT.

Many surgical and medical interventional procedures can be performed by minimally invasive ultrasound-guided techniques in horses, such as the localisation and removal of foreign bodies and fracture fragments in joints, draining of abscesses through needles or surgical procedures such as patellar ligament splitting. The advantages of procedures performed by minimally invasive ultrasound-guided techniques include reduced tissue trauma, reduced procedure time and client cost, and the ability to perform on a standing horse in appropriate cases and situations (Whitcomb *et al*. 2016). The possibility of avoiding vital structures such as nerves, arteries and tissues with variable angles of the needle entry is a huge advantage.

As in all joints, exact positioning of the needle in the articular cervical joint spaces is absolutely necessary, and aspiration of the synovial fluid is recommended to ensure intra-articular placement (Whitcomb *et al*. 2016), especially when injecting anaesthetic agents for diagnostic purposes. When an analgesia diagnostic procedure is performed in the cervical joints, there is a risk of partial anaesthesia of the nerves or spinal cord; therefore, the exact position of the needle in the joint becomes mandatory. Complications of extra-articular deposition may result in undesirable anaesthesia of the motor nerves or be erroneously interpreted as a lack of therapeutic response. Time detection in sport horses for some drugs varies enormously depending on whether the drug is administered exactly in the articular cavity or extra-articularly by mistake. Many studies (Barnsley *et al*. 1994) have demonstrated the clinical importance of intra-articular vs. periarticular (outside articular membrane) injection for the treatment of osteoarthritis in order to evaluate the success of the treatment because obtaining fluid from the joint is often not possible, and response to treatment may be considered as a success of the injection.

A complete study of the ultrasound-guided approach to the cervical articular process joints in horses (Johnson *et al*. 2017) described two approaches, dorsal (D) and craniodorsal (CrD), which showed a marked improvement in success rates with respect to previous studies that only used the D approach.

The CrD approach showed clear advantages in cases of osteophytes and prominent cranial articular process joints and a lower risk of puncturing the cervical canal, nerves or vessels.

With the use of the modified ultrasound-guided navigation technique (MUGT), the operator performance time decreased significantly compared with the use of ultrasound imaging alone. Although MUGT is associated with a nonsignificant increase in the success rate for the intra-articular presence of methylene blue, a significant decrease

TABLE 1: Mean runtime (in seconds per articular joint), number of attempts per articular joint, and technical accuracy (number of successful injections per technique) for the conventional and novel ultrasound-guided techniques used in this study

Ultrasound-guided technique	Runtime (seconds/ articular joint)	Number of attempts/ articular joint	Technical accuracy (number of successful injections/technique)
CUGT	32.1 a	2.4 a	8.2
MUGT	25.0 b	1.3 b	8.7

Within each column, values followed by a different letter are significantly different for $P \leq 0.05$. When comparing time needed to use the two techniques, MUGT needed less time and less attempts than CUGT.

Fig 5: Needle inserted into the joint space under guidance by MUGT in an alive horse, showing out-of-plane needle. Right is cranial, and left is caudal. 30°–40° out of plane in respect to the probe is present.

in degree of difficulty was achieved. The time used to perform the technique was less with MGUT than with CUGT.

One live horse was injected in the C6-C7 (**Fig 5**) joint with radiologic contrast with the modified ultrasound-guided navigation technique to confirm the technique in live horses. The Ezono 5000 with deeper penetration and trapezoidal mode was used for the live horse.

The results were similar regarding the success rate of the procedure; however, there were differences in the time employed (25.0 s median runtime for MUGT vs. 32.1 s median runtime for CUGT) and the degree of difficulty (1.3 attempts on average for MUGT vs. 2.4 attempts on average for CUGT).

The success of the technique (79, 54%) compared with that of other cadaveric studies (95, 4% to 83, 6%) can be appreciated from the results; although in this study, only intra-articular injections were considered compared with other similar studies. Operator experience should be considered as well.

With this new technique, less time, fewer attempts and less difficulty are achieved with the knowledge that the reflection of the needle does not need to be visualised constantly in the ultrasound image. This technique also offers wide possibilities of using different angles in the approach.

Conclusion

MUGT is a new tool used for ultrasound-guided techniques that allows the operator to perform these techniques more easily and faster. Based on the findings of this study, this modified technique increases the success rates in terms of time and difficulty, reducing the number of needle passes through the respective tissues, which consequently may reduce procedure complication rates.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The local committee of ethical requirements was consulted and approved the design of this study.

Authorship

P. Crecente contributed to study design, study execution and data analysis and interpretation. D. Arguelles contributed to data analysis and interpretation. M. Cifuentes contributed to study execution and data analysis and interpretation. All authors contributed to the preparation of the manuscript and gave their approval of the final manuscript.

Manufacturers' addresses

[1]Esaote spA, Florence, Italy.
[2]eZono AG, Spitzweidenweg, Jena, Germany.
[3]Becton, Dickinson and Company, Franklin Lakes, New Jersey, USA.
[4]Genéricos Españoles Laboratorio SA, Las Rozas, Madrid, Spain.

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Original Article

Plantar fasciitis in 19 endurance horses: Diagnosis, treatment and follow-up

***A. Paris*[†], *F. Beccati*[‡§*] and *M. Pepe*[‡§]**

[†]*Private Practitioner, Sigillo (PG);* [‡]*Department of Veterinary Medicine, Veterinary Teaching Hospital of the University of Perugia, Perugia; and* [§]*Sport Horse Research Centre, Department of Veterinary Medicine, University of Perugia, Perugia, Italy*
**Corresponding author email: francesca.beccati@unipg.it*

Keywords: horse; plantar fasciitis; curb; plantar fascia; endurance horses

Summary

Lesions of the peritendinous–periligamentous soft tissues of the tarsus (plantar fasciitis) commonly result in a curb-like appearance and are considered overrepresented in Standardbred racehorses; however, plantar fasciitis is also quite common in endurance horses. Nineteen endurance horses of different ages (median: 7 years; range: 3–13) and athletic activity level comprising a total number of 25 plantar fasciitis cases were described in this study. In nine cases, injury developed during a training session, and in 16 cases, it developed during competition. In 18 cases, there was swelling, heat and pain on palpation, and in six cases, only swelling was detected. Eight cases were not lame at the time of examination, while in 17 cases, lameness ranged from grades 1–3 on the American Association of Equine Practitioners modified grading scale. The degree of swelling was significantly related to the lameness grade. Ultrasonography revealed differing amounts of thickening of the plantar fascia plantar to the superficial digital flexor tendon and peritendinous–periligamentous oedema of heterogeneous appearance. Horses were treated conservatively with several combinations of rest, controlled exercise, ice-therapy, corticosteroids, local application of working counterirritants and therapeutic shoeing. Seventeen of 25 cases (68%) did not develop re-injury after treatment and rehabilitation, whilst eight of 25 (32%) developed one or more re-injury/injuries. Overall, 21 of 25 cases (84%) returned to the previous or a higher level of competition; in one case (4%), the injury was the cause of retirement from athletic activity. Plantar fasciitis can be considered a sport-related injury in endurance horses of all ages and athletic activity level. Re-injury rate is low; however, adequate rest and rehabilitation protocols are important. Plantar fasciitis rarely leads to retirement from athletic activity, but it can result in 2–5 months out of training and competition.

Introduction

Enlargement and swelling over the plantar aspect of the hock and proximal metatarsus is historically defined as curb (Ross *et al*. 2002; Major and Zubrod 2006; Ross and Genovese 2011; Sullins 2011). Several injuries are responsible for this condition, and its cause can include inflammation and thickening of the long plantar ligament, superficial digital flexor tendonitis, and haemorrhage and other types of subcutaneous fluid accumulation (Ross *et al*. 2002; Major and Zubrod 2006; Ross and Genovese 2011; Sullins 2011). There is some confusion regarding the cause of curb. Horses with sickle-hocked conformation are classified as curby (Ross *et al*. 2002; Major and Zubrod 2006); however, horses can show a curby conformation without sustaining injuries that manifest as curb. Additionally, horses with a normal conformation can also develop a curb (Ross *et al*. 2002). The curby conformation is also detected in foals due to collapse of the dorsal aspect of the tarsal bones (Clegg 2003).

A previous ultrasonographic study demonstrated that 68% of horses with curby appearance showed peritendinous–periligamentous swelling with or without the involvement of the superficial digital flexor tendon (SDFT) rather than injury of the long plantar ligament (Ross *et al*. 2002).

Curby appearance as a consequence of lesion of the peritendinous–periligamentous soft tissues is considered a primary injury of racehorses and appears to be overrepresented in Standardbred racehorses, in which it is thought to be due to excessive strain from race training (Denoix and Hernandez 1998; Ross *et al*. 2002; Major and Zubrod 2006; Ross and Genovese 2011; Sullins 2011). Standardbred racehorses more commonly show conformational abnormalities such as sickle-hocked that potentially increase the stress on the distal plantar tarsus; however, a cause-and-effect relationship has not been demonstrated (Ross *et al*. 2002). This peritendinous–periligamentous soft tissue is in the anatomical location of the plantar fascia (Denoix 2019a,b); based on comparative imaging with human medicine, ultrasonographic detection of thickening and hypoechogenicity of the fascia, loss of fibrillar pattern and perifascial fluid accumulation (i.e. peritendinous–periligamentous oedema) supports the use of the term plantar fasciitis to define this injury, as previously reported in 10 horses (Denoix and Hernández 1998).

The incidence of plantar fasciitis in novice and experienced runners ranged from 4.5% to 10% and up to 11% in ultra-marathon runner athletes (Petraglia *et al*. 2017). Lesions of the peritendinous–periligamentous soft tissue (defined as plantar fasciitis) represented 5.1% of orthopaedic injuries detected in 180 endurance horses (unpublished data).

The aim of this study was to describe the history, clinical presentation, ultrasonographic findings, treatment and follow-up of lesions of plantar fascia of the distal aspect of the tarsus in 19 endurance horses. The authors propose to describe lesions of the peritendinous–periligamentous soft tissue of the plantar tarsus as plantar fasciitis, as previously described and named by Denoix and Hernandez (1998).

Materials and methods

Inclusion criteria

Two of the authors (A.P. and F.B.) reviewed the records of horses with acute onset of swelling of the plantar aspect of the distal aspect of the hock and/or proximal aspect of the metatarsus, and ultrasonographic diagnosis of lesions of the peritendinous–periligamentous soft tissue (defined here as plantar fasciitis) examined in the field between January 2008 and September 2019. Horses used for an endurance discipline with a complete clinical and radiographic examination of the affected area were included. Horses used for other disciplines were excluded.

Diagnostic procedure

All horses were examined by two of the authors (A.P. and F.B.); history of presentation was extrapolated from the records and collated along with level of activity of the horse at the time of the injury. The level of activity was considered as novice (30–90 km competition at regular speed [15–16 km/h]), intermediate (80–119 km competitions [free speed]) or elite (120–160 km competitions [free speed]) and referred to the longest competition the horse had participated in or the category in which they were trained. Development of lesions during training or competition was recorded.

Clinical examination consisted of inspection, palpation, evaluation of the gait at walk in a straight line and on the figure of eight, trot in a straight line and a circle (if appropriate, depending on the severity of the lameness), and evaluation of the response to hindlimb flexion test (Ross 2011a) (if appropriate). Abnormal conformation of the hindlimb was recorded. The degree of swelling was classified as mild, when only a small convexity of the area was detected, and moderate/severe, when there was a substantial convexity at the plantarodistal aspect of the hock. The degree of lameness was assigned using the modified American Association of Equine Practitioners grading scaling (Ross 2011b).

Ultrasonographic examination of the tarsus and proximal metatarsus was performed with an ultrasound machine (M-Turbo®)[1] equipped with a 7.5–10 MHz linear transducer with a stand-off pad, using plantar, plantaromedial and plantarolateral approaches in transverse and longitudinal scans (Ross *et al*. 2002). Retrospectively, the degree of thickening of the plantar fascia and amount of peritendinous–periligamentous oedema was subjectively classified (from mild to severe) comparing the findings of the affected limb with that of the contralateral limb. Radiographic examination of the tarsus, including the proximal aspect of the metatarsus, was acquired using lateromedial and dorsoplantar radiographic projections (Butler *et al*. 2017).

Treatment and follow-up

Cases were treated conservatively with several combinations of rest, controlled exercise, ice-therapy, injection of corticosteroids, local application of working counterirritants (iodine solutions/ointments) and therapeutic shoeing; treatment in each case was recorded. Re-injury was recorded as well as time of re-injury. Re-injury was diagnosed by the detection of swelling of the plantar aspect of the hock (curby appearance) and re-injury of the plantar fascia confirmed by ultrasound examination.

Statistical analysis

Statistical analysis was performed using dedicated statistical software packages (JASP Version 0.11).[2] The continuous variable (age) was assessed for homoscedasticity using Shapiro–Wilk's test for normality, and Levene's test for homogeneity of the variance and subsequent tests applied as appropriate. Horses eliminated for reasons other than plantar fasciitis were not included in the statistical analysis for this parameter. Chi-squared or Fisher's exact test was used, as appropriate, to test for differences among level of activity (novice, intermediate, elite), development of the injury during or just after competition (no, yes), degree of swelling (mild, moderate/severe), sickle-hocked conformation (no, yes) and re-injury (no, yes). Mann–Whitney's U test was used to assess differences in age and degree of lameness for development of the injury during or just after competition (no, yes), degree of swelling (mild, moderate/severe), sickle-hocked conformation (no, yes) and re-injury (no, yes). The Kruskal–Wallis test was applied to assess differences in age and degree of lameness, as well as between each of them and the level of activity (novice, intermediate, elite), and Dunn's test was used as a *post hoc* analysis. Significance was set at $P < 0.05$.

Results

Included cases

A total of 19 endurance horses were included in this study. These comprised 11 (57.9%) Arab, six (31.5%) Anglo-Arabian, one (5.3%) Warmblood and one (5.3%) Arab crossbred; 11 (57.9%) were geldings and eight (42.1%) were female. Ten horses had a bilateral sickle-hocked conformation, one had bilateral sickle-hocked and valgus conformation, and another one had bilateral sickle-hocked and varus conformation of the hocks. In seven horses, no conformational defects were identified. Six horses developed the lesion bilaterally, but at different times resulting in a total number of 25 identified plantar fasciitis incidents (each referred to as a 'case' hereafter); 14 involved the right hindlimb and 11 the left hindlimb. The average age of the horses at the time of lesion development was 7.9 years (median: 7 years; range: 3–13); the level of activity was novice in 10 cases, intermediate in five and elite in 10.

Nine cases developed the injury during a training session; plantar fasciitis developed after an endurance resistance training session in five, two cases occurred during breaking in, and after walk and trot training session on up-hills in another two. Sixteen cases developed the injury during competition; the injury was the reason for elimination or retirement from competition in six cases. In 18 cases, there was swelling, heat and pain on palpation of the plantar aspect of the tarsus/proximal metatarsus; in the remaining six, only swelling of the area was detected. The degree of swelling was mild in 13 cases and moderate/severe in the remaining 12. Eight cases were not lame at the time of examination; in the remaining 17, lameness ranged from grade 1 to 3 (median: 2). Hindlimb flexion test was performed in 15 out of 25 cases, and the response ranged from mild to moderate. Additional details of the time of development, and clinical and dynamic examination in each case are presented in **Table 1**.

There was no significant difference between level of activity and development of the injury during competition

TABLE 1: Details of time of development, clinical and dynamic examination in 25 cases of plantar fasciitis detected in 19 endurance horses

Case (*horse*)	Developed in competition	Details 'development in competition'	Elimination from competition	Clinical findings	Lameness grade*	Response to flexion test	Other information
1 *(1)*	Yes	After the end CEI*	No	Mild swelling, heat, pain at palpation	1	++	Lameness resolved in 2 days but positive flexion test (++)
2 *(2)*	No	–	–	Moderate/severe swelling, heat, pain at palpation	2	++	–
3 *(2)*	No	–	–	Mild swelling, heat, pain at palpation	0	+	After 3 weeks worsening during competition and elimination
4 *(3)*	Yes	After the end national 90 km	No	Moderate/severe swelling, heat, pain at palpation	3	Na	Lameness improved the next day but positive flexion test (++)
5 *(3)*	Yes	After the end CEI*		Mild swelling, heat, pain at palpation	1	++	Lameness resolved the next day but positive flexion test (++)
6 *(4)*	No	–	–	Mild swelling, heat, pain at palpation	1	++	
7 *(5)*	No	–	–	Mild swelling	0	–	After 17 days marked worsening during competition (lame grade 3) and elimination
8 *(6)*	Yes	At the 2° VG CEI**	Yes, lame LF	Mild swelling, heat, pain at palpation	0	+	–
9 *(7)*	Yes	After the end national 90 km	No	Mild swelling	0	+	–
10 *(7)*	Yes	After the end CEI**	No	Mild swelling	0	+	–
11 *(8)*	No	–	–	Moderate/severe swelling, heat, pain at palpation	2	++	–
12 *(8)*	Yes	At the end CEI**	No	Mild Swelling	0	–	–
13 *(9)*	Yes	At the 2° VG CEI**	Yes	Moderate/severe swelling, heat, pain at palpation	2	Na	–
14 *(10)*	Yes	At the 3° VG CEI***	No	Mild swelling	0	+	–
15 *(10)*	Yes	At the 3° VG CEI***	Yes	Moderate/severe swelling, heat, pain at palpation	3	Na	Lameness resolved in 2 days. After 2 months re-injury during competition and elimination
16 *(11)*	Yes	At the 3° VG CEI**	No	Moderate/severe swelling, heat, pain at palpation	2	+	Lameness resolved in 4 days but positive flexion test (+)
17 *(12)*	No	–	–	Mild swelling, heat, pain at palpation	1	+	
18 *(13)*	Yes	At the 2° VG, second day CEI***	Yes	Moderate/severe swelling, heat, pain at palpation	3	Na	Lameness improved the next days but positive flexion test (++)
19 *(14)*	Yes	At the 2° VG national 90 km	Yes	Moderate/severe swelling, heat, pain at palpation	2	Na	
20 *(15)*	Yes	At the 2° VG national 81 km		Moderate/severe swelling, heat, pain at palpation	3	Na	Lameness resolved the next day but positive flexion test (++)
21 *(16)*	Yes	At final VG national 60 km	Yes	Moderate/severe swelling, heat, pain at palpation	3	Na	Lameness improved the next days but positive flexion test (++)
22 *(17)*	Yes	At 1° VG CEI*	Yes	Mild swelling	2	Na	Lameness resolved in the next days
23 *(18)*	No	–	–	Moderate/severe swelling, heat, pain at palpation	2	++	

TABLE 1: Continued

Case (*horse*)	Developed in competition	Details 'development in competition'	Elimination from competition	Clinical findings	Lameness grade*	Response to flexion test	Other information
24 *(18)*	No	–	–	Moderate/severe swelling, heat, pain at palpation	2	++	
25 *(19)*	No	–	–	Mild Swelling	0	+	

Italics numbers represent horses with sickled-hocked conformation. CEI, concours d'endurance internationale; LF, left forelimb; Na, not applicable; VG, vet gate.
Number of asterisks (*,**,***) represents number of stars of international competition.

(P = 0.29), degree of swelling (P = 0.34) or sickle-hocked conformation (P = 0.92); between development of injury during competition and swelling (P = 1.00) or sickle-hocked conformation (P = 0.21), or between degree of swelling and sickle-hocked conformation (P = 0.89).

There was no significant difference in age at development of the injury during competition (P = 0.19), degree of swelling (P = 0.62), sickle-hocked conformation (P = 0.06) or degree of lameness (P = 0.46); however, novice horses (median: 6 years) were significantly younger at the time of injury compared with elite horses (median: 9 years; P = 0.01).

There was no significant difference in degree of lameness and level of activity (P = 0.35), development of injury during competition (P = 0.53) or sickle-hocked conformation (P = 0.62); however, horses with moderate/severe swelling had a significantly higher degree of lameness (median: grade 2; range: 2–3; P < 0.001) compared to horses with mild swelling (median: grade 0; range: 0–1).

Diagnostic imaging findings

Ultrasonographic findings of plantar fasciitis were characterised by differing amounts (from mild to severe) of thickening of the plantar fascia plantar to the superficial digital flexor tendon in all cases (**Figs 1** and **2**). Peritendinous–periligamentous oedema (from mild to severe) of heterogeneous appearance was localised at the medial aspect of the SDFT and plantar to the lateral digital flexor tendon in 20 out of 25 cases, and was localised laterally to the SDFT and plantar to the long plantar ligament and/or proximal aspect of the fourth metatarsal bone in 22 out of 25 cases (**Fig 3**). In 11 out of 25 cases, the severity of peritendinous–periligamentous oedema was of the same severity on the medial and lateral side compared with the position of the SDFT; five cases showed involvement only, or more severe, of the area medial to the SDFT whereas eight cases showed involvement only, or more severe, of the area lateral to the SDFT (**Fig 3**). Additional ultrasonographic findings detected were thickening of the wall of the flexor retinaculum of the affected limb compared with that of the contralateral limb in five cases (**Fig 4**), associated with mildly increased amounts of synovial fluid in the tarsal sheath in one case, and localised new bone formation with regular bone outline at the plantar aspect of the calcaneus just distal to the origin of the long plantar ligament (exostosis) in one case.

In all cases, radiographic examination revealed soft tissue swelling at the distoplantar aspect of the hock. Additional radiographic abnormalities detected included osteophytes/enthesophytes at the dorsoproximal aspect of the third metatarsal bone (n = 5), increased radiopacity (sclerosis) of the spongious bone at the dorsal aspect of the third tarsal bone (n = 3) and/or central tarsal bone (n = 6), abnormal shape of the third tarsal bone (n = 2), new bone formation at the insertion of the short medial collateral ligament of the tarsus on the medial aspect of the talus (n = 1), smooth and localised new bone formation at the plantar aspect of the calcaneus and osseous-cyst like lesion on the distal aspect of the tibia (n = 1) and flattening of the intermediate ridge of the tibia (n = 2).

Treatment

Twenty-three out of 25 cases were treated by topical application of ice-therapy or cold water for 72 h and osmotic products (uptite poultice paste) daily for 7 days. Non-steroidal anti-inflammatory drugs were administered intravenously (phenylbutazone 4.4 mg/kg i.v. once a day) for 3–7 days in 13 cases; 10 cases were treated by local injection of corticosteroid (triamcinolone 10–40 mg with or without dexametasone 4–8 mg). After the acute inflammatory phase (7 days), iodine working blisters were applied in 18 cases. In 21 cases, a rehabilitation programme comprised 3 weeks to 5 months of paddock rest and controlled exercise by hand-walking or horse-walker depending on the lesion severity. Four cases with mild plantar fasciitis were maintained in light work to allow participation in competition at owner's discretion, contrary to veterinary advice.

Corrective shoeing consisting of a heart bar shoe composed of synthetic material with a metal inlay (Duplo Composite Horse Shoe)[3] was applied at return to training in four cases; and in an additional three cases, corrective shoeing was applied after re-injury. Additional details of the treatment and rehabilitation programme in each case are presented in **Table 2**.

Follow-up

Average follow-up time was 1080 days (range: 365–4015 days). Seventeen out of 25 (68%) cases did not develop re-injury after treatment and rehabilitation; however, of these three (18%) were retired from athletic activity at the owner's discretion (n = 1) or sustained other injuries (n = 2). The remaining 14 returned to the previous or a higher level of competition. Eight out of 25 (32%) horses developed re-injury. Six cases developed one re-injury; of these three cases were not rested to allow participation in competition and developed re-injury at the first participation in competition after 15, 21 and 60 days after the initial diagnosis,

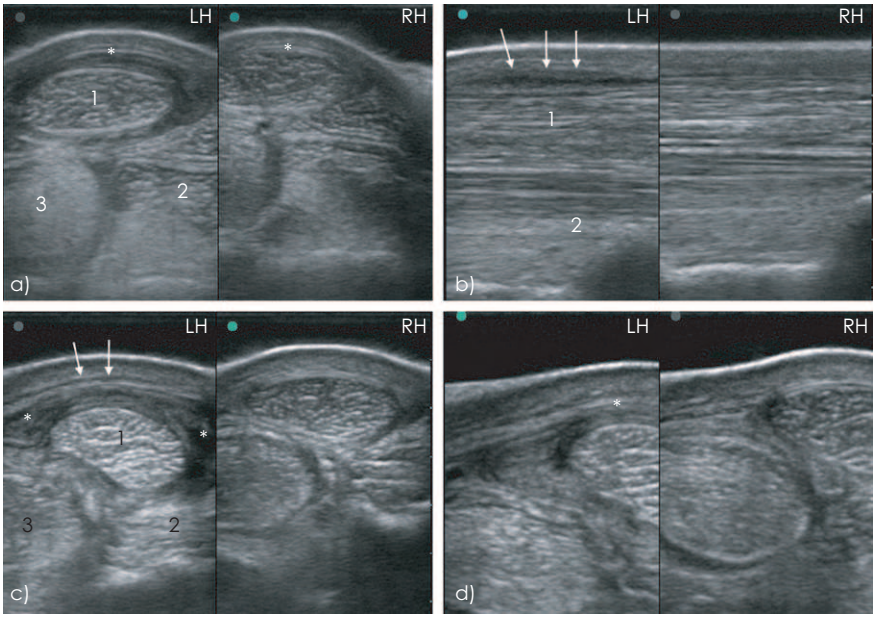

***Fig 1:** Ultrasonographic findings of plantar fasciitis and controlateral limb comparison in* **Case 14** *(a,b) and* **Case 16** *(c,d). a) Transverse ultrasonographic images of the left (LH) and right (RH) plantar fascia at the level of the distal tarsus. Note the increased thickness of the left plantar fascia compared with that of the right hindlimb (asterisk) and the peritendinous–periligamentous thickening/fluid accumulation plantar to the superficial digital flexor tendon and long plantar ligament. b) Longitudinal ultrasonographic images of the left (LH) and right (RH) plantar fascia at the level of the distal tarsus. Note the hypoechogenic peritendinous–periligamentous fluid accumulation plantar to the superficial digital flexor tendon (arrows). c) Transverse ultrasonographic images of the left (LH) and right (RH) plantar fascia at the level of the distal tarsus. Note the increased thickness of the left plantar fascia (arrows) compared with that of the right hindlimb and the peritendinous–periligamentous fluid accumulation plantar to the long plantar ligament and flexor retinaculum/lateral digital flexor tendon (asterisks). d) Transverse ultrasonographic images of the left (LH) and right (RH) plantar fascia obtained with a plantaromedial approach. Note the increased thickness of the left plantar fascia (asterisk) compared with that of the right hindlimb and the peritendinous–periligamentous fluid accumulation plantar to the flexor retinaculum/lateral digital flexor tendon. 1. Superficial digital flexor tendon. 2. Long plantar ligament. 3. Lateral digital flexor tendon. Medial and proximal is to the left.*

respectively. In the remaining three cases, re-injury developed at 3, 9 and 20 months after initial diagnosis, respectively. These cases were treated in the same way as for the initial lesion, but a longer duration of rest was allowed and corrective shoeing applied in two cases. These cases returned to the previous or a higher level of competition. Two out of eight cases developed two re-injuries; the first was at 4 and 10 months, and the second after additional 7 and 6 months. One of these returned to its previous level of competition, and in the other case, the lesion was the cause for retirement. They were treated in the same way as for the initial lesion but a longer duration of rest was allowed and corrective shoeing applied in one case after the second re-injury. Overall, 21 out of 25 cases (84%) returned to the previous or a higher level of competition; in one case (4%), the injury was cause for retirement from athletic activity.

There was no significant difference between re-injury and level of activity ($P = 0.57$), development of injury during competition ($P = 0.58$), degree of swelling ($P = 1.00$), sickle-hocked conformation ($P = 0.33$), age at the time of injury ($P = 0.08$) and degree of lameness ($P = 0.85$).

Discussion

Historically, curb is defined as an enlargement of the distoplantar aspect of the hock and proximal metatarsus caused by lesion of the long plantar ligament (Sullins 2011). However, it has also been shown to be related to injury of the SDFT, deep digital flexor tendon and/or peritendinous–periligamentous tissue (Ross *et al*. 2002; Sullins 2011). Furthermore, it is recognised in foals with wedging of the distal tarsal bones (Clegg 2003; Sullins 2011). Ultrasound examination has demonstrated that peritendinous–periligamentous tissue changes are the most common cause of plantar soft tissue swelling (Ross *et al*. 2002). It has allowed the identification of a thin subcutaneous fibrous tissue along the plantar aspect of the SDFT, which is considered peritendinous–periligamentous tissue (Ross *et al*. 2002); however, this tissue occurs in the anatomical location of the plantar fascia (Denoix and Hernandez 1998; Denoix 2019a,b). Diagnostic analgesia in such cases was not performed as the sudden development of swelling with or without lameness was a clear indication of the development of plantar fasciitis. Horses with tendon and/or ligament injuries frequently present clinical signs of local swelling, heat and thickening with or without lameness (Denoix 1994).

In horses, the plantar fascia (*Fascia plantaris*) is composed of two laminae, one deep and one superficial. The superficial layer lies just under the skin, representing the continuation of the superficial layer of the crural fascia (Barone 2012a,b; Denoix 2019c) and covers the common calcaneal tendon, the cap of the SDFT, the lateral and medial aspect of the

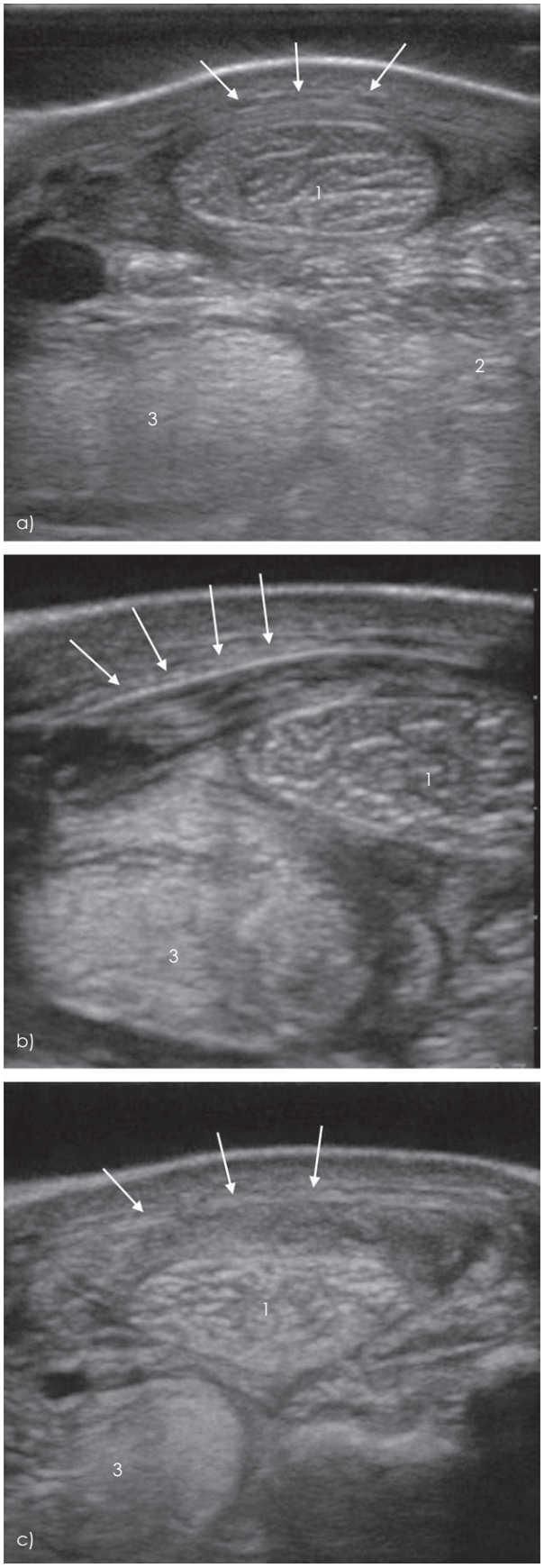

Fig 2: Transverse ultrasonographic images with different amounts of thickening of the plantar fascia (arrows). a) Mild thickening of the plantar fascia detected in Case 6. b) Moderate thickening of the plantar fascia detected in Case 4. c) Severe thickening of the plantar fascia detected in Case 13. 1. Superficial digital flexor tendon. 2. Long plantar ligament. 3. Lateral digital flexor tendon. Medial is to the left.

calcaneus, and the SDFT (Barone 2012a,b). At the level of the plantar aspect of the tarsus, it is referred to as plantar tarsal fascia (Denoix 2019a); at the level of the metatarsal area, it is called plantar metatarsal fascia, where the superficial layer is very thin (Barone 2012a; Denoix 2019b). The long plantar ligament (*Ligamentum plantare longum*) originates from the plantar aspect of the calcaneus and inserts on the fourth tarsal bone and fourth metatarsal bone; it is considered a strong reinforcement of the plantar fascia (Barone 2012b).

Plantar fasciitis is common in humans, especially in runners; ultrasonographic examination typically shows thickening and hypoechogenicity of the fascia, loss of fibrillar pattern and perifascial fluid accumulation (i.e. peritendinous–periligamentous oedema) (Tsai *et al*. 2000; Draghi *et al*. 2017). In all horses presented in the current study, ultrasonographic findings were characterised by increased thickness and reduced echogenicity of the plantar fascia, and perifascial fluid accumulation. This supports the use of plantar fasciitis in the definition of this injury, which commonly involves both the tarsal and proximal metatarsal portion, resulting in the clinical appearance of curb. Considering the anatomical differences compared with humans, it is the authors' opinion that the evaluation of the fibrillar pattern is more challenging to evaluate in horses considering the curvilinear nature of this structure, similarly to the palmar/plantar annular ligament of the fetlock.

Physiopathology of plantar fasciitis is not completely understood in human medicine; based on histological samples, it seems to be a degenerative rather than an inflammatory process and high mechanical stress and repetitive microtrauma have a role in the development of the injury in human athletes. Prolonged walking, running or standing lead to an overuse lesion (Lemont *et al*. 2003); abnormal limb conformation, incorrect training and inadequate footwear act as intrinsic and extrinsic risk factors in human athletes (Petraglia *et al*. 2017).

Lesions of the peritendinous–periligamentous soft tissue at the level of the plantar fascia or plantar fasciitis seem to develop more commonly in racehorses, especially Standardbred horses, as a consequence of overload or excessive strain on the plantar aspect of the hock related to a higher incidence of sickle-hocked conformation (Denoix and Hernandez 1998; Ross *et al*. 2002). It has also been described in sport horses in a previous study, but direct trauma was the most common aetiology (Ross *et al*. 2002). In the present study, only endurance horses were included and they developed injury of the plantar fascia most commonly during competition (64%) or after training session; history of trauma could be excluded in these cases. For this reason, plantar fasciitis in endurance horses could be related to overload and/or excessive strain during athletic activity. It is the authors' opinion that endurance horses develop injury

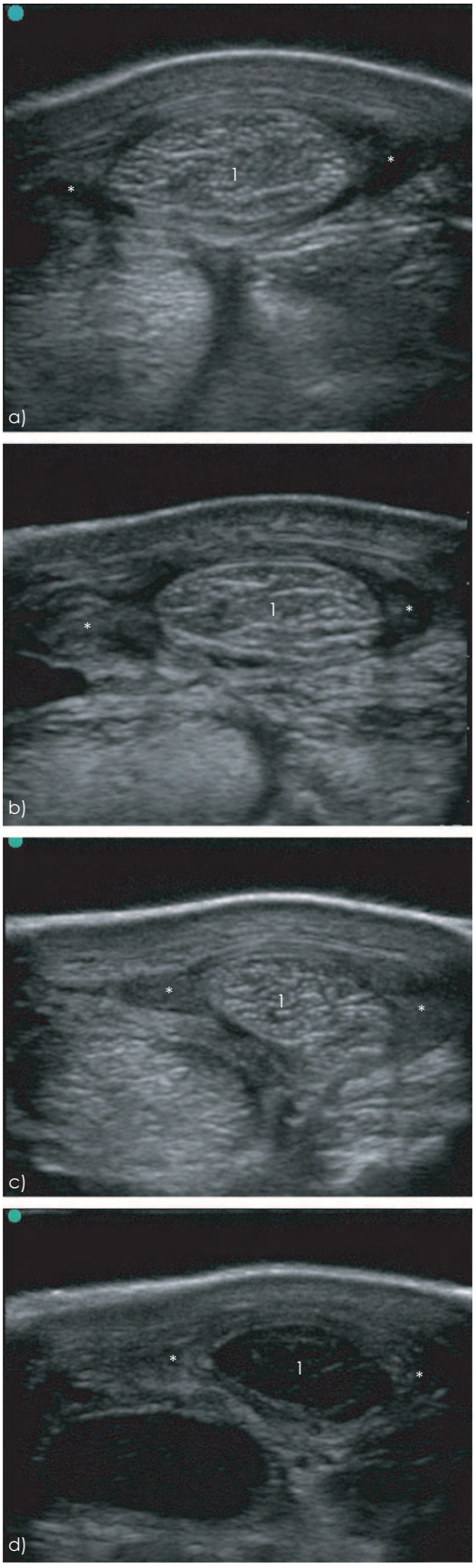

Fig 3: Transverse ultrasonographic images showing different amounts of peritendinous–periligamentous fluid accumulation (asterisks). a) Case 18: approximately the same amount of peritendinous–periligamentous thickening is detected on the lateral and medial sites of the superficial digital flexor tendon. b) Case 6: the amount of peritendinous–periligamentous thickening is higher on the medial aspect of the superficial digital flexor tendon compared with the lateral site. c) Case 8: the amount of peritendinous–periligamentous thickening is higher on the lateral aspect of the superficial digital flexor tendon compared with the medial site. d) Same images of (c) obtained with off-incidence technique to highlight the peritendinous–periligamentous thickening. 1. Superficial digital flexor tendon. Medial is to the left.

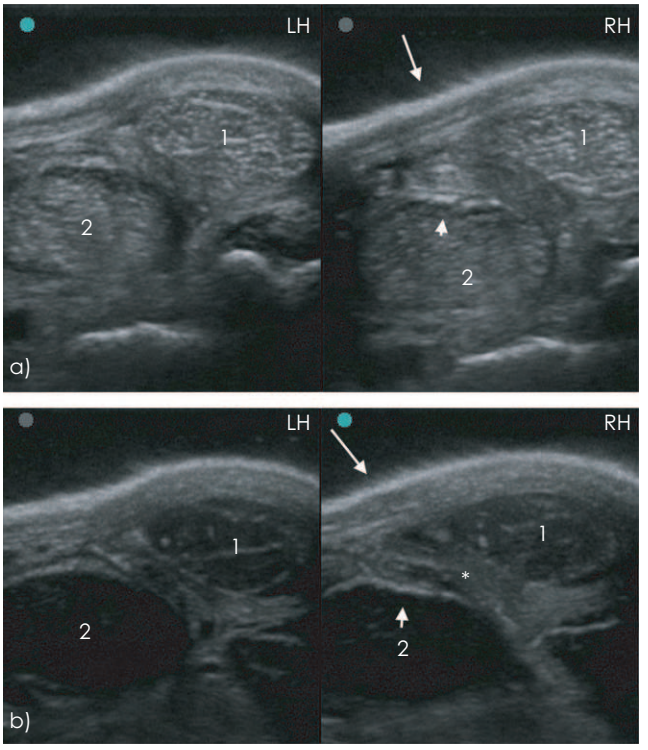

Fig 4: Transverse ultrasonographic images of increased thickness of the flexor retinaculum in Case 9, which showed also a mild plantar fasciitis. The images were obtained using a plantaromedial approach. a) Note the increase thickness of the flexor retinaculum (asterisk) and the abnormal shape of the lateral digital flexor tendon (arrowhead), compressed by the flexor retinaculum, on the right hindlimb (RH) compared with the left hindlimb (LH); note also the convex shape of the skin of the right hindlimb (arrow) compared with the left hindlimb. b) Same images of (a) obtained with off-incidence technique to highlight the increased thickness of the flexor retinaculum. 1. Superficial digital flexor tendon. 2. Lateral digital flexor tendon. Medial is to the left.

more commonly during competition on deep surfaces (i.e. sandy or muddy surfaces), as is common for soft tissue injuries and may be related to higher muscular fatigue on these types of terrain. Speed does not seem to influence this injury since plantar fasciitis was detected in horses with different levels of activity and also in competition at regular speed.

TABLE 2: Details of treatment and rehabilitation programme in 25 cases of plantar fasciitis detected in 19 endurance horses

Case (*horse*)	Anti-inflammatory drugs	Local injection	Local treatment	Duration of paddock rest with hand-walking or horse-walker	Corrective shoeing (Duplo Sport Horse)	Re-injury
1 *(1)*	PBZ 4.4 mg/kg i.v. once a day for 5 days	–	Iodine blister	8 weeks	–	No
2 *(2)*	PBZ 4.4 mg/kg i.v. once a day for 3 days	Dexa 8 mg	–	8 weeks	–	No
3 *(2)*	No	–	–	–	–	Yes
4 *(3)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	Triamcinolone 12 mg	Iodine blister	16 weeks	–	No
5 *(3)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	Triamcinolone 40 mg + dexa 4 mg	Iodine blister	8 weeks	–	No
6 *(4)*	PBZ 4.4 mg/kg i.v. once a day for 5 days	–	Iodine blister	10 weeks	Yes, after re-injury	Yes
7 *(5)*	No	Dexa 8 mg	–	–	Yes, after re-injury	Yes
8 *(6)*	PBZ 4.4 mg/kg i.v. once a day for 3 days	–	Iodine blister	12 weeks	Yes	No
9 *(7)*	No	–	Iodine blister	3 weeks	–	Yes
10 *(7)*	No	–	Iodine blister	16 weeks	–	No
11 *(8)*	PBZ 4.4 mg/kg i.v. once a day for 5 days	Triamcinolone 10 mg	Iodine blister	16 weeks	Yes, after re-injury	Yes
12 *(8)*	No	–	–	–	Yes	No
13 *(9)*	PBZ 4.4 mg/kg i.v. once a day for 5 days	Triamcinolone 18 mg + dexa 6 mg	Iodine blister	20 weeks	Yes	Yes
14 *(10)*	No	–	Iodine blister	16 weeks	–	No
15 *(10)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	Triamcinolone 12 mg	–	–	–	Yes
16 *(11)*	No	Triamcinolone 12 mg + dexa 6 mg	Iodine blister	16 weeks	Yes	No
17 *(12)*	No	–	Iodine blister	8 weeks	–	No
18 *(13)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	–	Iodine blister	12 weeks	–	No
19 *(14)*	PBZ 4.4 mg/kg i.v. once a day for 5 days	–	–	8 weeks	–	Yes
20 *(15)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	–	Iodine blister	16 weeks	–	No
21 *(16)*	PBZ 4.4 mg/kg i.v. once a day for 7 days	–	Iodine blister	16 weeks	–	No
22 *(17)*	No	–	Iodine blister	12 weeks	–	No
23 *(18)*	No	Triamcinolone 10 mg + dexa 6 mg	–	8 weeks	–	No
24 *(18)*	No	Triamcinolone 10 mg + dexa 6 mg	–	8 weeks	–	No
25 *(19)*	No	–	–	12 weeks	–	No

Italics numbers represent horses with sickled-hocked conformation.
Dexa, dexamethasone; PNZ, phenylbutazone.

Similar to Standardbred horses, sickle-hocked conformation may play a role in the development of the lesion; this type of conformation was detected in 12 out of 19 horses (63%) in this study, alone or together with other conformational defects of the hocks. It was unsurprising that some of these horses showed radiographic changes at the level of the tarsometatarsal and/or distal intertarsal joint. Sickle-hocked conformation results in increased tension on the plantar aspect of the hock and increased pressure on the small tarsal joints (Ross and McIlwraith 2011). However, in the present study radiographic changes were considered as incidental findings and not responsible for the clinical presentation in these horses.

In the present study, 68% of the cases were lame at evaluation and the degree of lameness in these cases was also variable (1–3). However, there was a significantly higher degree of lameness detected in horses with moderate/severe swelling compared with horses with mild deformation of the outline of the plantarodistal aspect of the hock. It is possible to hypothesise that the degree of lameness may be related to a compartmental syndrome as a consequence of inflammation of the area and constriction of the fascia, an anatomical structure with poor elasticity.

Plantar fasciitis that developed during competition did not always result in elimination, and in some horses (**Table 1**), it became clinically significant in the hours just after the end of the final loop. However, three out of four cases (*Cases 3, 7 and 15*) developed the injury some weeks before a competition and the plantar fasciitis was not tolerated during the competition when they developed a more severe injury resulting in elimination between 60 and 90 km. These horses were not rested after the injury was initially detected (**Table 1**) for commercial reasons, contrary to veterinary advice. In accordance with previous observations (Major and Zubroid 2006), this highlights the importance of rest and controlled exercise to allow the fascia to heal. Additionally, ultrasonographic examination can reveal inflammation and injury of the plantar fascia in horses that are not lame or with a mildly positive hindlimb flexion test result and show only a mild swelling. This contradicts a previous study, in which the presence of lameness was considered the most important clinical signs of the need for rest or decreased level of exercise (Ross *et al*. 2002). However, in the present authors' opinion, the type of athletic activity (race vs. endurance) may be the reason for a different ability to tolerate injuries of the plantar fascia, and endurance horses that are trained and compete for long distances are probably less tolerant even if only the plantar fascia is injured.

Ultrasonographic examination is essential for the evaluation of the distoplantar aspect of the hock to differentiate the injured structures. Evaluations of the plantar, plantaromedial and plantarolateral aspects are equally important because even if all horses had thickening of the plantar fascia plantarly to the SDFT, perilesional fluid accumulation can be more severe in the plantarolateral or plantaromedial site. In addition, ultrasonographic examination can be used to monitor progression of healing and can aid in rehabilitation. In humans, ultrasound and magnetic resonance imaging (MRI) are the first- and second-choice modalities, respectively, for diagnosis of plantar fasciitis (Draghi *et al*. 2017). Ultrasound is inexpensive and reliable, and for this reason in human, medicine is preferred to MRI, which should be used to rule out other conditions as well as plain radiographs (Monteagudo *et al*. 2018; Trojian and Tucker 2019). The same approach of ultrasound examination as first-choice diagnostic technique may be used in horses with plantar fasciitis and MRI examination can be performed in cases that do not respond to medical treatment.

In the present study, treatment protocols were not standardised depending on the severity of the lesion, the time of the season in which they developed or the economical restraint of the owners; however, treatment options were those commonly reported in the literature for this type of injury (Ross *et al*. 2002; Major and Zubrod 2006; Ross and Genovese 2011; Sullins 2011). In some horses, corrective shoeing consisting of a heart bar shoe comprising synthetic material with a metal inlay was applied when the horse returned to training and competition. The low number of horses in which this was applied was related to the only recent availability of the synthetic material; heart bar shoe made of aluminium or steel are considered inappropriate for use in endurance horses, aluminium is not durable on hard terrain and steel is heavy and has poor grip, especially on asphalt.

Rate of re-injury was relatively low (32%), and retirement from athletic activity for plantar fasciitis was low (4%); however, this can be a frustrating injury as it results in missed training and exclusion from competition for 2–5 months.

In conclusion, in the 19 horses included in this study with sudden curby appearance of the plantarodistal aspect of the hock, isolated lesions of the plantar fascia were recognised by ultrasound examination, without involvement of the SDFT and/or the long plantar ligament. Plantar fasciitis can be considered a sport-related injury in endurance horses of all ages and athletic activity level, and sickle-hocked conformation may act as a predisposing factor. Re-injury rate is low, but adequate rest and rehabilitation protocols are mandatory; plantar fasciitis rarely results in retirement from athletic activity but results in 2–5 months out of training and competition.

Authors' declarations of interests

No conflicts of interest have been declared.

Ethical animal research

Ethics committee evaluation not required for this retrospective study.

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Authorship

Cases management was by A. Paris and F. Beccati. Clinical and imaging interpretation was by A. Paris and F. Beccati. The manuscript was drafted by A. Paris, F. Beccati and M. Pepe. All authors gave their final approval of the manuscript.

Manufacturers' addresses

[1]Fujifilm Sonosite, Amsterdam, Netherlands.
[2]JASP, University of Amsterdam, Amsterdam, Netherlands.
[3]Duplo, Grainet, Germany.

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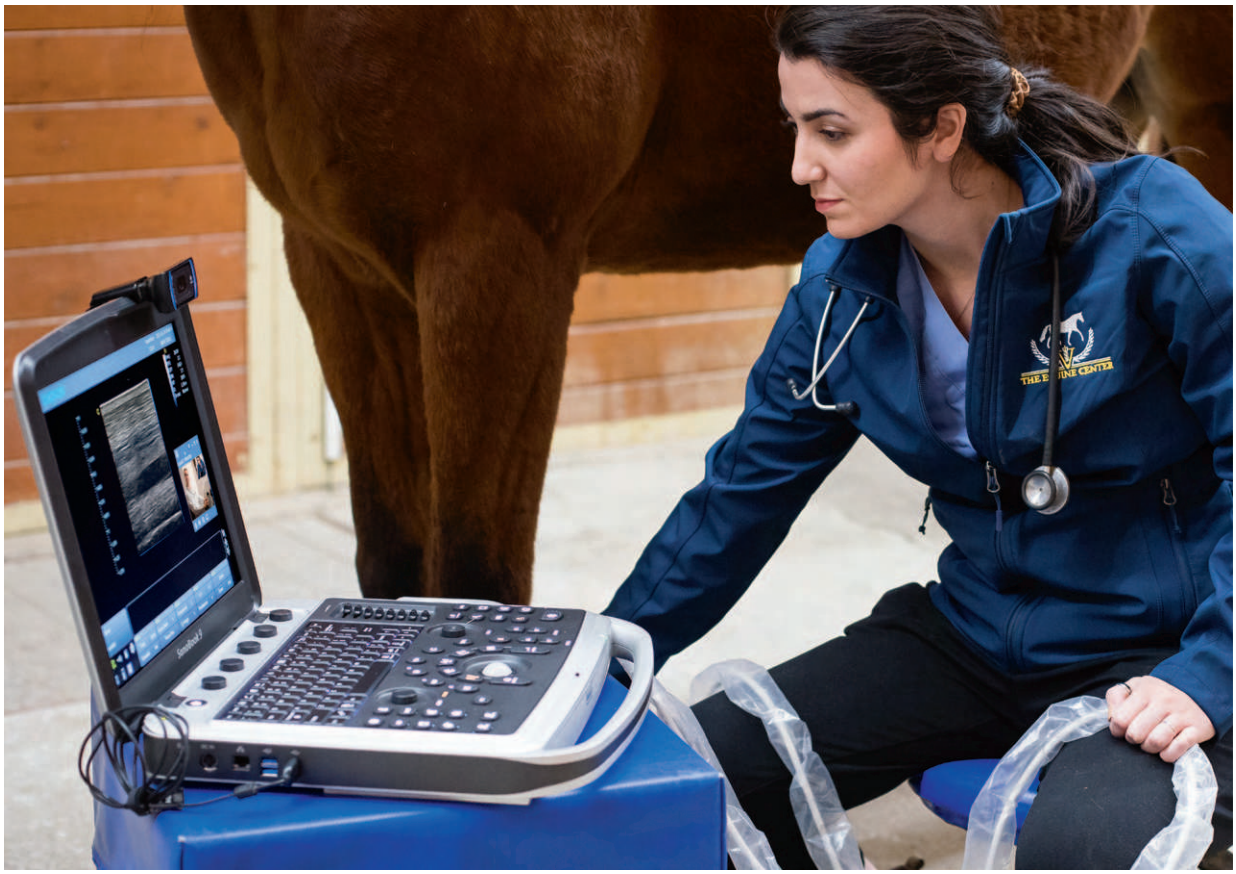

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Review Article

Responsible antimicrobial use in critically ill adult horses

B. Dunkel*

RVC Equine, Clinical Science and Services, Royal Veterinary College, North Mymms, Hatfield, Hertfordshire, UK
**Corresponding author email: bdunkel@rvc.ac.uk*

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Summary

Due to increasing antimicrobial resistance, pressure on veterinarians is mounting to adhere to responsible use of antimicrobial drugs. Antimicrobials are frequently included in the treatment of systemically ill horses due to the strong likelihood of an infection and the innate difficulties in differentiating systemic inflammation secondary to noninfectious from infectious causes. In light of increasing antimicrobial drug resistance and the potential negative impact of antimicrobials on equine patients, every attempt should be made to identify noninfectious disease, choose first-line antimicrobials and discontinue treatment as soon as possible. In most cases, a short duration of antimicrobial therapy ranging from a single dose (e.g. preoperatively) to 24–72 h might be sufficient with long-term treatment being rarely required. This article aims to provide practical guidelines for antimicrobial drug usage in critically ill adult horses by describing ancillary diagnostic aids that can help establishing whether or not an infection is present, discussing commonly encountered pathogens and their typical antimicrobial drug sensitivity patterns, and providing some guidance how to safely shorten the duration of antimicrobial therapy.

Introduction

Critical or intensive care in people extends beyond internal medicine dealing with a subset of patients with immediate life-threatening conditions (Marshall *et al*. 2017). In equine medicine, the term is used more loosely, often referring to animals that require more intense support than the average equine patient or simply animals with systemic and potentially life-threatening disease (Lascola *et al*. 2017). Many critical illnesses in horses are associated with infection or with significant absorption of bacterial products and toxins causing activation of the inflammatory and coagulation systems. Clinically, both scenarios are often indistinguishable. Although not effective against purely inflammatory conditions, antimicrobials are frequently included in the treatment of these animals due to the strong likelihood of an infection and the innate difficulties in differentiating systemic inflammation secondary to noninfectious causes from infections. However, due to increasing microbial resistance, pressure on veterinarians is mounting to adhere to responsible use of antimicrobial drugs. A recent study in a UK referral hospital over a 10-year period demonstrated an increase in prevalence of extended-spectrum beta-lactamase (ESBL)-producing *E. coli* as well as increased antimicrobial resistance to frequently used antimicrobials including doxycycline, gentamicin and third-generation cephalosporins (Isgren *et al*. 2019); other studies have confirmed increasing resistance in bacteria isolated from horses, particularly after antimicrobial therapy (Maddox *et al*. 2011; Theelen *et al*. 2020). Unnecessary or unnecessarily long use of antimicrobial drugs enhances development of resistance in pathogens, increases the cost of treatment and exposes the patient to possible side effects, most noticeably disruption of the intestinal microbiome and antimicrobial-induced diarrhoea (Gronvold *et al*. 2010; Johns *et al*. 2012; Barr *et al*. 2013; Costa *et al*. 2015). Every attempt should therefore be made to limit their use. This can be achieved by making every effort to identify noninfectious disease, choosing first-line antimicrobials in the first instance and discontinuing treatment as quickly as possible. The use of drugs of veterinary and human medical importance including 3rd-, 4th- and 5th-generation cephalosporins, glycopeptides (vancomycin), quinolones (enrofloxacin, marbofloxacin), macrolides (erythromycin, azithromycin, clarithromycin), newer, extended-spectrum penicillins and carbapenems should be avoided unless there is confirmed infection with a susceptible organism or for the treatment of life-threatening conditions unlikely to respond to first-line choices (Raidal 2019). Many clinicians feel that some antimicrobials such as vancomycin and carbapenems should not be used in animals under any circumstances. Even drugs commonly used in horses and other veterinary species such as gentamicin, rifampicin, ampicillin and amoxicillin-clavulanic acid are now on the World Health Organisation list of critically important antimicrobials which could lead to restrictions of their use in veterinary medicine in the future (https://www.who.int/foodsafety/publications/antimicrobials-sixth/en/). In most cases, a short duration of antimicrobial therapy ranging from a single dose (e.g. preoperatively) to 24–72 h might be sufficient with long-term treatment being rarely required. Recent studies in human medicine have shown impressive reductions in antimicrobial resistance with a reduction of not only overall use but also with a decrease in days of antimicrobial therapy highlighting the importance of shortening treatment duration (Dona *et al*. 2020).

Unfortunately, in everyday life clinicians' efforts are often impeded by the inability to differentiate infectious from noninfectious conditions due to nonspecific clinical signs, difficulties of culturing relevant pathogens, financial limitations impeding repeated testing and pressure from the owners, yard managers or trainers to use antimicrobial drugs. To further compound the issue, prospective studies investigating responsible antimicrobial drug use in horses are lacking and most guidelines are based either on information gained from human research or, more commonly, clinical impressions, which are subjective and unreliable at best.

Identifying the need for antimicrobial treatment

Antimicrobial drugs are unlikely to have a significant beneficial effect against anything but infectious diseases,

usually bacterial or rarely fungal or protozoal in origin. Although some antimicrobials such as tetracyclines also have anti-inflammatory effects (Pradhan *et al*. 2016), their use for purely inflammatory conditions is controversial and use of classic anti-inflammatories such as nonsteroidal anti-inflammatory drugs is far more appropriate. Unfortunately, it is extremely difficult to reliably rule out an infectious process. Clinical examination findings are nonspecific and rarely help with the differentiation. Heart and respiratory rates are greatly influenced by pain, cardiovascular compromise and systemic inflammation making them much more useful in judging disease severity rather than an infectious or noninfectious nature. While the presence of a fever increases the clinical suspicion of an infection, it is by no means conclusive as inflammation, hyperthermia, neoplasia or significant tissue trauma can also lead to an increase in rectal temperature. Equally, the absence of a fever does not rule out even severe infection. Haematology and acute-phase protein concentrations such as fibrinogen or serum amyloid A (SAA) can be difficult to interpret as increases in concentrations can be triggered by infectious and noninfectious inflammatory conditions alike (Westerman *et al*. 2015; Long and Nolen-Walston 2020). Although a statistical difference in SAA concentrations between infectious and noninfectious airway disease has been reported, there was significant overlap between groups, and in some horses with infection, SAA concentrations remained low or at 0 mg/L (Viner *et al*. 2017). In adult horses, leucopaenia is commonly observed with significant inflammation, often originating from the gastrointestinal system, and caused by margination and extravasation of leucocytes at the site of inflammation. It does not necessarily indicate the presence of infection or the need for antimicrobial treatment. Leucocytosis in mature horses can be observed with inflammatory, infectious and neoplastic conditions or following administration of corticosteroids and is therefore also of limited use when trying to differentiate infectious from noninfectious conditions (Targowski 1975; White *et al*. 2009; Meichner *et al*. 2017). As immediate treatment is usually required, the clinician needs to make an educated guess whether or not infection is likely and antimicrobial drugs are needed. Many equine viral and some bacterial diseases can be diagnosed by polymerase chain reaction (PCR) with results often being available the following day. Cytological samples, submitted in addition to samples for culture and sensitivity, can be of great value when trying to rule out an infectious aetiology as results are much more quickly available compared to culture and are not compounded by difficult culturing processes. In cases where clinicians have already initiated antimicrobial treatment but PCR or cytological results do not support an infection or identify a viral cause for the disease, antimicrobial treatment should be discontinued immediately. The old concept that 'a course of antibiotics needs to be finished to avoid development of resistance' is incorrect and obsolete. The perception that stopping antibiotic treatment early encourages antibiotic resistance is not supported by evidence, while increasing length of antimicrobial use undoubtedly increases the risk of resistance development (Llewelyn *et al*. 2017). In contrast, reducing the length of treatment has a significant effect on decreasing previously existing resistance (Dona *et al*. 2020). Submitting samples for culture and sensitivity remains essential as results will provide guidance for further antimicrobial choices if the initial treatment fails to resolve the infection. Over time, results also provide invaluable insight into regional pathogens and their antimicrobial sensitivity patterns (Johns 2017; Raidal 2019). Reports on commonly identified bacteria, the organ system they were cultured from and their sensitivity patterns can often be obtained from regional laboratories providing insight into local resistance patterns.

Limiting the duration of antimicrobial treatment in proven infections can be challenging. Fear of negating a treatment success often leads clinicians to prolong the use of antimicrobial drugs in clinically apparently recovered patients. Unfortunately, studies to identify the minimum effective treatment duration have rarely been performed, even in people, let alone in horses. Current guidelines are therefore often purely based on absence of data for efficacy of shorter courses rather than the explicit need for long therapies (Llewelyn *et al*. 2017). In the past, many clinicians have used return to normal haematologic parameters or normal concentrations of acute-phase proteins, mainly fibrinogen, as a marker to safely discontinue antimicrobial treatment. Plasma fibrinogen has a relatively long half-life of 4.1–5.2 days in horses and awaiting normal concentrations likely results in over-treatment (Coyne *et al*. 1985). Return to normothermia, improved appetite and return of normal demeanour might be better indicators that further treatment is not necessary. It is also common practice to initially treat systemically ill horses with injectable antimicrobial drugs for 48–72 h, often in a hospital setting, followed by continued oral treatment at home. In most cases, this continuation of antimicrobial treatment is not necessary. An alternative approach is stopping antimicrobial treatment after 48–72 h and monitoring the patient for another 24 h while still in the hospital (or close monitoring by the owner at home). The additional cost for hospitalisation is at least partially offset by saving cost for drugs. Should signs of infection re-occur, such as recurrence of a fever, a decrease in appetite or change in demeanour, treatment can easily be re-initiated. If not, the patient can be discharged off all medications.

Responsible use of antimicrobials in gastrointestinal diseases

Horses with a primary complaint of colic rarely require antimicrobial therapy. The examination is focused on establishing the nature of the problem and deciding whether medical or surgical options should be pursued. Horses with fever and vague colic signs with or without diarrhoea often suffer from intestinal inflammation such as enteritis and colitis or from peritonitis. There is no evidence that antimicrobial therapy is beneficial in cases of intestinal inflammation. Some clinicians even feel that their use is contraindicated, considering the negative impact of antimicrobials on the microbiota, adding further insult to an already disturbed microbial environment (Harlow *et al*. 2013; Shaw and Stampfli 2018). Exceptions include colitis caused by *Neorickettsia risticii* (Potomac horse fever) or rare cases of *Lawsonia intracellularis* in adult horses (Page *et al*. 2014) where treatment with oxytetracycline is indicated. Antimicrobial treatment has also been considered for clostridia-associated diarrhoea. An association between metronidazole treatment and survival was identified in horses diagnosed with clostridial diarrhoea but metronidazole had no effect on survival of horses with non-clostridia-associated diarrhoea (Weese *et al*. 2006). However, administration of metronidazole has also been

linked with identification of metronidazole-resistant *Clostridium difficile* strains. These strains are suspected to be more virulent and carried an increased risk of mortality compared to horses infected with metronidazole-susceptible strains (Magdesian *et al*. 2006; Schoster and Staempfli 2016). Considering the controversial evidence and pressure of building resistance, refraining from use of metronidazole in horses with diarrhoea might be preferable. Bacteraemia has been reported in adult horses with colitis and is sometimes considered as a reason for use of antimicrobials in these patients. However, prior treatment or treatment during hospitalisation with antimicrobial drugs did not protect horses from development of bacteraemia arguing against their use (Johns *et al*. 2008).

Peritonitis, a less common but potentially life-threatening disease, is also often associated with fever and vague intestinal signs. Peritoneal fluid analysis can quickly rule peritonitis in or out and is a procedure that can be easily performed in the field. The gross appearance of the sample can be misleading and an accurate cell count and protein concentration should always be obtained to avoid misinterpretation. An increased cell count (>20–50 $\times$ 10^9/L) and protein concentration (>25-30g/L) in a horse with compatible clinical signs are sufficient to make a diagnosis of peritonitis, usually bacterial in origin. However, intestinal necrosis and infarction, for example secondary to migrating *Strongylus vulgaris* larvae, can also result in peritonitis (Pihl *et al*. 2018). Best treatment options and prognosis for peritonitis depend highly on the underlying cause and presenting signs. Horses with *Actinobacillus equuli*-associated or so-called idiopathic peritonitis (defined as peritonitis without identifiable cause such as trauma, abdominal surgery, intestinal necrosis, infarction or rupture or neoplasia) with little or no systemic compromise have a much better prognosis and might respond to monotherapy with first-line antimicrobials (Henderson *et al*. 2008; Odelros *et al*. 2019). In contrast, surgical exploration should be strongly considered in any horse with a history of previous trauma or abdominal surgery, a palpable or ultrasonographically visible mass or suspicion of foreign body ingestion. In a recent study of horses with wire ingestion, all survivors underwent exploratory laparotomy highlighting the fact early surgical intervention can be life-saving (Marley *et al*. 2018). Surgical exploration might also be indicated in horses non-responsive to medical treatment within 48–72 h to exclude the presence of significant intestinal compromise or other primary disease process (Pihl *et al*. 2018). The benefits of surgery include identification and possible correction of an underlying cause and recognition of cases with a poor prognosis, decreasing the need for prolonged or ineffective use of antimicrobials.

Intra- or extracellular bacteria can be identified in 17–53% of peritoneal fluid samples (Hawkins *et al*. 1993; Matthews *et al*. 2001; Odelros *et al*. 2019) and pleomorphic Gram-negative rods might be indicative of *Actinobacillus equuli* peritonitis (Matthews *et al*. 2001). In an older study, the presence of bacteria in peritoneal samples was associated with non-survival (Hawkins *et al*. 1993) but this is likely different for idiopathic cases and cases of *A. equuli* peritonitis. For these horses, the prognosis is usually good and microscopic presence of bacteria should not be interpreted as a worse prognostic indicator (Matthews *et al*. 2001; Odelros *et al*. 2019). Bacterial peritonitis secondary to release of bacteria from the intestine usually results in mixed infections with anaerobes and *Enterobacteriaceae* predominating, most commonly *E. coli*. (van der Bogaard 1990; Davis 2003; Henderson *et al*. 2008). Gram-positive bacteria might also be present, and this should be considered when choosing antimicrobial therapy (Hawkins *et al*. 1993). Penicillin remains a good first-line choice for Gram-positive infections and most anaerobes. Susceptibility patterns of Gram-negative bacteria are more difficult to predict. Although increasing resistance can be problematic (Reuss and Giguere 2015), aminoglycosides remain a good initial choice. Early data indicated that penicillin-resistant *Bacteroides* spp. were isolated from 10 to 20% of equine peritonitis cases. A combination of penicillin, gentamicin and metronidazole has therefore traditionally been recommended while awaiting culture and sensitivity findings and use of this combination resulted in a reported survival rate of 86% in horses with peritonitis (Davis 2003; Henderson *et al*. 2008; Nogradi *et al*. 2011). However, in a more recent study, 91% of horses with idiopathic peritonitis without signs of systemic inflammation responded to penicillin alone. The remaining cases were predominately treated with penicillin and gentamicin and only 1% (n = 2) received a combination of penicillin, gentamicin and metronidazole with an overall survival rate of 94% (Odelros *et al*. 2019). Similarly, 61% of horses with *Actinobacillus equuli* infection respond to penicillin alone, the remainder to penicillin and gentamicin (Matthews *et al*. 2001). In light of these findings, it might be appropriate to use penicillin as monotherapy in horses with suspected *Actinobacillus equuli* or idiopathic peritonitis that show little evidence of systemic inflammation or cardiovascular compromise. Should the clinical condition fail to improve within 24 h, addition of gentamicin might be indicated. In horses with predisposing factors or systemic compromise, a combination of penicillin, gentamicin and metronidazole and consideration of surgical exploration if the condition fails to improve would be appropriate. The use of abdominal lavage with or without closed-suction abdominal drains has been described in horses with peritonitis (Nieto *et al*. 2003; Nogradi *et al*. 2011). Further studies are necessary to determine whether both techniques improve the outcome or decrease the length for antimicrobial therapy.

Clinical signs and repeated peritoneal fluid analysis are probably the most useful tools when trying to establish whether therapy is successful and when treatment can be discontinued. Repeated abdominocenteses have no effect on peritoneal cell counts (Schumacher *et al*. 1985) and can be performed every 24–48 h, or more frequently, as required by the case. The cell count should be substantially reduced but does not need to be normal before antimicrobial drugs can be discontinued as inflammation is likely to persist longer than infection. The author uses an arbitrary cut-off point of a nucleated cell count of <10–20 $\times$ 10^9/L before discontinuing antimicrobial drugs which appears to be clinically safe. Enterocentesis can increase the cell count significantly, up to 113 $\pm$ 88 $\times$ 10^9/L, and will make interpretation of samples impossible for the next 3–4 days (Schumacher *et al*. 1985). Intraperitoneal antimicrobial treatment administered via an intraperitoneal catheter has experimentally achieved higher peritoneal fluid concentrations than intravenous administration; however, the clinical usefulness and negative side effects still need to be fully evaluated before this can be recommended (Alonso *et al*. 2018).

Responsible use of antimicrobials in respiratory diseases

The history and general examination can help differentiate noninfectious from infectious respiratory disease. A horse with

a chronic cough that is bright, alert and still performing, although not quite as well as usual, is unlikely to have an infectious pneumonia. Adventitious lung sounds are mainly caused by bronchoconstriction and mucus and exudate accumulation and can be present in infectious and noninfectious diseases alike. In contrast, a horse with fever and adventitious lung sounds that has recently travelled or suffered from choke should be suspected of having an infectious pneumonia or pleuropneumonia. Even if a horse with such a history is normothermic and has normal thoracic auscultatory findings, significant intrathoracic disease cannot be ruled out and further diagnostics are indicated. Thoracic ultrasonography is a quick and easy way to rapidly identify infectious pneumonia and pleuropneumonia. If no areas of consolidation, free pleural fluid or large amounts of comet tails are visualised, a significant intrathoracic infection is highly unlikely. Cytological examination of a tracheal lavage or pleural fluid sample is very helpful in differentiating infectious from noninfectious respiratory conditions and add invaluable information. While often marked neutrophilic inflammation is common in infectious and noninfectious conditions, number and location of bacteria (intra- or extracellular), morphology and Gram stain are helpful in identifying infections and essential for correct interpretation of culture results. Cases of bacterial pneumonia usually show an abundance of intra- and extracellular bacteria and profuse bacterial growth. A positive bacterial culture from a sample with neutrophilic inflammation but no or very few visible bacteria is in the vast majority of cases indicative of noninfectious airway inflammation such as equine asthma, particularly if growth is scant. These cases will likely respond to environmental management and/or anti-inflammatory treatment alone without the need for any antimicrobial treatment.

In respiratory tract infections, *Streptococcus equi* subsp. *zooepidemicus* is one of the most commonly isolated Gram-positive pathogens (Arroyo *et al*. 2017; Carvallo *et al*. 2017). *Streptococcus* spp. are almost always sensitive to penicillin which is therefore one of the cornerstones in treatment of respiratory infections in horses (Reuss and Giguere 2015). Other penicillin-susceptible organisms include most Gram-positive and Gram-negative anaerobic bacteria with the noticeable exception again being *Bacteroides fragilis*. Penicillin-resistant *Bacteroides* spp. were isolated from approximately 8% of pleuropneumonia cases (Hirsh and Jang 1987; Tomlinson *et al*. 2015). A foul smell, as it is often noted when draining pleural effusions, has been associated with anaerobic bacterial involvement even if no anaerobic organisms are isolated (Popp 1977; Ashford *et al*. 1984; Brook 2008; O'Brien 2012). Inadequate or delayed sample handling significantly reduces the chances of culturing anaerobic organisms as exposure to oxygen for any length of time can damage or kill anaerobic bacteria (Brook 2008; Strobel 2009). Many clinicians therefore include metronidazole in their treatment regime if chances of an anaerobic infection are high. Gram-negative bacteria involved in equine pleuropneumonia are variable but *E. coli, Klebsiella, Pseudomonas* and *Actinobacillus* have been isolated (Arroyo *et al*. 2017). Either penicillin and gentamicin (pneumonia and pleuropneumonia without overt evidence of anaerobic infection) or a combination of penicillin, gentamicin and metronidazole (strong suspicion of anaerobic involvement) is typically recommended while awaiting culture and sensitivity findings (Davis 2003; Henderson *et al*. 2008; Nogradi *et al*. 2011). In a recent study, 92% of respiratory samples from ambulatory practice submitted to a laboratory in the South of England were sensitive to the combination of penicillin and gentamicin and 87% to trimethoprim-sulfamethoxazole. Sensitivities of respiratory samples submitted from a referral hospital to the same laboratory were slightly lower but still very acceptable with 83% being susceptible to penicillin and gentamicin and 75% to trimethoprim-sulfamethoxazole (Potier and Durham 2019).

Although available information is limited and highly dependent on the geographical region, it is questionable whether third- or fourth-generation cephalosporins would offer a significant treatment advantage over the combination of penicillin and gentamicin (Toombs-Ruane *et al*. 2015; Awosile *et al*. 2018; Potier and Durham 2019). Considering their reserved status, third- or fourth-generation cephalosporins should only be used if indicated by culture and sensitivity when first-line choices are not available. Enrofloxacin should not be used as stand-alone or first-line therapy as it has no activity against *Streptococcus* spp. and anaerobes and, as a fluorquinolon, is a reserved antimicrobial drug. If first-line choices do not improve the condition within 48–72 h, enrofloxacin could be used as a substitute for gentamicin if indicated by culture and sensitivity results in life-threatening disease due to its greater activity against *Enterobacteriaceae*, better penetration into phagocytic cells and tissues, and better activity in purulent material (Reuss and Giguère 2015). In the recent UK-based study, no predictable efficacious second choice antimicrobial was identified for respiratory isolates resistant to the first-line antimicrobials highlighting the importance of obtaining a culture and sensitivity results early in the disease process (Potier and Durham 2019).

Pneumonia cases without significant tissue damage often only require a short course (2–4 days) of antimicrobials. Resolution of clinical signs or, ideally, repeat cytological evaluation of a repeated tracheal lavage can be used for guidance. Determining a safe point for discontinuation of antimicrobial treatment in pleuropneumonia cases is much more difficult as tissue damage is often extensive and abscess formation is common. Treatment for a minimum of 10 days or until clinical signs and diagnostic imaging findings indicate resolution has been recommended (Reuss and Giguère 2015; Raidal 2019). Although this is not supported by any scientific evidence, it offers a reference point, keeping in mind that discontinuation of treatment after 2–4 days should be considered in cases with minimal tissue damage.

In summary, the desire to protect individual patients often leads veterinarians to use antimicrobial drugs 'just in case' and to extend antimicrobial treatment for longer than necessary. Using easily available diagnostic tools such as cytology and ultrasonography can help identifying animals with a high chance of bacterial disease. Restricting the use of antimicrobial drugs to these horses and decreasing treatment duration, even if only by a couple of days, will reduce resistance development and benefit patients and the profession.

Author's declaration of interests

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Not applicable.

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Review Article

Haematogenous septic arthritis, physitis and osteomyelitis in foals: A tutorial review on pathogenesis, diagnosis, treatment and prognosis. Part 1

***C. Lindegaard*[†]*, *G. van Galen*[‡], *S. Aarsvold*[§], *L. C. Berg*[†] and *D. Verwilghen*[‡]**

[†]*Department of Veterinary Clinical Sciences, Faculty of Health Sciences, University of Copenhagen, Taastrup, Denmark;* [‡]*School of Veterinary Sciences, Faculty of Science, University of Sydney, Sydney, New South Wales, Australia; and* [§]*Puchalski Equine Imaging, Petaluma, California, USA*
**Corresponding author email: casper.lindegaard@sund.ku.dk*

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Summary

Haematogenous septic arthritis, physitis and osteomyelitis (SAPO) is a potentially debilitating or even life-threatening disease entity encountered in foals of all ages between birth and approximately 7 months old. Correct, and complete, diagnosis and successful treatment require collaboration between specialties including medicine, anaesthesia, diagnostic imaging, surgery and rehabilitation services. However, in order to succeed, it is important that all specialties have an overall knowledge of all aspects of the disease complex. Therefore, the aim of this review is to give an overview of aetiology, presenting complaints, clinical findings, diagnostic imaging, treatment, rehabilitation and prognosis. Part one deals with all aspects of aetiology and how to make a diagnosis. Part two deals with all aspects of treatment, rehabilitation and prognosis.

Introduction

Septic or infectious arthritis refers to inflammation in one or more joints as a result of infection by bacteria. Per definition, 'sepsis' means infection of the bloodstream, which can also be termed septicaemia. However, in equine veterinary literature it is generally accepted that septic arthritis refers to any type of joint infection, regardless of whether the infectious agent was introduced into the joint haematogenously or via an open trauma. Foals can be affected by both types of septic arthritis, but the haematogenous type is more common and differs from the traumatic type in many aspects.

Septic arthritis of haematogenous aetiology can occur in foals from immediately after birth and up to at least 7 months of age, but it is more common in neonatal foals secondary to sepsis (Platt 1977; Vos and Ducharme, 2008; Hepworth-Warren *et al*. 2015; Wright *et al*. 2017; Wright and Lindegaard, 2018). It is characterised by a severe inflammatory reaction, which can eventually lead to cartilage destruction, hypertrophy of the joint capsule, reduced range of motion and lameness (**Fig 1**) (Platt 1977; Firth 1983; Vos and Ducharme, 2008; Wright *et al*. 2017; Richardson and Stewart 2019). If treatment is delayed, insufficient and/or ineffective, damage can become chronic in the form of osteoarthritis (OA), and the foal may be unable to pursue an athletic career (Martens *et al*. 1986; Richardson and Stewart 2019). In a worst-case scenario, the foal may even need to be subjected to euthanasia for humane reasons or die because of inability to stand and nurse or due to development of sepsis from the initiating bacteraemia (Cohen 1994). Recently, it has been suggested that septic arthritis, physitis and osteomyelitis (SAPO) may also lead to osteochondrosis (Wormstrand *et al*. 2018) potentially causing an additional risk for joint disease at older ages.

In a recent retrospective study from multiple referral centres in Sweden and Denmark, 80 out of 585 (14%) hospitalised neonatal foals (0-14 days old) had swollen joints recorded on admission (G. van Galen, unpublished data – from data set used in Bohlin *et al*. 2019). This data set does not contain enough details to be able to provide a more precise prevalence of SAPO in that population, since other reasons for swollen joints may have been included, and foals that developed SAPO during hospitalisation were not counted. However, it provides a rough estimate of likely SAPO cases from a more recent data set compared to the other existing reference dating back to 1977, in which septic arthritis in Thoroughbred foals was reported to occur with an incidence of up to 1% (Platt 1977). Even though SAPO is accepted to be a relatively common disease, the true incidence thus remains largely unknown.

The aim of this review (Parts 1 and 2) is to present current knowledge on aetiology, pathogenesis, clinical signs, diagnostic work-up, treatment options, rehabilitation and prognosis of haematogenous septic arthritis, physitis and osteomyelitis in foals.

Methods

Since this is considered a tutorial review, the authors aim to provide a selected review of the most relevant literature combined with the authors' experiences on the subject. Consequently, it should not be seen as a systematic review, and the reference list may not be exhaustive.

Classification, aetiology and pathogenesis

SAPO represents slightly different presentations of infection in the joint or the surrounding bone occurring as sequelae to bacteraemia or even sepsis in neonatal or young foals. Despite the differences, they share similarities in presentation that can make discrimination challenging (Firth *et al*. 1980; Firth 1983). Haematogenously disseminated bacteria originate

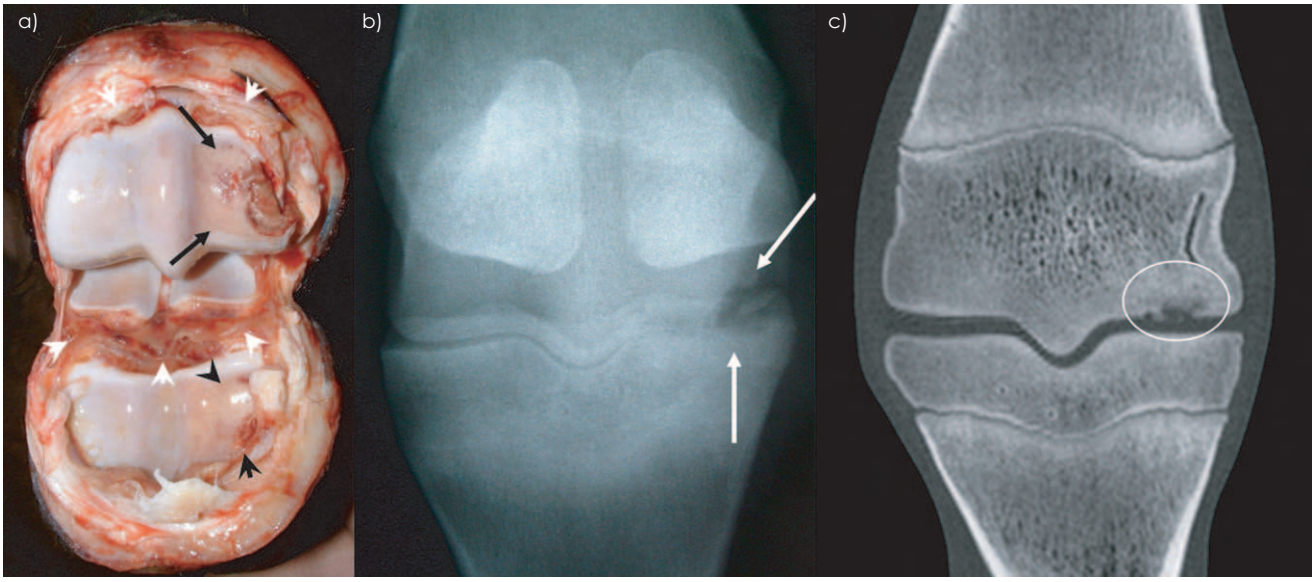

Fig 1: Septic arthritis and osteomyelitis might lead to severe destruction of the articular cartilage and the joint. a) Severe erosion of cartilage and osteolysis of the underlying bone (black arrows) in a foal with a Type E MC3 condylar septic arthritis. b) Dorsopalmar radiograph showing a lytic region of the abaxial aspect of the medial third metacarpal condyle causing moderate irregularity of the articular margin. There is also moderate collapse of the joint space, more pronounced on the side with the subchondral defect. c) Dorsal plane computed tomographic image of the metacarpophalangeal joint in a bone window (WL: 1000; WW: 3000) showing a similar lesion to the radiographic and gross images. There is loss of the subchondral compact bone and lysis of the subchondral trabecular bone surrounded by mild sclerosis. The defect causes focal irregularity of the articular margin.

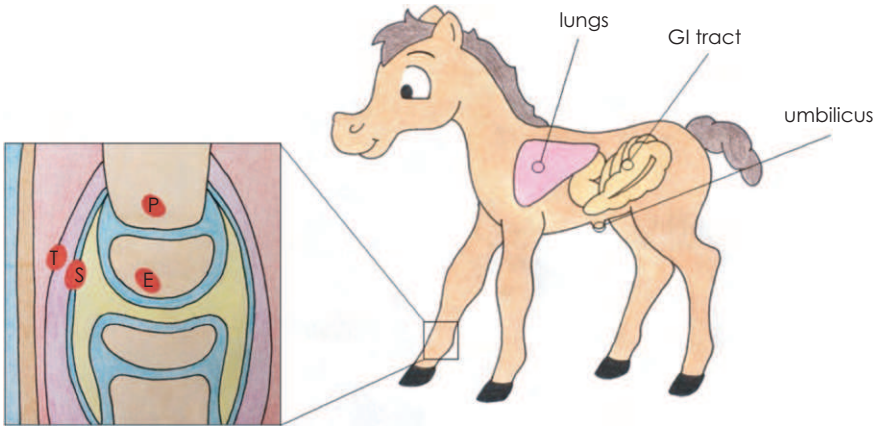

Fig 2: Septic arthritis in foals occurs in four different forms depending on the specific anatomical location of the inoculated bacteria: via haematogenous inoculation of the synovial membrane – Type S (S); via haematogenous inoculation of bacteria in the epiphysis – Type E (E); via haematogenous inoculation of the physis – Type P (P); or via trauma with direct external inoculation – Type T (T). In cases of haematogenous septic arthritis, the entry of bacteria is most often via the lungs, gastrointestinal tract (GI) or the umbilicus. Type T septic arthritis is not depicted in the figure, but refers to haematogenous septic arthritis with inoculation of the small carpal or tarsal bones and thereby resembles Types E and P. Drawing: Valentina Vitale.

from among others the gastrointestinal tract, the respiratory system, the umbilicus (Steel *et al*. 1999) or the heart (Porter *et al*. 2008), sometimes without obvious signs of systemic illness or other diseases (**Figs 2** and **3**). Foals are dependent on passive transfer of immunity, making failure of passive transfer a major risk factor for the development of SAPO (Mcguire *et al*. 1977; Firth 1983; Firth and Poulos 1983; Liepman *et al*. 2015).

Bacteria isolated from SAPO are dominated by *E. coli*, *Actinobacillus* spp, *Klebsiella* spp, *Staphylococcus* spp, *Streptococcus* spp and *Rhodococcus equi* (Hardy 2006; Vos and Ducharme 2008; Hepworth-Warren *et al*. 2015; Glass and Watts 2017), but include many different types of bacteria with various patterns of antimicrobial susceptibility. Isolates cultured from foals have been shown to vary with geography and environment and may even change over time (Theelen *et al*. 2014a,b). More information regarding relevant bacterial isolates is provided under 'Diagnosis'.

In the adult horse, blood supply to the metaphysis is provided through the nutrient artery, but in the foal, there is a

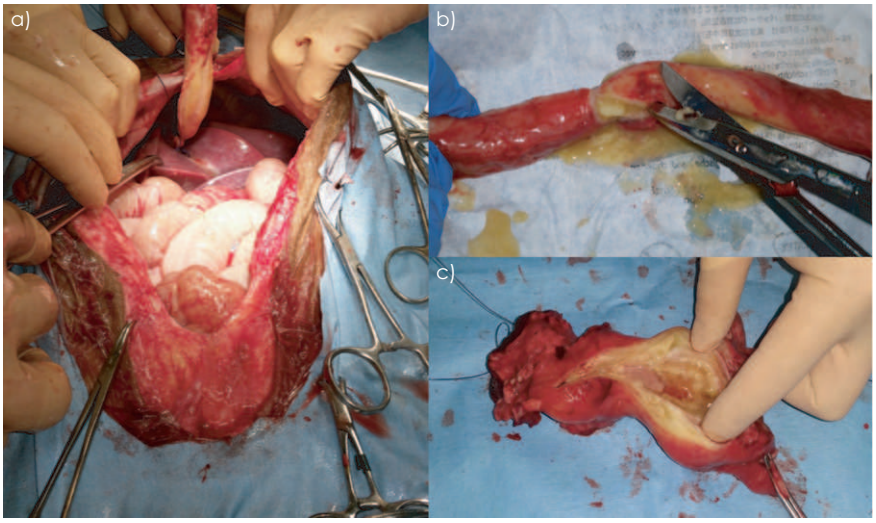

Fig 3: Removal of an infected umbilicus in a 10-day-old foal with multiple joint septic arthritis. View from caudal to cranial of an explorative celiotomy to remove a severely infected umbilicus and umbilical vein. a) The vein is retracted through the cranial part of the incision, and it is ligated at its termination on the liver. b) The resected vein is cut open to reveal the purulent contents, and c) the umbilicus is opened in the same way to reveal the infectious material.

vast network of transphyseal vessels supplying the metaphyseal side of the physis. The transphyseal vessels close within the first 2 weeks of life, and the metaphyseal side of the physis is then supplied by arterial branches from the nutrient artery (Firth 1983; Firth and Poulos, 1983). This is likely to make septic or bacteraemic foals more vulnerable to the development of SAPO in this time frame. Inoculation of bacteria occurs when bacteria become trapped in the smallest, peripheral capillaries, which are prone to infection by small septic thrombi (Firth and Poulos, 1983). SAPO can be classified into S-, E-, P- and T-type (Firth *et al*. 1980; Firth 1983): S-type refers to a part of the disease complex, where infection initially locates to or originates from the synovial membrane, leading to true septic arthritis. In E-type, bacteria disseminated by the bloodstream are inoculated in the subchondral bone of the epiphysis. For P-type, the infection is initiated in the physis or metaphysis, whereas T-type refers to infection of the cuboidal bones of the tarsus or carpus. The existence of transphyseal vessels means that bacteria in the blood becomes trapped in the synovial membrane and the epiphysis, making S- and E-type more common in very young foals (up to 7-10 days), although E-type can also occur in slightly older foals. Closure of the transphyseal vessels at 7-10 days of age results in P-type becoming the predominant SAPO type in older foals (Firth 1983).

It is crucial to understand the different SAPO types to allow for appropriate selection of the diagnostic modalities to correctly diagnose and classify each case. For instance, the septic nidus in the subchondral bone of E-type and the physis of P-types will act as reservoirs for continued spreading to the synovial cavity of affected joints (Firth 1983; Hall *et al*. 2012 and personal experiences). Truly effective treatment can therefore only be achieved if and when the nidus of infection is targeted and removed (Hall *et al*. 2012).

With the availability of more advanced imaging modalities, case reports and case series have documented that SAPO can affect any joint or bone in the body, with the tarsocrural, femoropatellar, fetlock and elbow joints being most commonly affected (Steel *et al*. 1999; Neil *et al*. 2007; Vos and Ducharme, 2008; Roberts *et al*. 2010; Haggett *et al*. 2012; Kay *et al*. 2012; Hepworth-Warren *et al*. 2015; Wright and Lindegaard, 2018; Wright *et al*. 2018). Approximately 40% of SAPO cases have only one affected joint, approximately 40% have two affected joints, and 20% have more than two affected structures (Steel *et al*. 1999; Vos and Ducharme, 2008; Hepworth-Warren *et al*. 2015; Wright *et al*. 2017). Thus, we have to remind ourselves that regions difficult to image with more basic imaging techniques (axial skeleton, pelvis and proximal limbs) may be acting as ongoing niduses of infection (**Fig 4**), and unresponsive cases may therefore benefit from more advanced imaging modalities, particularly CT, in order to establish diagnosis and ensure effective treatment.

Clinical signs and diagnosis

Initial complaint

Depending on the affected anatomical structure, the owner's initial complaint in foals with SAPO is often the observation of one or more swollen joints, obvious lameness in one or more limbs, changed or impaired movement/gait and/or signs of a stiff back or neck (Firth *et al*. 1980; Firth 1983; Steel *et al*. 1999; Munsterman *et al*. 2007; Vos and Ducharme, 2008; Neil *et al*. 2010; Kay *et al*. 2012; Wright and Lindegaard, 2018; Wright *et al*. 2018). They may also report that these impairments prevent the foal from ambulating, getting up and lying down, and/or nursing properly. In some cases, the owner believes that the foal might have a fracture or other trauma from being stepped on by the mare, which is, however, in the authors' experience, a much rarer event than the occurrence of SAPO (Hardy 2006). In some foals, the initial complaint includes indications of failure of passive transfer and/or signs of sepsis with fever, recumbency, reduced appetite and/or lethargy.

Clinical signs

All subtypes of SAPO will eventually include one or more of the following signs: lameness, altered movement of back and neck, joint distension, soft tissue swellings and soreness on

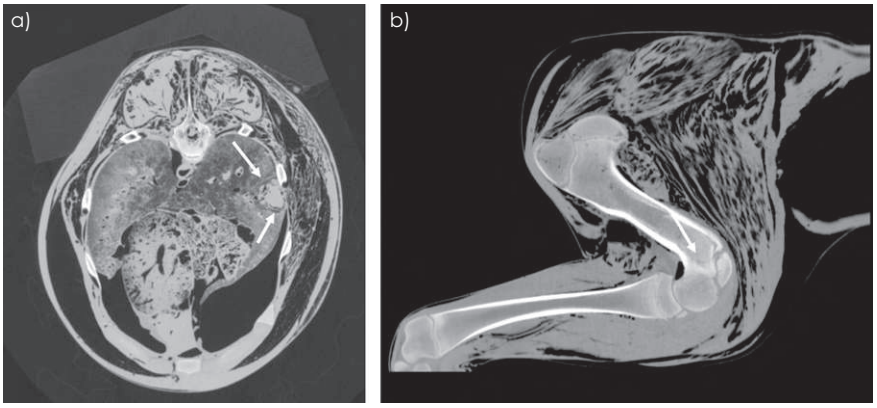

Fig 4: Computed tomography bone window images acquired post-mortem on a foal with a pulmonary abscess and a P-type lesion affecting the distal humeral metaphysis. a) Transverse image of the thorax. The pulmonary abscess (white arrows) is characterised by a well-defined region of hyperattenuation within the pulmonary parenchyma of the left caudal lung lobe. b) Sagittal image of the humerus, elbow and radius. The distal humeral metaphyseal lesion (white arrow) is characterised by mild sclerosis of the medullary cavity of the distal metaphysis surrounding a small region of poorly defined, irregularly shaped region of lysis. Marked gas accumulation within the subcutaneous tissues, pleural space, vasculature and vertebral canal is secondary to post-mortem artefact.

palpation (**Fig 5**) (Firth 1983; Schneider *et al*. 1992; Steel *et al*. 1999; Vos and Ducharme, 2008; Neil *et al*. 2010). In many cases, the anatomical structure(s) involved is (are) evident and a tentative diagnosis of septic arthritis can be made easily. However, in cases where more proximal joints or the axial skeleton is affected, joint distension and swelling may not be obvious and a diagnosis more difficult to reach (Oliver *et al*. 2017; Lindegaard 2018; Wright and Lindegaard, 2018; Wright *et al*. 2018). Lameness is a hallmark of septic arthritis in adult horses, but not all foals will be overtly lame initially. Lameness can be difficult to identify early in the septic process, when multiple limbs are affected, or in a systemically ill or recumbent foals (Firth 1983). The absence of distinct lameness should therefore never be used to rule out a diagnosis of SAPO.

Other septic foci, including the lungs, the umbilicus and the heart among others, may accompany SAPO and should be investigated, localised and treated for a successful outcome. As a general rule, all foals suspected of having SAPO should be thoroughly examined for signs of sepsis and other foci of infection, and similarly, all foals with sepsis or one or more foci of localised infections should be thoroughly examined for signs of SAPO. While SAPO most often develops after birth, it is worthwhile considering that systemic sepsis, and therefore potentially also SAPO, could also start *in utero* in mares with placentitis (Canisso *et al*. 2015), and foals of any age may present with a suspicion of SAPO.

Synovial fluid analysis

The next step of the examination is to perform an aseptic arthrocentesis. Synovial fluid (SF) analysis should start with visual inspection with normal SF being clear, yellow and viscous. SF from an infected joint will be turbid, darker yellow or orange, perhaps with obvious fibrin or pus conglomerates along with reduced viscosity. After visual inspection, SF should be analysed for total protein (TP), total white blood cell count (WBC) and white blood cell differentiation (WBC diff) (**Table 1**) (Hardy 2006; Richardson and Stewart 2019; Personal experience).

It is important to note that E- and P-type septic arthritis may not always lead to sepsis of the synovial cavity itself, particularly in the early course of the disease. In fact, if the infection is located in the epiphysis or physis adjacent to the joint capsule, there is more likely to be reactive inflammation of the joint instead of fulminant synovial sepsis. Consequently, TP, total WBC and WBC diff values may be inconclusive, not distinguishing clearly between an inflammatory and infectious process (Firth 1983; Personal experiences). Such results should make the clinician suspect a potential E- or P-type infection instead of S-type septic arthritis (**Table 1**).

Other less conventional markers in synovial fluid have been shown to be able to differentiate between septic and nonseptic SF in adult and/or foal septic arthritis, including serum amyloid A (SAA) (Jacobsen *et al*. 2006; Ludwig *et al*. 2016; Robinson *et al*. 2017; Stack *et al*. 2019), glucose (Anderson *et al*. 2018), D-dimer (Ribera *et al*. 2011), myeloperoxidase (Wauters *et al*. 2013) and neutrophil gelatinase-associated lipocalin (NGAL) (Jacobsen *et al*. 2019). Handheld devices are available for glucose and SAA analysis, and the handheld SAA device has been shown to offer reliable detection of synovial sepsis in horses (Stack *et al*. 2019). The leucocyte esterase test from urinary dipsticks has proven an accurate bedside test in human medicine to differentiate inflammatory from infectious SF processes (Yeganeh *et al*. 2020), but remains to be validated in an equine model.

Bacterial culture and sensitivity testing of SF and blood

It is highly recommended to perform culture and sensitivity testing of both SF and preferably also blood to: 1) confirm a septic process and/or systemic sepsis, 2) gain knowledge about the type of bacteria involved and 3) guide or adapt antimicrobial therapy. From a biosecurity point of view, these cultures are invaluable for monitoring local geographical bacterial populations and shifts in sensitivity patterns, so that appropriate antimicrobial therapy can be applied as early as possible (Johns and Adams, 2012).

The type of collection and culture method used has a significant impact on the likelihood of achieving bacterial

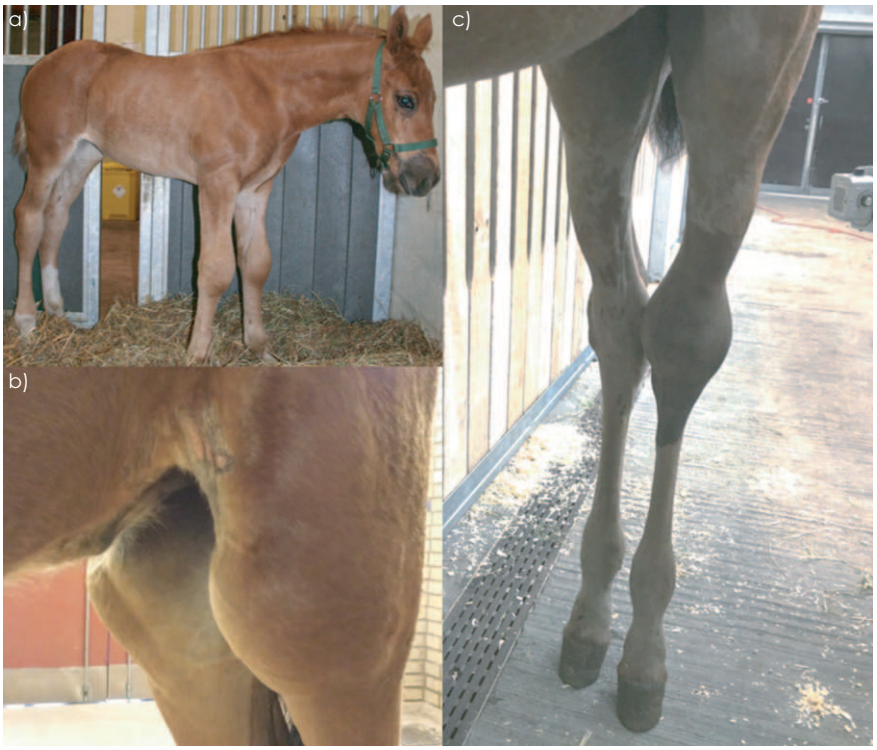

Fig 5: a) A 3-month-old foal with distended carpal joints and obvious signs of depression and pain; the position of the ears, lifted upper eyelid, contracted muzzle and dilated nostrils. b) severely distended left femoropatellar joint c) and severely distended left tarsocrural left joint (image b - Courtesy of Professor Stine Jacobsen, University of Copenhagen).

TABLE 1: Synovial fluid is assessed visually and examined for total white blood cell count (WBC), percentage of neutrophils (Diff WBC) and protein

	Normal	Septic arthritis	Suggestive of Type P or E septic arthritis
Visual Inspection	Clear yellow and viscous	Turbid yellow to orange	From slightly unclear to opaque
WBC	<0.5 × 10^9 cells/L	>20 × 10^9 cells/L	2-15 × 10^9 cells/L
Diff WBC	<50-60%	>85% neutrophils	75-90% neutrophils
Total Protein	<25 g/L	>30-40 g/L	>25 g/L

The column 'Normal' refers to commonly recognised values for noninfected and noninflamed synovial fluid. The column 'Septic arthritis' refers to commonly recognised values for infected joints. The column 'Suggestive of type P or E septic arthritis' refers to values experienced by the authors to be found in joints with P- or E-type lesions.

growth. Blood and SF cultures require sterile sampling techniques, and several studies have shown that initial inoculation in blood culture media may yield a significantly higher proportion of bacterial growth (up to 79%), compared to direct agar culture which might yield bacterial growth in as low as 37.5% of confirmed septic cases (Pille *et al*. 2007; Dumoulin *et al*. 2010). Culture samples are ideally collected prior to administration of antimicrobials (Scheer *et al*. 2019). Blood culture results take a couple of days and may have a significant percentage of false negatives (Wilson and Madigan, 1989). This is also the case for SF cultures, which present with only 45-85.7% growth rates from septic joints (Madison *et al*. 1991; Steel *et al*. 1999; Hardy 2006; Vos and Ducharme, 2008; Dumoulin *et al*. 2010; Hepworth-Warren *et al*. 2015). Currently, the use of a BACTEC paediatric system, requiring only a small amount of sample SF, is considered the most effective method for obtaining a positive culture in septic conditions (Dumoulin *et al*. 2010). Early instigation of the correct treatment is important, and limiting the time needed to confirm bacterial growth and sensitivity is essential. Consequently, the BACTEC system offers advantages, revealing growth within 24 h, and combining the BACTEC system with direct E-test (a reagent strip designed to determine susceptibility and a precise MIC value) will also provide rapid sensitivity results, at least 24 h faster than with other methods (Dumoulin *et al*. 2017). Sampling of both blood and SF for culture will increase the likelihood of a positive culture from a septic patient. Bacterial isolates can be similar in both types of fluid, but may also differ (Hepworth-Warren *et al*. 2015). In the latter scenario, both isolates may be of clinical importance for the foal, but it is worth noting that false positives might occur due to contamination or in the case of blood cultures due to bacteraemia without sepsis. During surgical exploration of the

joint, a synovial biopsy can be performed for histology and bacterial culture, yielding an additional opportunity to identify the causative organism (Madison *et al*. 1991). As mentioned above, Gram-positive as well as Gram-negative and mixed isolates are commonly found in septic arthritis, including *E. coli*, Actinobacillus spp, Klebsiella spp, Staphylococcus spp, Streptococcus spp and *Rhodococcus equi* (Hardy 2006; Vos and Ducharme 2008; Hepworth-Warren *et al*. 2015; Glass and Watts 2017). It has been suggested that isolates of septic joints depend on age; the neonatal period is more frequently caused by Gram-negative infections, while Gram-positive infections generally occur after the neonatal period (Schneider *et al*. 1992; Hardy 2006; Vos and Ducharme 2008; Annear *et al*. 2011). However, others have not been able to confirm this association (Hepworth-Warren *et al*. 2015).

Blood analysis

Standard biochemistry, haematology and blood gas analysis will further establish the degree of general systemic disease, and efforts should be made to rule in or rule out systemic sepsis. In addition to the diagnosis of sepsis, blood work is critical in order to diagnose and monitor clinical or subclinical organ involvement, nutritional and immune status, and electrolyte and acid–base status. Blood analysis has also been shown to be useful in diagnosing septic arthritis. Serum SAA can differentiate septic from nonseptic joint processes in adult horses (Jacobsen *et al*. 2006; Ludwig *et al*. 2016; Robinson *et al*. 2017), and presumably, this is similar in foals, as they have been shown to mount a similar systemic SAA response after systemic inflammatory and infectious processes (Hulten and Demmers 2002; G. van Galen, unpublished data). Plasma fibrinogen concentrations higher than 9 g/L have been suggested to be an indicator of physeal or epiphyseal osteomyelitis in foals (Newquist and Baxter, 2009).

Diagnostic imaging

Due to the diagnostic challenges stated above, diagnostic imaging is essential for reaching the correct diagnosis. It should be seen as an integrated part of the diagnostic work-up, regardless of the age of the foal.

Imaging characteristics of septic arthritis depend on the type, distribution and stage of lesions. For S- and E-types, synovial effusion and joint distension will be the earliest findings, which can be identified on radiographs, ultrasound, CT or MRI (**Fig 6**). For P-type, early imaging findings include irregularity of the physeal margin and/or widening of the physis that progresses to lysis of the metaphyseal and epiphyseal trabecular bone (Suarez-Fuentes and Tatarniuk, 2019). Later, imaging findings include irregular regions of bone loss with a distribution depending on type and location. Often the regions of bone loss will be surrounded by sclerosis, and an irregular periosteal reaction will also likely appear if they are located superficially (Butler *et al*. 2008). For all diagnostic imaging modalities, interpretation can be challenging, and knowledge of anatomy, development and appearance of pathological processes on various diagnostic imaging modalities is very important. When in doubt, imaging of the contralateral limb should be obtained for comparison, although it is key to realise that SAPO frequently presents as a bilateral disease.

Diagnostic imaging modality selection and findings

Radiography

Radiography is the obvious first choice in any case suspected of SAPO as it is readily available, cheap and can be performed in the field. Radiographs can visualise moderate volume synovial effusion in most joints (Lawson *et al*. 2012). However, radiographic sensitivity for bone loss is relatively low, requiring a 30-50% reduction in bone density for it to be radiographically visible (Harris and Heaney, 1969). Another drawback of radiography is superimposition of structures. In complex joints, such as the carpus or tarsus, the superimposition of osseous structures may inhibit adequate recognition and evaluation of small regions of lysis, particularly along the joint surface and at the physis. Radiography may also underdiagnose abscesses located within the soft tissues close to the physeal area due to limited soft tissue contrast resolution and similar tissue density between abscess (fluid) and soft tissues.

On radiographs, the appearance of S-type lesions varies depending on severity, with joint swelling becoming detectable when effusion becomes moderate. E-type lesions in noncomplex joints can be detected along the chondral surface and appear as poorly defined or irregularly shaped regions of lysis that may, or may not, communicate with the articular surface of the subchondral bone. For complex joints, alternative radiographic projections, including flexed and skyline views, may be required to better assess the articular margins. P-type pathology has a similar appearance to E-type with irregular regions of lysis, but they communicate with the physeal margin instead of the articular margin. P-type lesions can be associated with abscessation of the regional tissues, which radiographically can be visible as focal soft tissue swelling in the region of osseous change (Butler *et al*. 2008) (**Fig 7**). In order to interpret radiographs correctly, knowledge of anatomy and of the normal processes of growth and development in the foal (e.g. the evolution of growth plates and irregular bony surfaces) is crucial, as is understanding of other pathological processes involving joints in foals (e.g. incomplete ossification of the tarsal, carpal or crural bones and osteochondrosis) (**Fig 8**).

Ultrasonography

Similar to radiography, ultrasonography is readily available in the field and is useful to identify joint effusion and superficial bone lesions. Ultrasound also allows for assessment of the articular cartilage and can show early sites of erosion or cartilage loss (Redding 2001). This is especially true for the tarsocrural and femoropatellar joints, because of the ability to see a large portion of the articular margin (**Fig 9**). Ultrasound cannot, however, identify lesions along the weightbearing surfaces of most bones, particularly the cuboidal bones of the carpus and tarsus.

Ultrasonographic appearance of S- and E-type SAPO typically includes synovial thickening and effusion with variable echogenicity of the synovial fluid. This is particularly useful when effusions are in locations where they are more difficult to inspect and palpate. The synovial surface may appear irregular and fibrillated. Depending on the location of osseous lesions, they can be visualised as irregularity of the bone surface and a change in the echogenicity of the overlying articular cartilage. The articular cartilage can also

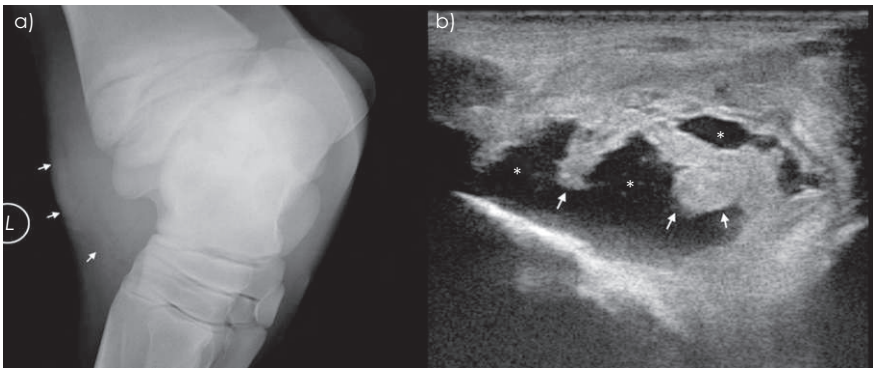

Fig 6: Radiograph a) and ultrasound b) of a foal with S-type septic arthritis. Radiographically, there is moderate to marked circumferential swelling at the level of the tarsocrural joint (white arrows) with increased opacity of the soft tissues. Ultrasonographically, there is a large volume of effusion within the tarsocrural joint (*) and moderate to marked thickening of the synovium (white arrows) and joint capsule.

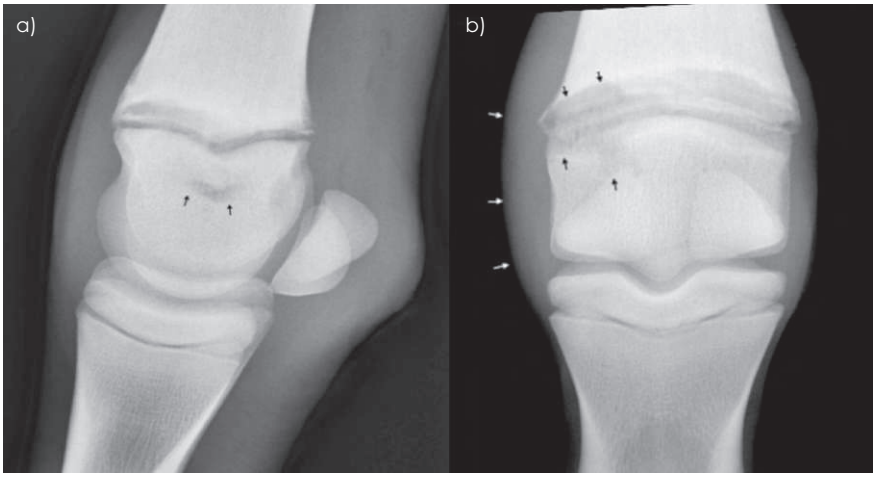

Fig 7: Lateromedial a) and dorsopalmar b) radiographs of the left front metacarpophalangeal joint of an 8-week-old foal showing poorly defined lysis of the trabecular bone within the medial aspect of the distal metaphysis and epiphysis of the third metacarpus that is poorly marginated and immediately adjacent to the physis (black arrows). There is mild regional soft tissue swelling along the medial aspect of the limb, centred at the level of the distal third metacarpal physis (white arrows).

have an altered thickness depending on the stage of the disease process. P-type lesions are difficult to identify on ultrasound, though periphyseal abscessation can be imaged and typically appears as a thick-walled structure with echogenic fluid centrally (Annear *et al*. 2011).

Note that an irregular physeal margin is not always associated with SAPO. Consequently, any ultrasonographic changes must be interpreted with caution and correlated with the overall clinical picture.

Particularly in less accessible joints, ultrasound guidance can be helpful for aspiration of SF, but for most joints, synoviocentesis is straightforward and ultrasound guidance unnecessary. On the other hand, the use of intraoperative ultrasound guidance is largely beneficial for direction of surgical instruments to the affected portion of the physis, thereby limiting damage to unaffected regions (personal experience).

Computed tomography

In the authors' opinion, computed tomography (CT) is the gold standard imaging modality for identifying changes associated with SAPO. CT is more sensitive than radiography for detecting bone loss (Lean *et al*. 2018), and cross-sectional imaging eliminates the issue of superimposition allowing for clear evaluation of all structures of complex joints (**Figs 10** and **11**). It also allows for clearer delineation of soft tissue structures, including better identification of abscesses surrounding physeal changes. While CT requires anaesthesia, the scan time is relatively short. Depending on the patient, contrast medium can be administered via an intravenous or intra-articular route to further enhance delineation of soft tissue changes. Typically, gantry size limits proximal limb evaluation in adult patients, but most foals will fit entirely into the CT machine, allowing examination of the full body, including areas that are challenging to image with radiography.

In the authors' experience, on CT, S-type SAPO manifests as thickening of the synovial structures with increased volume of joint effusion. If cartilage irregularities occur with disease progression, intra-articular contrast allows for clearer visualisation of cartilage changes (Nelson *et al*. 2016) as well as better definition of degree of thickening of the synovium.

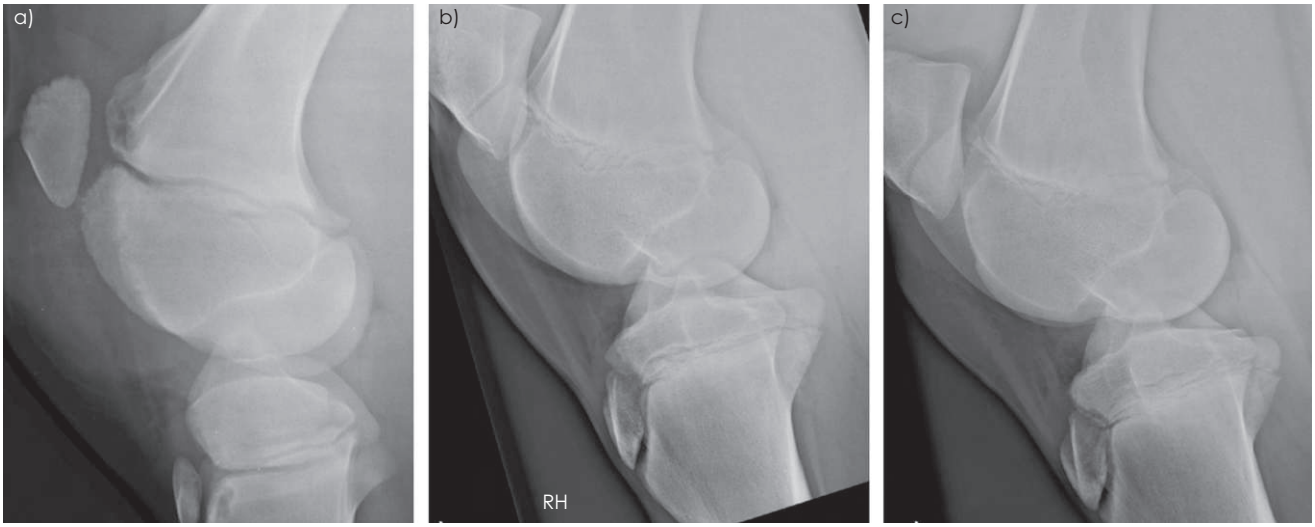

Fig 8: Radiographic images of the stifle, and particularly the femoral trochleas, may be difficult to interpret since the normally developing trochleas might look very irregular almost resembling P-type septic arthritis or osteochondrosis. a) Radiograph showing normal irregular trochleas in a foal with incomplete ossification of the distal femoral physis in a 6-month-old foal. b) Radiograph showing normal regular femoral trochleas in a 6-month-old foal and c) radiograph showing early osteochondrosis in a 6-month-old foal presenting with acute severe lameness, distended femoropatellar, slightly elevated temperature (38.8 degrees C) and slightly elevated total WBC in the aspirated synovial fluid. However, the percentage of neutrophils was low and blood biochemistry revealed no evidence of inflammation or infection; hence, a diagnosis of osteochondrosis and not septic arthritis was made.

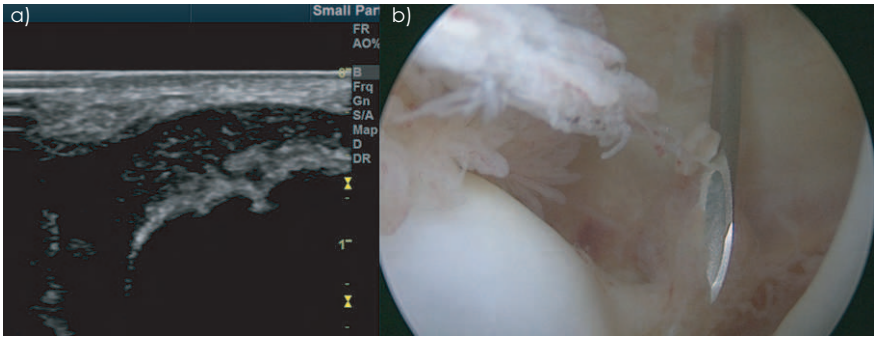

Fig 9: Ultrasonography can be difficult to interpret for diagnostic purposes but very useful for guidance of surgical debridement. a) Longitudinal ultrasonographic image of the lateral trochlea of the talus of a 6-week-old foal with septic arthritis which shows an indentation in the cartilage and bone. However, the defect cannot be recognised during arthroscopic lavage and visualisation of the distal lateral trochlea of the talus (b).

With E-type lesions, the subchondral bone becomes irregular and lytic, with eventual progression to irregular regions of lysis of compact and trabecular subchondral bone. Sometimes, the lysis will expand within the trabecular bone leaving a shelf of compact bone along the joint margin. This can lead to collapse of the subchondral compact bone and permanent irregularities of the articular margin.

Imaging changes associated with P-type SAPO include physeal lysis with irregularity and widening of the physeal margin, at times with formation of minor sequestra within the lytic area (**Fig 12**). As the disease progresses, physeal abscesses can become visible as fluid-filled, thick-walled structures at the level of the physis (Munsterman *et al*. 2007; Puchalski 2007; Wright and Lindegaard, 2018).

Magnetic resonance imaging

Magnetic resonance imaging (MRI) allows for excellent soft tissue detail, eliminates superimposition of osseous structures and allows for evaluation of active bone turn over. Fluid-specific sequences, such as short tau inversion recovery (STIR), can identify regions of bone remodelling/inflammation that may not be delineated on CT and thus could, in theory, identify regions of 'active' infection (**Fig 13**). However, subtle bone loss is poorly defined, particularly on low-field MRI (Smith *et al*. 2012). Furthermore, MRI scan times are often longer (1-2 h) and therefore might be considered suboptimal in systemically ill foals, particularly if the anaesthesia time is going to be prolonged further by surgery immediately following imaging. In human medicine, high-field MRI is the gold standard, particularly due to the lack of required

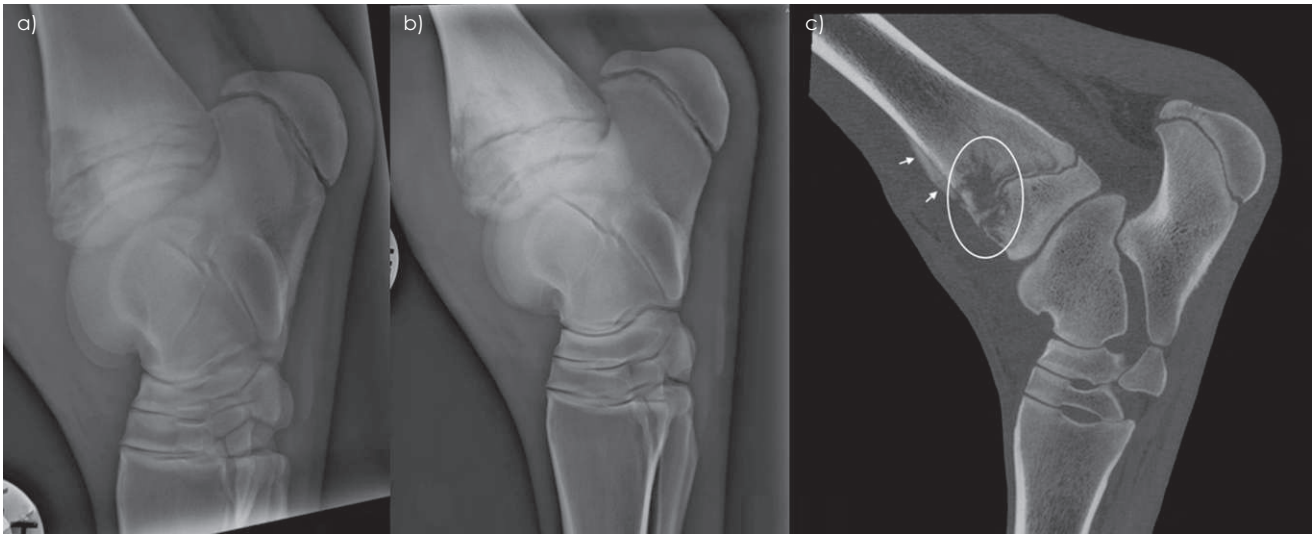

***Fig 10:** Typical appearance of P-type lesions of the distal tibial physis. a) Lateral radiographs of the hock area of the foal depicted in Fig 4c immediately at admittance to the hospital and 19 days later. (b) Initially, the loss of bone density surrounding the dorsal distal tibial physis is relatively subtle. However, 19 days later treatment seems ineffective and loss of bone is severe. (a and b – courtesy of Professor Stine Jacobsen, University of Copenhagen). c) Sagittal computed tomographic image of a lesion similar to the one depicted in (b). The oval shows the severely osteolytic area and the white arrows deposition of smoothly marginated new bone arising from the cranial margin of the distal tibial metaphysis. (CT bone window: WL: 1000; WW: 3000).*

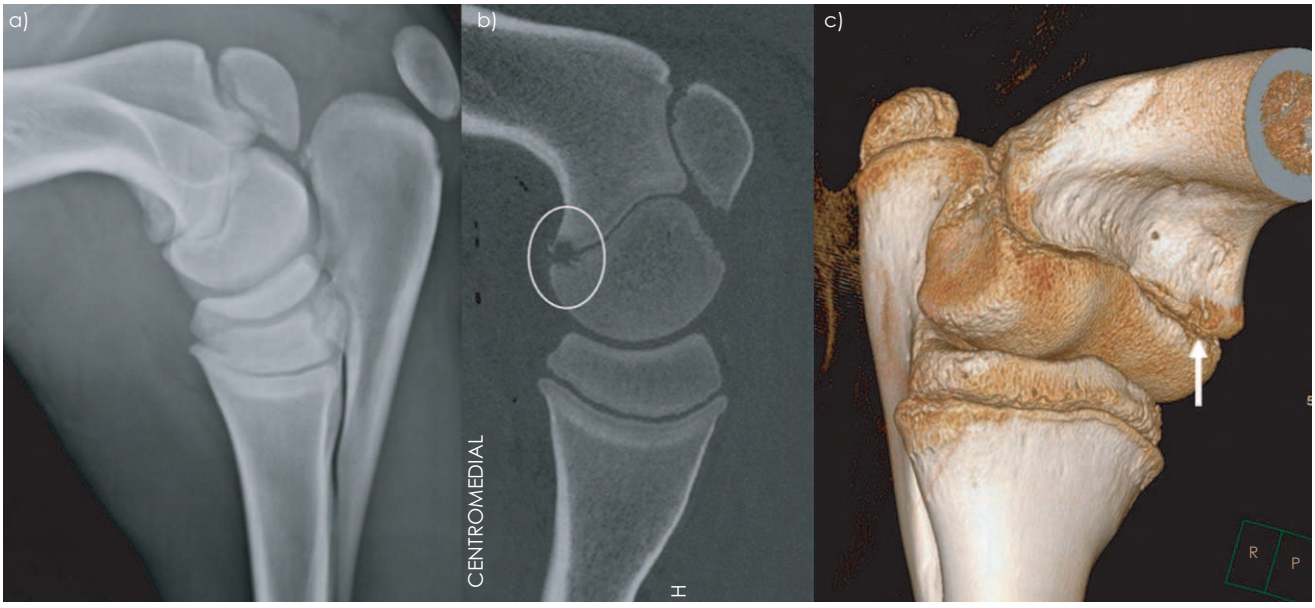

***Fig 11:** The distal humeral physis is a common location for P-type lesions. One-month-old filly with septic arthritis of the radio-humeral joint. Radiography (a) did not reveal any signs of bony involvement (gas can be seen in the caudo-proximal joint due to recent synoviocentesis). Since the foal did not improve after 4 days and 2 times of arthroscopic lavage, a computed tomography was performed and revealed a P-type lesion of the cranial distal humeral physis (b). c) A 3-dimensional rendering shows a small sequestrum in the very small osteolytic defect (white arrow).*

anaesthesia, availability of high-field magnets and succinct imaging protocols that allow for shorter imaging times. High-field MRI has been shown to have the same diagnostic accuracy for detecting osteomyelitis as single-photon emission computed tomography (SPECT) and positron emission tomography (PET) (Llewellyn *et al*. 2019).

Nuclear scintigraphy

Nuclear scintigraphy (NS) utilises a radioisotope tagged to a phosphate to show regions of high bone turnover. In normal foals, the physes often have moderate radioisotope uptake, which may inhibit detection of disease (physitis) in these regions. Additionally, NS has poor anatomical localisation,

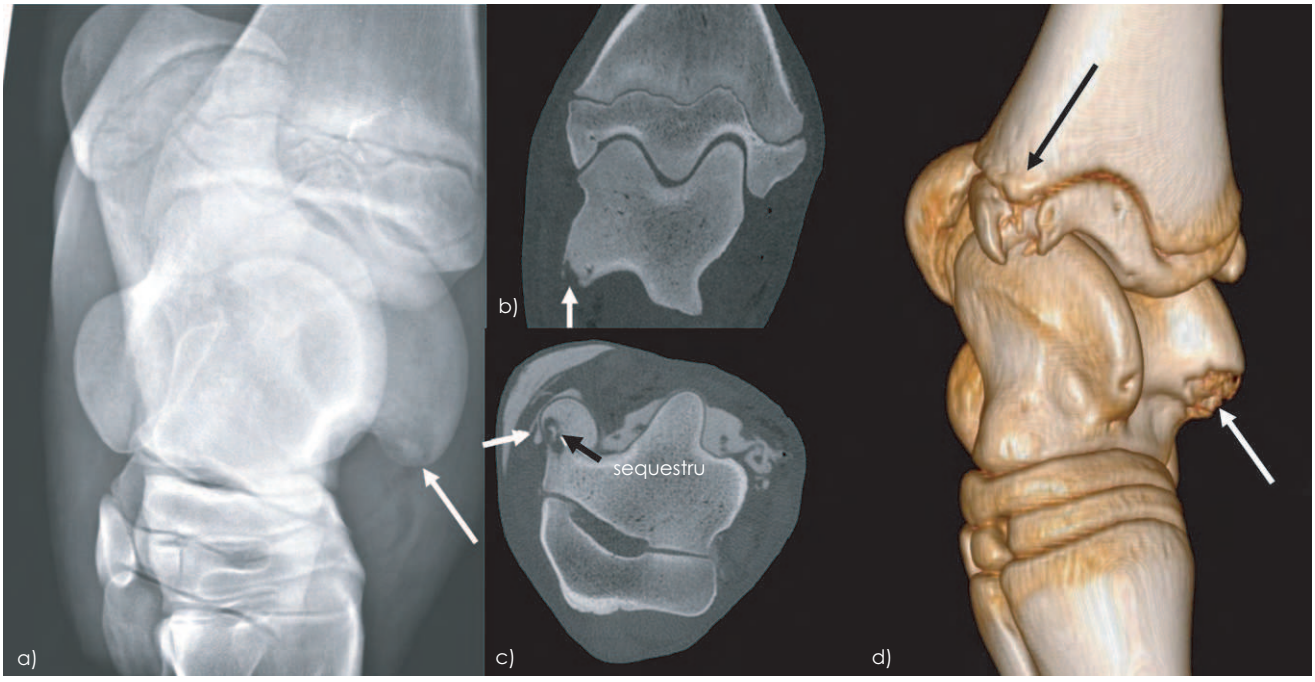

Fig 12: The hock is a common site for various types of septic arthritis lesions. a) Radiograph of an obvious E-type lesion of the distal lateral trochlea of the talus in a 3.5-month-old foal (white arrow). The lesion was, however, not visible arthroscopically, and a computed tomography was performed (b) and revealed a defect of the distal lateral trochlea (white arrow). c) An intra-articular contrast study revealed that the defect, which was completely covered with cartilage (contrast does not enter the defect – white arrow), contained a small sequestrum (black arrow). d) shows a 3-dimensional reconstruction of a computed tomography study of similar case which has a E-type defect of the distal lateral trochlea (white arrow) and a P-type lesion of the medial distal tibial physis and the medial malleolus (black arrow).

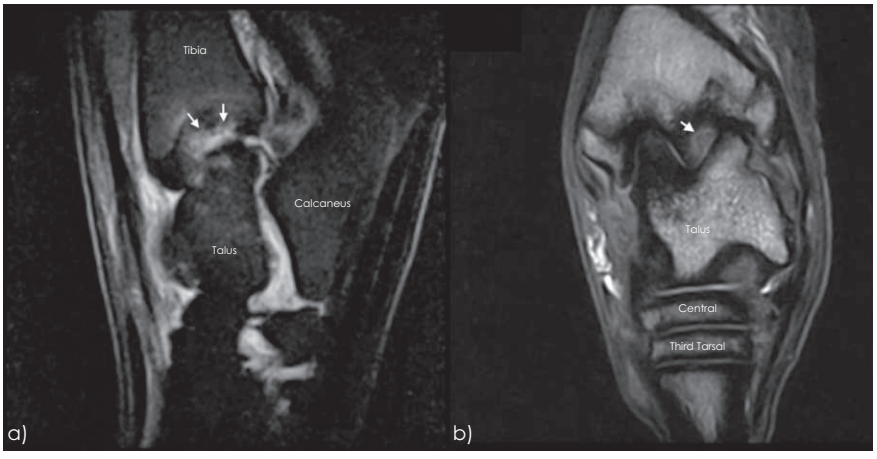

Fig 13: a) Sagittal and b) dorsal plane STIR low-field magnetic resonance images of the tarsus of a 2-year-old Icelandic horse with septic arthritis of the tarsocrural joint and concurrent osteomyelitis of the distal tibia. In a), Cranial/dorsal is to the left and proximal in the top. In b), lateral is to the right and proximal in the top. A small-to-moderate volume of effusion is present in the tarsocrural joint space with thickening of the synovium. There is a large osteolytic lesion present in the distal tibia located at the lateral aspect of the distal intermediate ridge of the tibia (white arrows). The talo-calcaneal joint space is mildly widened. Image courtesy of Dr Henrik Sten Andersen, Hørsholm Equine Hospital, Denmark.

particularly in foals due to their small size. There are potentially also interpretational challenges based on the high variability in activity levels (recumbent vs. active ambulation) and growth rates of foals (bone growth can be minimal or stopped in sick foals and bone resorption may even occur, while healthy foals will have active bone growth) (Firth and Rogers 2005; Kamr *et al*. 2020). Furthermore, any foal undergoing nuclear scintigraphy will be radioactive following the procedure, which may further complicate handling and delay treatment, consequently rendering NS irrelevant for diagnosis of SAPO in foals for the time being. Experiences with PET and SPECT (which combines principles of NS with CT) (Llewellyn *et al*. 2019; Plate *et al*. 2020) in people and recent advances made with PET in horses (Spriet *et al*. 2018) may

add diagnostic value in relation to SAPO when routinely available for equine medicine in the future.

Specific advantages with CT vs. standard radiography based on the clinical experience and opinion of the authors

Over the past years, some of the authors (C.L., D.V. and S.A.) have acquired significant experience with management of SAPO in foals with the help of CT as a diagnostic tool. Together with smaller published case series and the literature in general (Munsterman *et al*. 2007; Barba and Lepage, 2013; Lindegaard 2018; Wright and Lindegaard, 2018; Wright *et al*. 2018), this leads us to come to the opinion that CT has a number of advantages over other currently available imaging modalities:

A Earlier definitive SAPO diagnosis due to the ability to recognise mild changes associated with bony or soft tissue involvement. This is of particular relevance in cases with confirmed septic arthritis that do not respond as expected to joint lavage, or suspected septic arthritis with SF analysis results in the range between inflammation and infection.
B SAPO diagnosis in more specific anatomical localisations, including those inaccessible for clinical palpation, synoviocentesis or radiography, for example the radio-humeral, scapulo-humeral, stifle and coxo-femoral joints, as well as the axial skeleton and pelvis.
C Enhanced presurgical planning. CT offers 3-dimensional understanding of the extent of the lytic lesion which offers the surgeon an excellent tool for meticulous planning of the least invasive approach. Subsequently, ultrasonography allows for intraoperative identification of the lesion, which enhances surgical precision and supports less invasive debridement, therefore resulting in minimal collateral damage.
D Diagnosis of additional clinical or subclinical pathologies, for example additional unexpected SAPO lesions in other locations (especially the axial skeleton and pelvis) or pneumonia.

Due to the much higher sensitivity of CT for detecting decreased bone density compared to radiography, it is the authors' impression that lesions often appear more 'catastrophic' on CT than on conventional radiography. However, with CT being a relatively new tool used for SAPO in foals, clinical interpretation of and experience with these catastrophic findings are a learning process that will take several more years. Therefore, the obtained information from CT investigation should focus on better therapeutic planning with careful prognostic interpretation. These impressions and opinions stated above are based on the authors' experience combined with case reports or case series (Munsterman *et al*. 2007; Griffin *et al*. 2012; Barba and Lepage, 2013; Lindegaard 2018; Wright and Lindegaard, 2018; Wright *et al*. 2018); hence, future research in the area will further elucidate on other potential advantages or disadvantages implementing CT or MRI in the management of SAPO cases.

Concurrent disease and differential diagnoses

Foals with lameness or joint effusion should be considered to have SAPO until proven otherwise (Neil *et al*. 2010; Hepworth-Warren *et al*. 2015). As mentioned above, a normal SF analysis does not entirely rule out SAPO. The main differential diagnoses to consider are primarily traumatic and/or iatrogenic synovial cavity contamination and sepsis without SAPO foci. Considering the severe consequences of not addressing or diagnosing SAPO correctly, and the similar treatment approach to SAPO and synovial contamination without SAPO, this distinction may not be clinically relevant considering how common SAPO is in the young foal (0-6 months). However, diagnostic imaging should always be performed in order to diagnose any potential fractures, although much less common than SAPO or traumatic septic arthritis.

Another differential diagnoses to consider are various types of joint flares. A joint flare refers to an acute synovial inflammatory reaction, clinically mimicking septic processes with synovial distension and lameness. They may occur due to drug-related toxicities, immune-mediated processes, congenital malformations or atypical early osteochondrosis manifestations as listed below (Adler *et al*. 2020).

A Fluoroquinolones, such as enrofloxacin, have been demonstrated to create lameness and distended joints in foals due to induced cartilage damage. SF analysis in those cases revealed decreased viscosity and suppurative, chronic inflammatory signs with mildly elevated protein concentrations (Vivrette *et al*. 2001).
B Immune-mediated polysynovitis can also occur. Bacterial cultures obtained from SF are generally negative; however, often there is a septic process elsewhere in the body, most often with *Rhodococcus equi* (Huber *et al*. 2018). This offsite infection can create high levels of circulating immune complexes that deposit in the synovial membrane and initiate a local reaction (Madison and Scarratt, 1988).
C Although osteochondrosis normally only manifests clinically in horses of older age, the disease process itself is present in neonatal animals in a large subset of cases (Dik *et al*. 1999). Reports on the disease have mentioned its diagnosis in foals as young as 3 days of age (**Fig 8**) (Stromberg and Rejno, 1978).
D Congenital bony malformations, such as dwarfism and defects of the spine (torticollis, scoliosis, synostosis, lordosis and kyphosis), can include bony changes and difficulties with ambulation. However, most often these are easily distinguishable from SAPO because of their presence since birth, obvious clinical signs and lack of signs of infection.

Conclusion

SAPO is a significant disease most commonly seen in foals <6-7 months old. Many foals with SAPO present with pain, joint swelling and/or lameness or gait abnormalities concurrent with some degree of systemic disease. However, some foals have only subtle clinical signs which makes a complete diagnosis challenging. Careful attention should be given to recognise and distinguish between S-, E-, P- and T-type SAPO, as they may present with only slightly different findings and may only be clinically distinguishable with careful attention to synovial fluid analysis combined with diagnostic imaging. Radiography is the most common diagnostic imaging modality, but due to its poor sensitivity to minor changes in

bone density, radiography might not be able to identify E- and P-type infections early in the course of disease. Due to a much higher sensitivity for minor changes of bone density and lack of superimposition, CT or high-field MRI, when available, should in our opinion be considered the gold standard for diagnostic imaging of at least challenging SAPO cases.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this review article.

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Authorship

All authors have framed and planned the review as well as contributed substantially to revision and proofreading. C. Lindegaard supervised the process, made major contributions to a majority of the sections and contributed to the artwork. G. van Galen has contributed to sections of aetiology, pathogenesis, diagnosis and medical treatment. D. Verwilghen has contributed significantly to framing the project as well as made major contributions to diagnosis, treatment and prognosis sections. S. Aarsvold has contributed to the diagnostic section, particularly diagnostic imaging and surgical treatment as well as contributed significantly to the artwork. L. Berg has contributed to the diagnosis section and authored the rehabilitation section. All authors have read and approved the manuscript and artwork.

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Balancing Passion and Practice

Veterinary industry professionals offer perspectives on best financial practices for a more fulfilling and successful work/life balance.

By Kimberly S. Brown

CareCredit—a financing solution for veterinary clients—brought together a diverse group of equine veterinary industry experts for a four-hour roundtable to talk about the current state of practice and vet life. Those participants included Amy Grice, VMD, MBA, Charlotte Hansen, MS, Wendy Krebs, DVM, Kyle Palmer, CVT, and Kelly Zeytoonian, DVM, MBA. These experts discussed the gold standard of client payment, financial preparedness of clients, how veterinary businesses are run compared to small animal, dealing with on-farm bill pay, handling non-pay clients, and the balance of economics and emotions.

The "Money" Talk

In the 2020 Equine Practice and Passion Survey by CareCredit, 90% of veterinarians surveyed said they don't like to talk about money with clients. Dr. Grice said, "Equine practitioners need to embrace the value that they provide and feel confident in charging appropriately for what they do ... Veterinarians really need to do a little soul searching and realize that most of them have a hard time talking about money, and it makes them feel kind of squeamish, like they don't deserve to receive payment for taking care of somebody's horse."

Also, the 2021 AVMA Language of Veterinary Care Study has shown that clients want to know medical costs up front.

"I need to respect the client enough to have the financial discussion up front with them," said Dr. Krebs.

Hansen noted that "if clients can anticipate what they're going to need to budget for, that will be less stressful for them. And it will be less stressful for you and the veterinarian-client relationship."

Dr. Grice concluded, "When the client knows what to expect financially from the beginning of the relationship and they have a plan for payment … that allows the veterinarian and the horse owner to be on the same team. Then they can both just concentrate on caring for the horse, which at the end of the day is what veterinarians really want to do."

Payment at Time of Service

All roundtable attendees said a basic requirement for solving some of the business and stress issues in equine veterinary medicine is that payment at time of service should be the "gold standard" in how clients pay equine veterinarians for services. But collecting that money in the field presents issues.

"Veterinarians in the field collect money easier if it's easy for them to do. They just have to understand how to do it," said Palmer. "There's nothing better in terms of collecting the debt than not incurring it in the first place."

According to Dr. Grice's personal industry research, the stress of business and the comparisons to small animal work are causing a 50% loss of new equine veterinarians within the first five years of practice.

"It starts to feel for people like they're sacrificing their life on the altar of veterinary medicine," Dr. Grice said. "And they see their friends or people outside of veterinary medicine having a normal life that doesn't look like that. And they feel trapped in this thing that they love, but that is eating them alive ... We have the capability to have a positive future. We just have to create new paradigms in equine practice."

It comes down to clients paying and respecting their veterinarians as they would any other professional.

To put it simply, "It is not our job to subsidize someone's hobby," said Dr. Zeytoonian.

Dr. Krebs expanded on that idea, saying, "I am there to help [clients] to the best of my capability and within their resources, but it does not fall on my shoulders to enable them financially. I absolutely acknowledge to them the stress of the situation that they're under. I acknowledge that it's expensive, and I'm empathetic. But I can help provide solutions that are within their means. And that does not mean that I need to be the one that subsidizes their animals' health care."

Relational vs Transactional

When discussing "relational" vs "transactional" client relationships, Palmer said, "I think it's not really a question of one or the other. It's a question of how you use one in proper compatibility with the other. They can complement each other if you do them right."

Dr. Grice added that "with a strong relationship, the transactional part becomes much easier."

Moving Forward

Dr. Zeytoonian noted, "A small change that I think could make a big impact on clinics would be utilizing paperless billing and just getting bills out faster."

Palmer said online payments "have worked very well. It's a great tool and, by all rights, the next big evolution in payment processing."

Take-Home Message

"I think that we are at the moment in this industry where things could go really bad, or we could make some good decisions as an industry to change our pay scale, our fee schedules, increase compensations—start making equine work a better prospect for people," Palmer said. "Otherwise, I don't know what kind of conversation we're going to be having if we come back in five years and do this again."

Read more about how these panelists live in the equine veterinary industry of today and their opinions on the future with two articles—one in the Winter issue of EquiManagement magazine and an extended article on https://bit.ly/carecreditroundtable.

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