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American Edition | January 2022

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VOLUME 34 NUMBER 1



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

IN THIS ISSUE:

Meet 2022 AAEP President Dr. Emma Read

Ultrasonographic diagnosis of lateral meniscal rupture in two horses with severe lameness

Lateral patellar instability in Standardbred horses at the weanling age: Clinical and morphological features in four cases (2017–2019)

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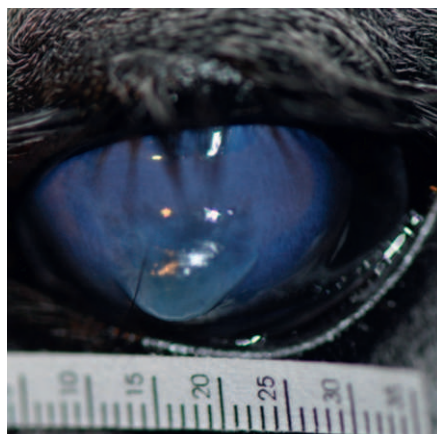


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CONTENTS



AAEP NEWS In this issue

Meet 2022 AAEP President Dr. Emma Read	III
Practitioners celebrate the return of in-person learning in Nashville	IV
Recent grads: Acquire new skills at labs-focused CE event	IX

Peer Reviewers in 2021	2
-------------------------------------	---

Highlights of Recent Clinically Relevant Papers

S. WRIGHT	4
-----------------	---

Editorial

Encouraging behavioural change in the growing challenge of complex welfare cases R. OWERS	6
--	---

Case Reports

Successful induction of lactation, foal grafting and maintenance of pregnancy in a nonparturient Thoroughbred mare G. PODICO, A. C. MIGLIORISI, P. A. WILKINS and I. F. CANISSO	8
Acute corneal hydrops of presumed traumatic origin: An uncontrolled case series (three horses) L. M. O'LEARY, L. SEBBAG, L. M. MOODY, K. A. DIEHL and R. A. ALLBAUGH.....	9
Venous air embolism during stifle arthroscopy in a horse M. E. KANTYKA, J. KUEMMERLE, A. BECSEK and S. K. RINGER	10
Ultrasonographic diagnosis of lateral meniscal rupture in two horses with severe lameness L. DILLENBECK, M. B. WHITCOMB, J. DECHANT and A. SOLE GUITART	11
Single-photon emission computed tomography of the pelvis and lumbar spine contributes to the diagnosis of injury in two horses P. G. HARDING, P. TUALY, A. M. CULLIMORE and K. PEREMANS	12
Treatment of a congenital lateral patellar luxation by recession trochleoplasty in a donkey foal A. M. ABU-SEIDA and A. A. SHAMAA	13
Surgical repair of congenital lateral luxation of the patella in an Arabian foal using a polypropylene mesh K. GUSTAFSSON, F. HONTOIR, G. A. SUTTON, G. KELMER and A. J. TATZ.....	14
Lateral patellar instability in Standardbred horses at the weanling age: Clinical and morphological features in four cases (2017–2019) – E. PAGLIARA, F. CANTATORE, M. PALLANTE, A. VALAZZA, B. RICCIO and A. BERTUGLIA	15
Large placental area of degeneration in a twin pregnancy in a mare (<i>Equus caballus</i>) A. RAPACZ-LEONARD and K. PAZDZIOR-CZAPULA	21
Multicavitary septic effusions associated with actinobacillosis in an adult Tennessee Walking Horse with weight loss – K. MEANS, K. TOWNSEND and P. JOHNSON	26

Clinical Commentaries

Patellar instability/patellar luxation in horses: Potential risk factors and treatment options E. BUSSCHERS.....	16
Luxation of the patella in foals: A treatment challenge – A. M. ABU-SEIDA.....	19
Love thy neighbour – unless they are sharing your uterus – S. WILSHER	22

Original Articles

Transfusion with 2 litres of hyperimmune plasma is superior to transfusion of 1 litre for protecting foals against pneumonia attributed to <i>Rhodococcus equi</i> P. FLORES-AHLSCHWEDE, S. K. KAHN, S. AHLSCHEDE, A. I. BORDIN and N. D. COHEN.....	27
Comparison of the efficacy of rifampin/azithromycin and rifampin/tulathromycin for the treatment of foals affected with pneumonia – B. GOEBEL, F. FREISE and M. VENNEN	28
What is equine hoarding and can 'motivational interviewing' training be implemented to help enable behavioural change in animal owners? B. WILLIAMS, P. HARRIS and C. GORDON.....	29

Review Articles

Haematogenous septic arthritis, physitis and osteomyelitis in foals: A tutorial review on pathogenesis, diagnosis, treatment and prognosis. Part 2 C. LINDEGAARD, G. VAN GALEN, S. AARSVOLD, L. BERG and D. VERWILGHEN.....	37
Systemic antimicrobial therapy in foals E. F. FLOYD, C. A. EASTON-JONES and M. J. P. THEELEN.....	49

Advertisers' Index	48
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Meet 2022 AAEP President Dr. Emma Read



Dr. Emma Read

The AAEP is pleased to introduce Dr. Emma Read as its 2022 president. Dr. Read is a board-certified surgeon and associate dean for professional programs at The Ohio State University College of Veterinary Medicine.

Born in Wales and raised in the United Kingdom as the oldest of three sisters, Dr. Read immigrated with her

family to Canada when she was 10. Her father Phil, a computer systems data manager, and mother Liz, a paralegal, saw more opportunities for their children to be raised in the outdoors in Calgary, Alberta.

Dr. Read grew up in Girl Guides and spent considerable time camping and backpacking. In high school, she took up rock climbing, ice climbing and skiing, and her summer job was leading a half-dozen 12-year-old girls on six-day horse packing trips through the mountains.

Long knowing she wanted to go to veterinary school, Dr. Read obtained her bachelor's in zoology from University of Calgary, during which time she met her future husband, Matt, now a prominent veterinary anesthesiologist. The couple attended vet school together at University of Saskatchewan, graduating in 1998 and marrying three days later. Following an internship at Okotoks Animal Clinic near Calgary and surgical internship at University of Saskatchewan, Dr. Read accompanied her husband on a job interview at University of Georgia. Not only did he get the job, but she unexpectedly landed a large animal surgery residency.

The couple returned to Canada in 2003, and Dr. Read became a staff surgeon at Ontario Veterinary College. She would return to Calgary in 2005, first at Okotoks Animal Clinic before joining the University of Calgary Faculty of Veterinary Medicine in 2007. She served as chair of the clinical skills program for eight years and associate dean academic for two years. During her 13 years in Calgary, Dr. Read also worked with international-caliber equine athletes as part of the treatment team at Spruce Meadows showjumping facility.

Recognized for her clinical skills, Dr. Read was tabbed by a movie props company to help develop and validate simulator models that were later commercialized to help veterinary students hone their diagnostic and practical skills. Her clinical skills also drew the attention of The Ohio State University College of Veterinary Medicine,

which recruited Dr. Read as associate dean in 2018 prior to opening its state-of-the-art Veterinary Clinical and Professional Skills Center.

At Ohio State, Dr. Read oversees the entire DVM program, including student recruitment, admissions, curriculum and academic standards, wellness initiatives, and new initiatives like the Frank Stanton Veterinary Spectrum of Care Clinic, which she helped conceptualize.

Throughout her professional journey, Dr. Read has been an advocate of organized veterinary medicine, particularly through her AAEP affiliation. She served on the board of directors from 2011–2013 and has been involved with various committees and task forces through the years, including the Educational Programs and Member Engagement committees. But she is particularly proud of her investment in AAEP's student programs as a means of giving back to the next generation by engaging and showing students why equine practice is a great opportunity and career choice.



Dr. Read leads a wound management lab for students.

Recruitment of students into equine practice and retention of early-career equine practitioners is an issue near to her heart. Lending her unique perspective as one who has been in private practice, academia and administration, Dr. Read looks forward to making continued progress on this and other important issues in the year ahead.

Away from practice, Dr. Read is the proud mom of two teenage daughters: Grace, an aspiring airline pilot who has begun taking flight lessons; and Kate, who is active in 3-day eventing, Pony Club and IEA. Not surprisingly, Dr. Read can often be found at the barn or at a horse show when not working. She also enjoys her morning runs and walking their four dogs.

Practitioners celebrate the return of in-person learning in Nashville

The AAEP's 67th Annual Convention in Nashville, Tenn., enabled equine practitioners to reestablish important industry relationships and reconnect to their passion by acquiring solutions for patient health and practice success. In all, 3,662 veterinary professionals, students, guests and exhibitors convened in Nashville for the return of in-person learning. Nearly 700 additional practitioners and students are participating remotely via on-demand access to recordings of educational sessions.

"After our necessary pivot to an exclusively virtual event last year, convention attendees were excited to gather together again in Nashville this year, which required reasonable safety measures be put in place," said AAEP Executive Director David Foley. "At the same time, we wanted to ensure that we had options for those who were hesitant to travel or whose practice obligations precluded them from attending in person. Enabling their participation virtually expands accessibility to the outstanding educational program offered in Nashville, ultimately benefiting the health of their equine patients."

We hope to see you at the 2022 convention in San Antonio, Texas, if not sooner at one of our other 2022 meetings.



Keynote: Creating a generationally inclusive practice

Between retirements, fewer veterinary students choosing equine and many of those who do leaving equine within five years after graduation, it is more important than ever for practices to embrace the unique strengths of the different generations within their practice. Doing so, according to keynote speaker Meagan Johnson, will help practices maintain outstanding service to horses and clients as well as facilitate the growth, satisfaction and long-term success of associates and interns.

Johnson suggests practices consider instituting monthly 15-minute conversations with younger employees to help advance skills, improve learning curves and facilitate satisfaction. The conversations should be built around four questions:

1. What is something you're better at now than you were last month?
2. What things would you like to get better at this month?
3. What is your plan for developing these skills?
4. What resources can I help you with?

Similarly, Johnson advises practices to consider replacing an employee's traditional annual review with periodic stay interviews to help ensure their professional growth and satisfaction, discover what they value and would like to improve upon, and identify any potential impediments that otherwise wouldn't be discovered until the employee's exit interview.

Finally, Johnson stresses the importance of young equine veterinarians feeling as impassioned as practice owners, who can expedite this process by not summarily dismissing ideas and suggestions from associates and new practitioners. Rather, practice owners should first explore how the ideas affect cost, quality, safety and service before making a determination.

Milne Lecture helps practitioners solve lameness puzzles

Much can be ascertained about a lameness from a thorough visual exam of the horse under different gaits, surfaces and exercises, but it is imperative that veterinarians understand and be able to interpret the biomechanics and functional anatomy to evaluate the significance of imaging findings and establish an appropriate rehabilitation program, according to Milne Lecturer Dr. Jean-Marie Denoix.

Using extensive video, diagnostic imaging and anatomical illustrations from many of his past cases and referrals, Dr. Denoix led attendees through the different steps of a clinical exam and what can be seen in specific situations. Although the trot is often used as the reference gait for lameness evaluation, Dr. Denoix urges practitioners to thoroughly examine the horse at a walk, which can reveal information that isn't as evident at a faster gait. Use of video increases accuracy by allowing the practitioner to examine the horse's gait in slow motion. Importantly, gathering as much information as possible from the clinical exam and imaging will help reduce the amount of blocking and injecting.

For more information and recommendations, Dr. Denoix's paper can be found in the *Proceedings* book, beginning on page 106. A video of his lecture is also among the on-demand offerings in the virtual convention.

Access Kester and Milne articles online

EVE and EVJ have released a virtual issue of the articles discussed during the Kester News Hour and referenced in the Milne Lecture. The articles are free access through Feb. 28 at <https://tinyurl.com/3epvxywc>.

Seven receive annual awards

Seven members were honored with 2021 awards during the Dec. 7 President's Luncheon:

AAEP Research Award:
Dr. Joy Tomlinson

Distinguished Educator Award – Academic:
Dr. Elizabeth Santschi

Distinguished Service Award:
Dr. Jim Morehead

Distinguished Life Member:
Dr. Bill Moyer

Sage Kester Beyond the Call Award:
Dr. Larry Bramlage

President's Award:
Dr. Carol Clark and Dr. Amy Grice

Foundation awards \$355,000 in scholarships

Prior to the Milne Lecture, 14 students shared in scholarship awards of \$355,000 through the generosity of The Foundation for the Horse's scholarship partners Coyote Rock Ranch, Merck Animal Health and Zoetis; and the inaugural award of the Dr. Bill Rood Leadership Scholarship. See page X for a list of recipients and photos.



The 2022 officers were installed during the President's Luncheon. From left: Dr. Katie Garrett, vice president; Dr. Amy Grice, treasurer; Dr. Rob Franklin, president-elect; Dr. Emma Read, president; and Dr. Scott Hay, immediate past president.

Promising researchers receive fellows



The Foundation for the Horse presented \$5,000 research fellows to up-and-coming investigators—all Ph.D. candidates—for their exceptional research contributions.

Dr. Drew Koch, from North Carolina State University, received the AAEP Past Presidents' Research Fellow for his investigation into use of mesenchymal stem cell licensing to advance therapy for osteoarthritis. Dr. Emily Hellstrom, also from North Carolina State University, received the EQUUS Foundation Research Fellow for her research into improving postoperative outcomes for surgical colic patients.

The Foundation for the Horse Research Fellow, instituted in 2021, went to Dr. Lauren Hughes at the University of Minnesota for her investigation of the genetics of pituitary pars intermedia dysfunction in horses.

Foundation gifts top \$460,000

Between Storytelling Nashville Style, My Mentor giving, donations at The Foundation for the Horse booth in the trade show, and achievement of a \$50,000 matching gift for donations at the booth, \$461,300 was raised for the welfare of horses. The Foundation sincerely thanks its individual and corporate donors for their generosity and commitment to its mission.

Report your CE credits

Convention attendees are reminded to report their continuing education credits using the CE form included in the packet received at registration. If you misplaced this form, you may request a replacement from Kristin Walker at (859) 233-0147 or kwalker@aaep.org.



5 things to know about AAEP this month

1. Download AAEP's new Equine Piroplasmosis Guidelines at aaep.org/document/aaep-infectious-disease-guidelines-equine-piroplasmosis.
2. Recent graduates: Don't get shut out. Register for one of only 60 spots at the AAEP's New Practitioners Symposium CE event in February at aaep.org/meetings.
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. Serve as a Virtual Wednesday Round Table moderator in 2022 by updating your Volunteer Interest Form accessible through the My Member Profile/Benefits button at the top of aaep.org.
5. Listen to the latest AAEP Practice Life podcast on the subject of collaborative business models at podcast.aaep.org. Thanks to podcast sponsor Boehringer Ingelheim.

Nominate a distinguished researcher for the 2023 AAEP Milne Lecture

Deadline to nominate is January 31

Help determine the 2023 Frank J. Milne State-of-the-Art Lecturer by nominating an accomplished researcher by Jan. 31.

Created in 1997, the Milne Lecture recognizes 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.

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 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.



Dr. Jean-Marie Denoix delivers the 2021 Milne Lecture on the topic of lameness.

The award recipient will be determined by a subcommittee of the AAEP Educational Programs Committee in February 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.

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.



AAEP publishes Equine Piroplasmosis Guidelines

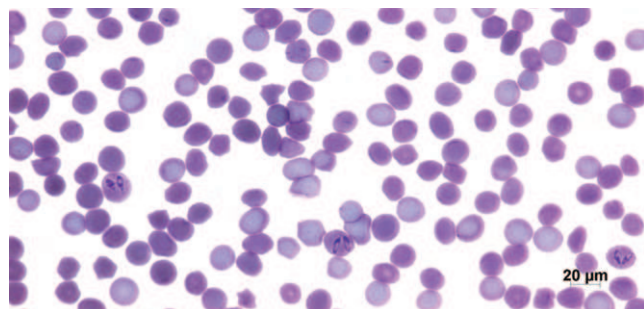
Comprehensive guidelines to assist veterinarians with identification, control and prevention of Equine Piroplasmosis (EP), a blood-borne protozoal infection of equids with a mortality rate for infected horses of up to 50%, are now available on the AAEP's website.

While natural tick-borne transmission of EP in the U.S. is rare, cases have been recognized in recent years specifically involving iatrogenic transmission in Quarter Horse racehorses. Guidelines author Dr. Angela Pelzel-McCluskey, national epidemiologist for equine diseases at USDA APHIS Veterinary Services, said most of these racehorses had direct ties to unsanctioned racing and unhygienic practices by their owners and trainers.

"Re-use of needles, syringes, and IV sets, blood-contamination of multi-dose drug vials, use of illegal blood products from other countries, and direct blood doping between horses have been identified as common methods of blood-borne disease transmission in this population," said Dr. Pelzel-McCluskey. "Equine practitioners should be aware of the risk for EP and other blood-borne diseases, such as EIA, in this high-risk population and provide educational outreach to clients on appropriate biosecurity to prevent disease transmission between horses."

It is recommended that current Quarter Horse racehorses be routinely tested for EP and EIA during their racing career. Equine practitioners encountering former Quarter Horse racehorses as part of a pre-purchase or routine exam should discuss with owners the risk of previous disease exposure and recommend testing.

EP is considered a foreign animal disease in the U.S. Any detection must be reported to the state veterinarian and/or



Dr. Don Knowlton

Blood smear of Babesia caballi, one of two causative agents of EP along with Theileria equi.

to USDA APHIS Veterinary Services. Horses infected with EP can be enrolled in a USDA APHIS-approved EP treatment program, which is often successful at permanently eliminating the infection.

The EP 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/aaep-infectious-disease-guidelines-equine-piroplasmosis.

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

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Share your research at the 2022 convention in San Antonio

Help create a meaningful educational experience for your colleagues by submitting a paper to be considered for presentation during the 68th Annual Convention in San Antonio, Texas, Nov. 18–22.

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. The presenting author will receive complimentary registration and an honorarium.

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.

New Practitioners Symposium now open to graduates since 2012

Only 20 spots available at press time for labs-focused CE event

If you graduated within the past 10 years, take another step forward in your career by strengthening and diversifying your skill set at 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. Early registration is strongly encouraged due to the attendance cap. If you need assistance or have questions, contact Kristin Walker at kwalker@aaep.org or (859) 233-0147.

Thanks to CareCredit and Arthramid® Vet for their sponsorship of the AAEP New Practitioners Symposium.



The Foundation for the Horse awards \$355,000 in scholarships

The season of giving kicked off in a big way for 14 veterinary students who shared in scholarship proceeds of \$355,000 from The Foundation for the Horse and its scholarship program partners during the AAEP's 67th Annual Convention. The awards include the inaugural Dr. Bill Rood Leadership Scholarship, an endowed scholarship established by friends, colleagues and clients of the retired co-founder of Rood & Riddle Equine Hospital.

The award of scholarships to promising students pursuing careers in equine medicine is one important way in which The Foundation helps improve the welfare of horses. The scholarships help offset the cost of a veterinary education

so that recipients can focus on patient care when entering practice.

Below are the check presentation photos with recipients' names and schools listed underneath. The Foundation for the Horse sincerely thanks its scholarship program partners for their ongoing investment in horse health and the future of the profession.



Four students received \$75,000 Coyote Rock Ranch Scholarships. From left: Alexandra Grobman, North Carolina State University; Virginia Logue, University of Minnesota; Kassidy Shelly, University of California, Davis; and Kara Robbins, Iowa State University.



Five students received \$5,000 Zoetis Foundation Scholarships. From left: Jeannie Jeffery of Zoetis; Jessica Conner, Western University of Health Sciences; Hannah Fain, Colorado State University; Meghan Marnier, Iowa State University; Deianira Smith, University of Arizona; and Bailey Ziegler, Iowa State University.



Five students received \$5,000 Merck Animal Health Scholarships. From left: Dr. Duane Chappell of Merck Animal Health; Brittany Campbell, Texas A&M University; Ashley Bonnette, University of Tennessee; Hannah Evans, Iowa State University; Morgan Falk, University of Wisconsin; and Foundation Advisory Council Vice Chair Dr. Anthony Blikslager. Not pictured: Taylor Tusso, Auburn University.



In addition to her Coyote Rock Ranch Scholarship, Alexandra Grobman also received the inaugural \$5,000 Dr. Bill Rood Leadership Scholarship. She is pictured with Rood & Riddle Equine Hospital co-founder Dr. Tom Riddle, left; and Foundation Advisory Council Vice Chair Dr. Anthony Blikslager, right.

Members in the News



Dr. Jennifer Durenberger

Dr. Jennifer Durenberger elected ROAP chair

The Racing Officials Accreditation Program board of directors elected Dr. Jennifer Durenberger as chair for 2022-2023.

ROAP accredits and provides continuing education to all racing officials, stewards and judges in the horse racing industry.

A graduate of Cornell University, Dr. Durenberger is The Jockey Club Steward for the New York Racing Association. She serves on the AAEP's Racing Committee and previously served on the Professional Conduct and Ethics Committee.



Dr. Jesslyn Bryk-Lucy

Dr. Jesslyn Bryk-Lucy named PATH Intl. Veterinarian of the Year

Dr. Jesslyn Bryk-Lucy, assistant professor of equine studies at Centenary University in Long Valley, N.J., and resident veterinarian for the school's horses, has been named the 2021 PATH Intl. Veterinarian of the Year, sponsored by American Regent Animal Health.

PATH Intl. certifies professionals and accredits equine centers that offer equine-assisted services for individuals with special needs. Dr. Bryk-Lucy, who received her veterinary degree from Cornell University, was recognized for her work with Therapeutic Riding at Centenary and ensuring the health of the program's herd.

AAEP mourns the passing of longtime members



Dr. Robert M. Carr

Dr. Robert M. Carr

Honor roll member Dr. Robert M. Carr, who served on the AAEP board of directors from 1991-1993, passed away Aug. 8 at the age of 83.

Dr. Carr received his veterinary degree in 1963 from Cornell University. He moved to Canandaigua, N.Y., the following year to start a racetrack practice at Finger Lakes Racetrack.

Besides his board service, Dr. Carr actively volunteered within AAEP throughout the 1980s and 1990s, serving multiple terms on the Racing, Horse Show, Exhibits and Computer Applications committees. He also served as president of the New York State Veterinary Medical Society in 1987 and on the board of the Finger Lakes Thoroughbred Adoption Program.



Dr. John W. Whittaker

Dr. John W. Whittaker

Dr. John W. Whittaker, longtime racetrack practitioner throughout the Midwest and former member of the AAEP's Racing Committee, died Nov. 28 at age 70.

After receiving his veterinary degree from Oklahoma State University in 1976, Dr. Whittaker established an equine practice in Hot Springs, Ark., before co-founding the Lake Hamilton

Animal Hospital and Equine Surgical Facility. In 1988, he established a racetrack and sports medicine practice. Dr. Whittaker retired from private practice in 2017 to become a Lasix coordinator and part-time regulatory veterinarian for the Arkansas State Racing Commission, Iowa Racing and Gaming Board, and Prairie Meadows racetrack.



A mentoring program designed to **help young equine veterinarians** successfully navigate equine practice and find long-term professional fulfillment.

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Over the past 25+ years, CareCredit has helped millions of clients pay for the veterinary care their animals need through every stage of life. The company is proud to be an AAEP Educational Partner and support initiatives that improve the health and welfare of horses as well as the financial health of equine veterinarians.

By bridging the gap between cost and care, CareCredit supports a healthy financial relationship between veterinarians and horse owners. Together, they can confidently move forward with the recommended care a horse needs, whenever it's needed.

To learn more about CareCredit, visit carecredit.com/equineinsights or call (844) 812-8111.

MEMBERSHIP

AAEP recognizes the service of outgoing member volunteers

The dedicated service of member volunteers is essential to fulfilling the AAEP's mission. The AAEP thanks the following members whose volunteer service on the board of directors or on a council or committee concluded in 2021:

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The following colleagues gave their time to peer review in the 12 months from October 2020 to October 2021, for which we are very grateful.

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Steven Zedler

Highlights of recent clinically relevant papers

Acute abdominal dehiscence

Incisional complications are a common cause of morbidity following laparotomy. Although uncommon, acute abdominal dehiscence (AAD) is a potentially fatal post-operative complication. This retrospective case series by Michelle Hann and co-workers in the UK, USA and Ireland described common features of AAD following ventral midline laparotomy, management and outcomes.

The hospital records of horses that underwent a ventral midline laparotomy at nine hospitals in the UK, Ireland and USA over a 10-year period were reviewed. Data were collected for pre-, intra- and post-operative factors that were considered relevant. A total of 63 cases of AAD were identified. AAD occurred due to tearing of sutures through the linea alba or rupture of the body wall adjacent to the suture line in 46 horses (73%). AAD occurred at a median of 5 days (0.5–70 days) post-operatively, and broodmares accounted for 25% of the cases ($n = 16$). Surgical site infection developed prior to AAD in 28 horses (44%); leakage of peritoneal fluid occurred in 5% of horses prior to AAD being identified. Surgical repair was performed in 27 horses (43%), 10 (16%) were treated conservatively and 26 (41%) were euthanised immediately. Repair was most frequently performed using suture ($n = 14$), wire ($n = 5$) or a combination ($n = 5$). Overall survival to hospital discharge was 39% (24/63). Where surgical repair was performed, 15 horses (56%) survived to hospital discharge; 9 horses (90%) managed conservatively survived to hospital discharge.

Surgical site infection following laparotomy and pregnant or early post-partum mares may be important risk factors for AAD and warrant further investigation.

Retrobulbar lidocaine injection

The aim of this randomised controlled study by Vanessa Yang and co-workers in the United States was to characterise the safety and efficacy of one published technique for retrobulbar anaesthesia.

Unilateral retrobulbar injection with 10 ml lidocaine (2%) was performed in eight sedated adult mares. Contralateral eyes served as untreated controls. Neurophthalmic parameters, intraocular pressure (IOP), and corneal and periocular sensation were measured awake, post-sedation and at periodic time points for 24 h following injection. Adverse effects were documented.

Injection of 10 ml lidocaine significantly increased IOP for up to 2 h, maximally at 30 min (mean [95% CI]: 6.0 [2.7, 9.2] mm Hg). Six of the eight treated eyes developed mild-to-moderate reversible chemosis for 2–24 h. One eye developed severe chemosis and superficial corneal ulceration at 24 and 48 h following injection respectively. Corneal sensitivity significantly decreased for 6 h, maximally at 10 min (−44.4 [−34.6, −54.1] mm). Periocular sensitivity (measured as increase in applied force) significantly decreased dorsally and medially for up to 2 h (maximal at 2 h: 367.1 [238.5, 495.7] g and at 30 min: 345.8 [202.6, 488.9] g respectively). Ventral and lateral sensitivity were not effectively decreased beyond 30 min. Optic nerve function was not consistently reduced following injection.

Retrobulbar injection using 10 ml lidocaine is safe in normal eyes of adult horses but causes a transient IOP increase. Reversible chemosis commonly develops 2–4 h following injection and may be severe in some horses with risk for corneal ulceration. Corneal anaesthesia is rapid and prolonged, but all periocular regions are not consistently anaesthetised so should be combined with other local anaesthetic injections for eyelid surgeries or enucleations.

Osteoarthritis of the fetlock joint treatments

In this study, Andrea Bertuglia and co-workers in Italy and Croatia compared the effects of tiludronate disodium and three other medical treatments on clinical and radiographic findings and biomarkers of disease progression in horses with osteoarthritis of the fetlock joint.

This study included 100 Standardbred racehorses with spontaneous traumatic injury of the fetlock joint. The horses were retrospectively grouped by whether they received tiludronate i.v. or triamcinolone acetonide and hyaluronan, polysulfated glycosaminoglycan or interleukin-1 receptor antagonist protein intra-articularly. Data were collected on clinical, radiographic and ultrasonographic findings and results for serum and synovial samples obtained before and 6 months after treatment. Lameness score, joint flexion test response, radiographic score, serum concentrations of tumour necrosis factor- α and carboxy-terminal telopeptides of collagen types I and II (CTX-I and II respectively), and synovial fluid concentrations of interleukin-1 β , prostaglandin E₂ and CTX-II were compared among treatments.

A significant improvement in lameness score and joint flexion test response at 6 months was seen with all treatments. Synovial fluid interleukin-1 β , prostaglandin E₂ and CTX-II concentrations decreased in horses that received triamcinolone acetonide and hyaluronan, suggesting this treatment inhibited progression of hyaline cartilage degeneration and inflammatory processes. Horses that received tiludronate were the only group that had a decrease in radiographic score and serum CTX-I concentration after treatment, supporting the effect of tiludronate on bone metabolism. Tiludronate treatment was also followed by increases in serum and synovial fluid concentrations of CTX-II, a marker of cartilage damage.

Tiludronate appeared to inhibit the radiographic progression of osteoarthritis in high-motion joints of racehorses at 6 months after treatment by inhibiting subchondral bone remodelling. Further investigation is needed to ascertain whether this effect was associated with a worsening of progressive cartilage damage.

Limb cellulitis and septic tendonitis or desmitis

The aim of this study by Hannah Cooper and co-workers at the University of Pennsylvania, USA, was to report the clinical features, treatment and outcome in horses with cellulitis and concurrent septic tendonitis and/or desmitis.

Horses with cellulitis and concurrent septic tendonitis and/or desmitis based on sonographic examination and positive bacterial culture were identified from medical records. Data recorded included signalment, ultrasonographic results,

bacterial culture, treatment, duration of hospitalisation and complications. Long-term outcome data were obtained from follow-up examinations and/or telephone interviews. Successful outcome was defined as return to intended use.

Eight horses met the inclusion criteria. All infections occurred in hindlimbs, with septic suspensory ligament in 6/8 horses, and septic superficial digital flexor tendon in 1/8 horses. Surgical debridement was performed in 6/8 horses. All horses were treated with systemic and regional intravenous antimicrobials and were discharged from the hospital. Long-term follow-up was available in 7/8 horses. Of these, four horses returned to their intended athletic function, two horses returned to their intended function as a broodmare or pasture pet, and one horse is still rehabilitating.

Septic tendonitis or desmitis is a rare but possible sequela of limb cellulitis. Prognosis for return to athletic function is fair to good for horses diagnosed with cellulitis and concurrent septic tendonitis or desmitis.

Dexmedetomidine treatment for endotoxaemia

Endotoxaemia causes inflammatory-mediated effects that might be attenuated by dexmedetomidine. This randomised controlled study by Rachel Hector and co-workers at Colorado State University, USA, evaluated the effects of a dexmedetomidine intravenous (i.v.) infusion on systemic and intestinal haemodynamics and arterial blood gas values in sevoflurane-anaesthetised horses administered Escherichia coli O55:B5 lipopolysaccharides (LPS).

A total of 13 horses weighing 456 ± 86 kg (mean $\pm$ S.D.) and aged 13.9 ± 9.0 years donated for euthanasia underwent ventral midline coeliotomy using sevoflurane anaesthesia. Baseline physiological variables were recorded after a 90-min equilibration period. All horses were given $0.1 \mu\text{g/kg bwt LPS i.v.}$ Horses were randomly assigned to no further treatment (group LPS; 7 horses) or i.v. administration of dexmedetomidine (loading dose $1.75 \mu\text{g/kg bwt}$ followed by $1.75 \mu\text{g/kg bwt/h}$; group LPS-Dex; 6 horses) with concurrent target sevoflurane dose reduction of 50%. Cardiac index (CI; thermodilution), intestinal blood flow, arterial blood parameters and plasma dexmedetomidine concentration measurements were recorded every 30 min until euthanasia at 390 min. Data were compared between and within groups to baseline using a mixed model analysis.

In LPS-Dex horses, intestinal blood flow and CI were transiently decreased after the dexmedetomidine loading dose, but no significant differences were found compared with baseline during the infusion. Sevoflurane dose was reliably reduced by approximately 40%. Significant differences were identified in creatinine ($115 \mu\text{mol/L LPS-Dex}$; $195 \mu\text{mol/L LPS}$), bicarbonate ($29.7 \text{ mmol/L LPS-Dex}$; 23 mmol/L LPS) and base excess ($2.0 \text{ mmol/L LPS-Dex}$; -5.3 mmol/L LPS). Dexmedetomidine plasma concentrations were highest after the loading dose and stable during infusion dosing.

A dexmedetomidine infusion with sevoflurane dose reduction attenuated some deleterious changes in anaesthetised horses administered LPS without sustained negative cardiovascular effects and may be beneficial during colic surgery.

Head and tail rope recovery

In this study, Luís Louro and co-workers in the UK compared the impact of head and tail rope recovery and unassisted

recovery on quality of recovery in horses undergoing colic surgery under general anaesthesia (GA).

Clinical data were obtained for horses undergoing emergency exploratory laparotomy over a 6-year period. Multivariable logistic regression analysis was used to identify the perioperative factors that affect quality of recovery. The final prediction model was assessed prospectively.

Records from 502 general anaesthetics (490 horses) were included. Multivariable logistic regression analysis showed that head and tail rope recovery (OR 2.2, 95% CI 1.4–3.3) and sevoflurane administration (OR 1.6, 95% CI 1.2–2.3) were associated with better quality of recovery when compared to unassisted recovery and isoflurane administration respectively. Increasing GA duration (OR 1.0, 95% CI 0.99–1.0), increasing intraoperative dosages (in mg/kg) of thiopental (OR 0.85, 95% CI 0.75–0.98) or ketamine (OR 0.67, 95% CI 0.46–0.99) were linked to poor quality of recovery. No statistically significant difference was found between groups in terms of mortality.

Head and tail rope recovery is significantly associated with better quality of recovery, compared to unassisted recovery, in horses undergoing emergency exploratory laparotomy. Sevoflurane administration, in detriment of isoflurane, was associated with better quality of recovery. Other risk factors, such as increasing GA duration, the use of higher intraoperative dosages of ketamine and/or thiopental, were associated with poor quality of recovery.

S. WRIGHT

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Editorial

Encouraging behavioural change in the growing challenge of complex welfare cases

The number of concerns reported to World Horse Welfare in Britain involving multiple equids is on the rise, as are the numbers of animals involved in a single incident. In the past, it would have been unusual for World Horse Welfare Field Officers to encounter situations involving 20–30 equids. Now the number of equids at a single job often exceeds 50, and it is not unusual to be faced with over 100 animals. The National Equine Welfare Council (NEWC), comprised of more than 40 equine rescue charities, recently surveyed its members to understand their current situation and how the ongoing COVID-19 pandemic was likely to impact them. This revealed that most were at maximum stocking levels (R Kay on behalf of NEWC, 2020, personal communications) and highlighted that there was little or no resilience within the sector to cope with a much-anticipated surge in equine welfare cases towards the end of 2020. Although no animal welfare organisation would choose to leave an animal to suffer, rescue centres cannot accommodate the 7000+ horses in England and Wales whose welfare is already suspected to be at risk. This, alongside the fact that authorities have largely delegated enforcement of the Animal Welfare Act to charities, means the animal welfare sector needs to find new ways of resolving the most intractable welfare problems.

Our team of Field Officers are highly skilled and have the ability to work with a wide range of owners to make immediate improvements whilst supporting them in taking responsibility for the long-term welfare of their animals. Situations that involve multiple equids are not just more time and resource consuming, but also more challenging to resolve. Often, when numbers have escalated to these higher levels, the wellbeing of the owner is also a key consideration. Although human health and welfare issues must always be fully considered in any animal welfare situation, even those involving one or two equids, they are more likely to play a major role in multi-animal welfare concerns.

With equid owners in the UK encompassing every age group, culture, religion and ethnicity, it is clear that there is no one reason why equids end up suffering or being neglected. With multi-animal cases continuing to rise, it is vital that we look at all potential correlating factors to ensure we are responding as effectively as possible to these situations. It is therefore important to understand whether a particular case is one of animal hoarding or not. The keeping of a large number of animals is not in itself indicative of hoarding. Hoarding occurs when there are a number of animals that are not being cared for adequately, in an environment that is not appropriate, with animals whose basic needs are unmet, who are ill and who are not receiving veterinary attention and treatment as discussed in the paper by Williams *et al.* (2022). This paper also describes some preliminary work that confirms that not only does equine hoarding exist but provides some novel categories of hoarding specific to equines.

It is important to recognise that hoarding is occurring because, in part, those exhibiting characteristics of animal

hoarding behaviour are unable to recognise they are compromising the welfare of their animals through lack of care and are usually unwilling to relinquish ownership of all or some of their animals, whilst often actively acquiring more (Patronek *et al.* 2006). In many cases, the owners may have started with good intentions before things spiralled out of control. They are often unable to see a way out or even see that there is a problem at all. Such owners are often unwilling to engage with our Field Officers and struggle to understand what might happen to them and their animals should the situation not improve. There is no doubt that hoarding behaviour is a complex issue. Such situations impact severely on animal welfare, but also on human welfare, and so, certain steps must be taken to ensure a positive outcome for all. Proceeding down an enforcement route with the animals being seized and removed, and the owner then facing prosecution, does not readily result in a happy or successful ending. It also rarely provides closure to a job as such owners frequently repeat the behaviour as soon as they have the opportunity to do so, often completely shutting out welfare organisations, meaning these repeat situations can be even more challenging to deal with than the original. Similar findings have also been reported by Patronek and HARC (2001), as well as Berry *et al.* (2005).

Working with owners to create lasting behaviour change that will improve the situation and empower them to take on responsibility is the main aim when dealing with any animal welfare case. However, there are situations, particularly involving owners showing signs of hoarding behaviour, when traditional methods of engagement are unlikely to be successful. World Horse Welfare has invested in training our Field Officers in Motivational Interviewing techniques. Although this method is regarded as highly successful in human health as outlined by Miller and Rollnick (2013), it is still in its infancy within the animal welfare sector. Bard (2018) identified Motivational Interviewing as a potential tool for improving communication between veterinarians and their clients, exploring its use within dairy herd management; however, globally limited research or anecdotal evidence exists as to how this technique can be used within an animal welfare context.

Motivational Interviewing is described as 'a collaborative conversation style for strengthening a person's own motivation and commitment to change' (Miller and Rollnick 2013). In an animal welfare context, this involves engaging with owners to develop a rapport built on trust so that the owner and Field Officer can discuss key issues about how the situation has developed as it has and explore what the current barriers to change are. Conversations can then lead on to what is within the owner's power to change, allowing the owner to identify the reasons for change and whether they are currently ready to make these changes. Once the owner is ready, discussions can then slowly begin to focus on how these changes can be brought to life. Williams *et al.* (2022) describe the outcome of training our Field Officers in these Motivational Interviewing techniques, which are proving

to have applications even in welfare cases not directly associated with equine hoarding. Successful outcomes are already being seen across much of our field work, such as supporting owners who are struggling to make a decision on when to euthanase their animal (delayed euthanasia) and in obesity cases, both of which are major equid welfare issues. One such example involved a job concerning two very overweight ponies. Although the owner was aware of the issue, they had yet to make any attempts to resolve it and were not pleased to be approached by a welfare organisation. Rather than advising the owner on what action to take, the Field Officer used Motivational Interviewing techniques to engage with the owner and build a rapport. This allowed the owner to describe what changes they could make and steps they could take, as well as explain the impact it would have on the ponies. One week later, the Field Officer returned to see the ponies had been moved to a smaller paddock, with less grazing, and the owner was happy to show them around and explain the other changes they had made to the way they cared for their ponies.

However, when working with an owner to change a long-term behaviour, there is no set time limit to the process. Change may take time, or it can happen very fast. It is important to recognise that concerned members of the public sometimes expect quick results when they report a welfare concern and can struggle with the situation continuing if they believe not enough is being done – which can cause growing frustration. Often a lot of resource and time is being invested into building trust and working with owners to create sustainable change, the progress of which is not something that can be shared with the public. This highlights the balance that many animal welfare organisations must achieve – protect animal welfare, promote human welfare and maintain public support.

In conclusion, with equine rescue organisations across the UK already operating at capacity coupled with the increased number of multi-animal incidents that many organisations are regularly responding to – alongside the continuing financial restrictions being placed on enforcement bodies to be able to effectively enforce animal welfare legislation – it is easy to see that a change in how we

respond to some situations is needed. For a variety of reasons, we cannot always readily remove animals from situations where their welfare is at risk and this approach may not always be the most appropriate, but instead we must find novel ways to ensure the owners take responsibility and change their behaviour to improve welfare for the animals as well as themselves. Motivational Interviewing techniques are one such way that can provide part of the answer.

Author's declaration of interests

No conflicts of interest have been declared.

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World Horse Welfare.

R. OWERS 

World Horse Welfare, Anne Colvin House, Norwich,
Norfolk, UK

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Case Report

Successful induction of lactation, foal grafting and maintenance of pregnancy in a nonparturient Thoroughbred mare

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Keywords: horse; orphan foal; sulpiride; nurse mare; adoption

Summary

An 8-year-old mare was presented for induction of lactation and adoption of a 30-day-old twin filly. In each of the two seasons prior to presentation, the mare had delivered a foal that died shortly after birth. The mare had been bred by live cover ~25 days prior to presentation to the Illinois Veterinary Teaching Hospital, but no pregnancy diagnosis was yet performed. Upon arrival at the hospital, pregnancy diagnosis confirmed a viable singleton gestational vesicle. The owner was informed about potential risks for abortion after the administration of PGF_{2α} in the presence of pregnancy but elected to pursue the adoption with this particular mare. Lactation was induced with dopamine D2 agonists. Immediately before grafting on Day 35 of gestation, the mare was started on altrenogest to provide exogenous hormonal support for the pregnancy. After two consecutive days of PGF_{2α} administration, the mare began to accept the foal (Fig 1), but by the next day, the mare had insufficient milk production and began to show signs of foal rejection. The mare was treated with acepromazine for sedation and stimulation of lactation, with concurrent analgesic support provided by flunixin meglumine and butorphanol. The pregnancy continued developing after the treatments with PGF_{2α}. No abnormalities were noted in the pregnancy fluids, embryonic and fetal structures, or embryonic and fetal heart rates. One ovulation was confirmed on Day 40, and a second ovulation was confirmed on Day 45 of

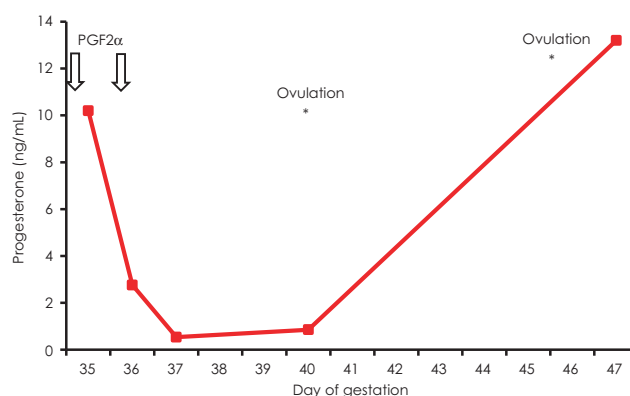


Fig 2: The serum concentration of progesterone before and after the administration of PGF_{2α}. The mare was administered 0.088 mg/kg, per os of altrenogest at 35–38 days, and then 0.044 mg/kg, per os from 39 to 50 days of gestation.

gestation. On Day 47 of gestation, after 11 days after adoption, serum progesterone concentration was 13.2 ng/mL (Fig 2). As this value was above the minimum level (≥ 4 ng/mL) necessary to maintain pregnancy, altrenogest administration was tapered and ultimately discontinued on Day 50 of gestation. The pair remained at the hospital for treatment of leukopenia in the filly for 12 more days. On Day 61 of gestation, 25 days after adoption, continued maintenance of pregnancy was confirmed in the mare, full lactation had been achieved, and strong bonding between mare and foal was apparent. Six months after discharge from the hospital, the filly and mare were apparently healthy, and the mare remained pregnant.



Fig 1: Mare and foal on the second day of adoption.

Key points

- The induction of lactation and foal grafting was effectively carried out in a nonparturient early pregnant mare.
- Altrenogest prevented abortion after repeated exogenous administration of PGF_{2α} in an early pregnant mare.
- Acepromazine, flunixin meglumine and butorphanol aided foal grafting.





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Case Report

Acute corneal hydrops of presumed traumatic origin: An uncontrolled case series (three horses)

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Keywords: horse; bullous keratopathy; keratoconus; corneal oedema; ocular trauma; Descemet's membrane rupture

Summary

Acute corneal hydrops is a condition that is reported in humans and cats where acute severe corneal oedema develops secondary to Descemet's membrane rupture. Three young horses (<3 years) presented with acute corneal hydrops, of presumed (2 cases) and witnessed (1 case) traumatic aetiology. Due to similarities in the clinical appearance and progression of disease with that which is reported in humans and cats, traumatic Descemet's membrane rupture was suspected to be the underlying aetiology in these equine cases, but was not confirmed. The cases presented with acute severe corneal oedema with intrastromal bulla formation and anterior bulging of the corneal contour (**Figs 1 and 2**). Focal posterior corneal changes were also seen in two of three cases. Mild anterior uveitis was also present in all cases. Other causes of corneal oedema (e.g. glaucoma) were ruled out based on presentation and clinical examination. Treatment approaches included various combinations of prophylactic topical antimicrobial therapy in case of secondary corneal ulceration and anti-inflammatory therapy for uveitis. Targeted



Fig 2: Case 2. Acute corneal hydrops at initial examination, note the severe corneal oedema and axial bullae with keratoconus.

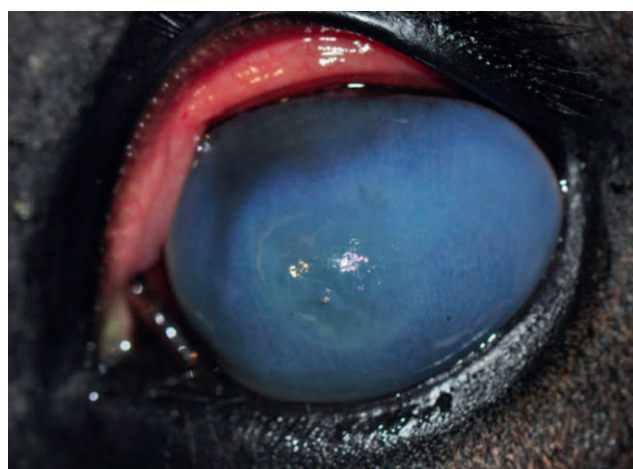


Fig 1: Case 1. Acute corneal hydrops at initial examination, note the severe diffuse corneal oedema and large axial intrastromal bulla formation leading to keratoconus (anterior bulging of the cornea).

oedema therapy was different for all three horses. Case 1 was treated with topical hypertonic saline as well as corneal cross-linking, Case 2 did not receive targeted oedema therapy, and Case 3 was treated with topical hypertonic saline and placement of a temporary partial tarsorrhaphy for corneal tamponade. The outcome was excellent in all cases, with rapid resolution of ocular changes.

Key points

- Acute corneal hydrops presents as acute severe corneal oedema which may also have anterior bulging of the corneal contour and intrastromal bulla formation.
- Young horses may be predisposed, and ocular trauma is the suspected aetiology.
- Clinical outcome can be excellent, and supportive medical management alone may suffice, but the use of a temporary tarsorrhaphy to tamponade the corneal hydrops could accelerate healing.



Case Report

Venous air embolism during stifle arthroscopy in a horse

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Keywords: horse; arthroscopy; air embolism; end-tidal carbon dioxide; capnography

Summary

A 16-year-old French Saddle Pony was presented for a diagnostic stifle joint arthroscopy. The horse had a 2–3/5 (AAEP scale) left hindlimb lameness since a fall, 5 weeks previously, and the diagnostic work-up pointed towards suspicion of caudal cruciate ligament avulsion. Apart from the stifle problem, the horse was considered healthy and physical examination on the day of surgery was unremarkable. Sedation was achieved with xylazine followed by ketamine and diazepam induction (at the standard dosages). Anaesthesia was maintained with isoflurane in oxygen–air mix and a constant rate infusion of xylazine. Dobutamine infusion was used for cardiovascular support as needed. The horse was placed in dorsal recumbency. Intra-anaesthetic monitoring consisted of electrocardiography, pulse oximetry (SpO_2), invasive blood pressure monitoring, arterial blood gas analysis and respiratory gas analysis (including end-tidal carbon dioxide monitoring – $\text{PE}'\text{CO}_2$). After routine aseptic preparation of the stifle, arthroscopy was performed. Carbon dioxide was insufflated into the joint using a designated pressure regulator set at 100 mmHg and a gas cylinder. The procedure was started with a standard approach to the femoropatellar joint, followed by a cranial approach to the cranial pouch of the medial femorotibial compartment. The course remained uneventful until 115 min from anaesthesia induction when arthroscopic evaluation of the medial femorotibial joint's caudal compartment was performed. Within a short time, laboured breathing was noticed. An increase in tidal volume from 4 to 7 L and respiratory rate from 8 to 15 breaths/min was seen, followed by a drop in $\text{PE}'\text{CO}_2$ from 47 to 30 mmHg. Simultaneously, an increase in heart rate (28–48 beats/min) was observed, and the SpO_2 decreased from 97 to 92%. Initially, a light plane of anaesthesia or nociception was suspected. However, the eye reflexes were tested, and the horse looked well anaesthetised. Therefore, arterial blood gas analysis was performed to aid further differentials. A decrease in the arterial partial pressure of oxygen (PaO_2 : 77 vs. 131 mmHg previously), hypercapnia (PaCO_2 : 99 vs. 54 mmHg previously) and large end-tidal to arterial CO_2 ($\text{PE}'\text{CO}_2$ – PaCO_2) difference as well as respiratory acidosis (pH 7.13) were noted, consequently raising the suspicion towards a venous air embolism (VAE). The treatment consisted of an

immediate increase in the fraction of inspired oxygen and reduction of the inspired isoflurane fraction. At first, it was suspected that the air entered via infusion lines or the infusion bag, but upon inspection, thoughts were directed towards the arthroscopy. The insufflation of carbon dioxide was ceased immediately, and the surgeon flooded the joint with fluids. After 10 min from the initial drop in the $\text{PE}'\text{CO}_2$, heart rate started normalising, followed by normoxaemia.

Upon completing the procedure, the horse stood up on its third attempt after two violent tries and left the hospital after one week without further complications. Heart auscultation (precordial or oesophageal) for characteristic waterwheel sounds or transoesophageal echography remains the gold standard of air embolism diagnosis. Although auscultation is easy to perform, transoesophageal echography often is out of reach to veterinarians. The end-tidal carbon dioxide monitoring in the case presented here was sensitive enough to aid a fast diagnosis. The severity of embolism depends on the amount and speed of gas entering the vascular bed – hence early cessation of the gas decreases the seriousness of embolism. Treatment of air embolism consists of end of gas insufflation, flooding the tissue with fluids, lowering surgical site below the level of the heart and supportive therapy as needed.

Key points

- Carbon dioxide insufflation during arthroscopies may aid better visualisation but carries a risk of causing a VAE. A pressure gradient between venous sinuses and intraarticular space, combined with the elevation of the surgical area above the heart level, contributes to the risk factors.
- Significant air embolism can lead to life-threatening consequences; treatment is applied accordingly.
- Close monitoring of the $\text{PE}'\text{CO}_2$ and the $\text{PE}'\text{CO}_2$ – PaCO_2 gradient is crucial during arthroscopies where gas is used as a distending agent. It can speed and ease the diagnosis of VAE. Monitoring of heart rate, respiratory rate and oxygen saturation can be helpful; however, they remain very unspecific.



Case Report

Ultrasonographic diagnosis of lateral meniscal rupture in two horses with severe lameness

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Keywords: horse; hindlimb; stifle lameness

Summary

A 4-year-old Arabian gelding (Case 1) was presented for worsening right hindlimb lameness, first noted after purchase 2 months prior for endurance purposes. On presentation, the horse exhibited a grade 4/5 right hind lameness that was markedly positive to upper limb flexion tests and improved 90% following intra-articular analgesia of all three stifle joint compartments. Mild lateral femorotibial joint effusion and moderate upper limb muscle atrophy were noted. Right stifle radiography revealed moderate to severe osteoarthritis of the lateral femorotibial joint.

A 19-year-old Percheron mare (Case 2) used for law enforcement was presented for progressive left hind lameness that began after falling into deep mud 3 weeks prior. Upon arrival, the horse demonstrated a grade 3-4/5 left hindlimb lameness and was resistant to hindlimb flexion tests. Stifle joint effusion was noted bilaterally but was difficult to discern. Intra-articular analgesia of all three stifle joint compartments improved the lameness 60-70%. Stifle radiography revealed mild bilateral medial femorotibial joint osteoarthritis.

Ultrasonographic examination in both horses revealed evidence of severe lateral meniscal injury (**Fig 1a–c**), including a lack of meniscal tissue in the mid-body region near the lateral collateral ligament, interpreted as meniscal rupture. The meniscus appeared markedly distorted cranial and caudal to the rupture. Case 1 showed mild effusion and moderate synovial thickening of both femorotibial joints, whereas Case 2 showed severe effusion and synovial thickening of the lateral femorotibial and femoropatellar joints.

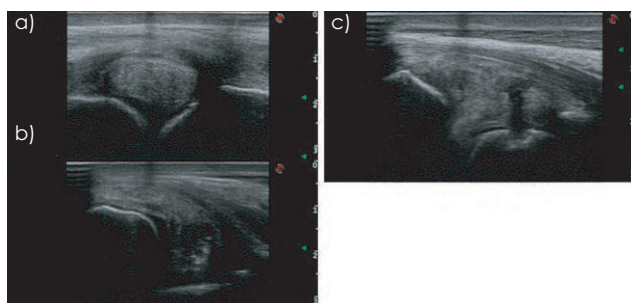


Fig 1: Ultrasound images of the lateral meniscus from Case 1 showing a lack of meniscal tissue at the site of rupture (b) with abnormally shaped and prolapsed meniscal tissue cranial (a) and caudal (c) to the rupture.

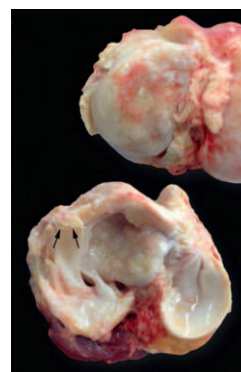


Fig 2: Post-mortem images of the distal femur and proximal tibia from Case 1 showing extensive cartilage erosion and mid-body rupture of the lateral meniscus (arrows).

Both horses were given a poor prognosis for soundness and athletic use. Case 1 was humanely euthanised after diagnosis. Case 2 was euthanised after a brief period of conservative management resulted in clinical worsening. Post-mortem examination in both horses confirmed complete disruption of the lateral meniscus at the mid-body level with separation into cranial and caudal meniscal segments, severe extensive cartilage erosion of the lateral tibial plateau and femoral condyle and exposed subchondral bone (**Fig 2**). No evidence of medial meniscal, collateral ligament or cruciate ligament injury was noted. Ultrasonography was essential for ante-mortem diagnosis of severe meniscal injury and rupture and aided with prognostication and clinical decision making in both horses.

Key points

- Lateral meniscal rupture is an uncommon injury but should be considered in horses with severe stifle lameness.
- Meniscal ruptures were visualised sonographically as severe injuries that divided the meniscus into two separate portions, creating a visible gap between the cranial and caudal meniscal segments.
- Thorough ultrasonographic examination was essential for diagnosis and prognostication in these cases. Lateral meniscal visibility was enhanced with the use of a microconvex transducer.



Case Report

Single-photon emission computed tomography of the pelvis and lumbar spine contributes to the diagnosis of injury in two horses

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Keywords: horse; lameness; musculoskeletal; sacroiliac; nuclear scintigraphy

Summary

Lameness originating from injury to the pelvis and lumbar spine remains a diagnostic challenge for equine veterinarians. Nuclear scintigraphy is frequently used to aid in the localisation of injuries to this region, however, the lack of image contrast due to anatomical superimposition in the pelvis and lumbar spine complicates image interpretation. The two horses presented for investigation of hindlimb lameness, along with traditional nuclear imaging, and they also underwent standing single-photon emission computed

tomography (SPECT) imaging of the pelvis and lumbar regions. SPECT images in Case 1 demonstrated clinically relevant increased radiopharmaceutical uptake (IRU) in the left sacroiliac joint, which was not evident on traditional planar images. In Case 2, when compared to planar images, SPECT imaging demonstrated moderate IRU more specifically at L5 (**Figs 1 and 2**). The findings on SPECT imaging improved diagnostic accuracy in both cases allowing more specific injury management to be undertaken. SPECT imaging of the pelvis and lumbar region in the standing horse was feasible in the two cases described by having the camera move in a 180-degree arc over the horse's lumbar and pelvic region. The imaging technique described holds merit in improving spatial resolution and anatomic detail of the equine pelvis and lumbar spine, thus increasing confidence in the diagnosis of sacroiliac and lumbar disease in the horse.

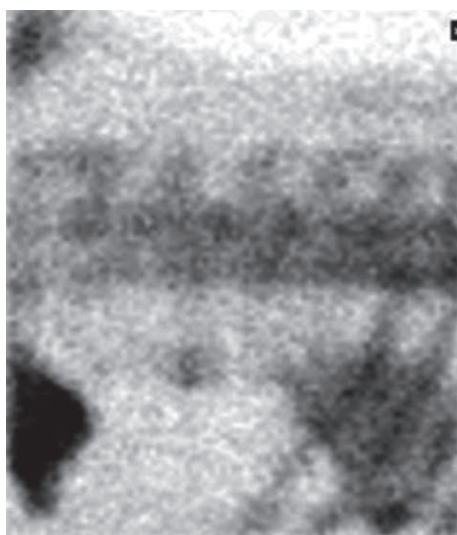


Fig 1: Case 2: Static lateral image of the caudal lumbar vertebral region.

Key points

- Single-photon emission computed tomography (SPECT) imaging of the pelvis and lumbar regions is achievable in the standing sedated horse.
- SPECT imaging holds merit in improving spatial resolution and anatomic detail of the equine pelvis and lumbar spine, thus increasing confidence in the diagnosis of sacroiliac and lumbar disease in the horse.
- SPECT images are acquired by the gamma camera moving in a 180-degree arc over the horse's lumbar and pelvic region.

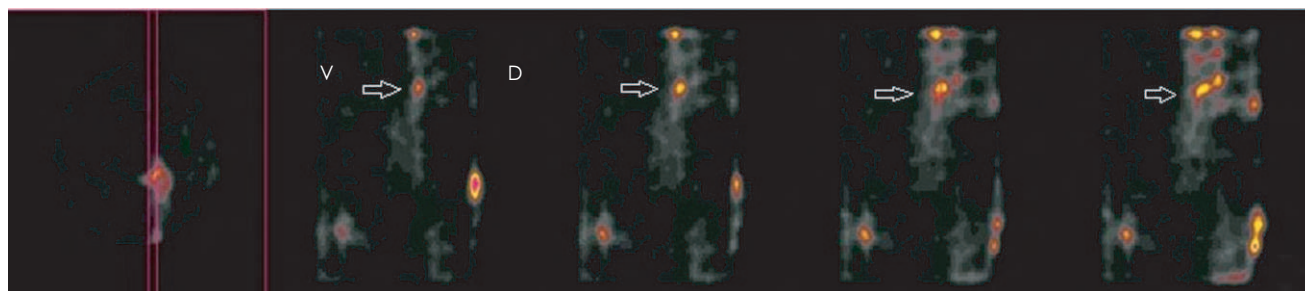


Fig 2: Case 2: Sagittal SPECT images indicating focal increased uptake in the area of the vertebral arch/articular processes of L5 as indicated by arrow (V: ventral, D: dorsal).



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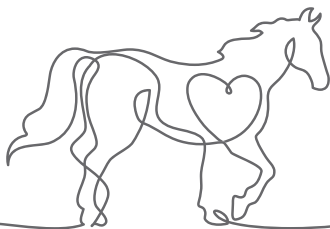
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Case Report

Treatment of a congenital lateral patellar luxation by recession trochleoplasty in a donkey foal

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Keywords: horse; equidae; femoropatellar joint; patella; recession sulcoplasty; trochlea

Summary

The present report describes the surgical treatment of a congenital lateral patellar luxation in a 6-month-old female donkey foal. The foal was presented with a slight crouched position, muscle atrophy, moderate lameness, reluctance to flex the right hindlimb at a walk and slight effusion of the right stifle joint (**Fig 1a**). The foal responded painfully to the stifle flexion test. Irreducible lateral luxation of the right patella was confirmed on physical examination and radiography (**Fig 1b**). The animal was treated surgically by recession trochleoplasty and imbrication of the medial joint capsule. The animal gradually improved after surgery, and good clinical results were reported after 6 months post-operatively. In conclusion, congenital lateral luxation of the patella should be considered as a congenital cause of lameness in donkeys and surgical repair by recession trochleoplasty and medial imbrication

of the joint capsule can be effective for managing of this problem.

Key points

- Congenital lateral luxation of the patella should be considered as a congenital cause of lameness in donkeys.
- Physical examination and radiography are confirmative for diagnosis of this problem.
- Recession trochleoplasty and medial imbrication of the joint capsule can be effective for managing this problem.



Fig 1: a) A 6-month-old female donkey foal with right lateral patellar luxation showing atrophy of the thigh muscles (black arrow), swelling of the right stifle joint and site of patellar luxation (white arrow). b) Caudocranial radiographic view of the right stifle joint of the same donkey foal showing the luxated patella (white arrow).



Case Report

Surgical repair of congenital lateral luxation of the patella in an Arabian foal using a polypropylene mesh**K. Gustafsson^{†*} , F. Hontoir[‡] , G. A. Sutton[†], G. Kelmer[†]  and A. J. Tatz[†]**

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Keywords: horse; patellar luxation; polypropylene mesh; surgery

Summary

A 3-h-old, 40-kg Arabian filly was referred to the Veterinary Teaching Hospital, due to inability to stand and nurse after birth. The left stifle was oedematous and warm, and the patella was palpated lateral to the distal end of the femur. Radiographs of the left stifle confirmed the patella to be luxated laterally. The trochlear groove of the femur appeared to be of normal depth, and no other radiographic abnormalities were observed. The filly was leucopenic ($3.0 \times 10^9/L$), had a normal packed cell volume (40%), and low concentration of total serum protein (44 g/L), suggesting that the filly likely suffered from failure of passive transfer.

The filly was treated with broad-spectrum antimicrobials and fresh-frozen plasma and stabilised systemically over the 3 following days. During this time, the patellar luxation deteriorated, and the stifle area became more swollen and oedematous. Hence, it was decided to proceed to surgical treatment.

The lateral patellar luxation was surgically treated by transecting the lateral parapatellar fascia, imbricating the medial parapatellar fascia and suturing a polypropylene mesh to the imbricated fascia.

Under general anaesthesia, the filly was positioned in dorsal recumbency. A longitudinal skin incision was made on the lateral aspect of the stifle, extending from 5 cm proximal to the proximal aspect of the patella to 2 cm distal to the tibial tuberosity. The patellar dislocation was reduced after transecting the tendon of gluteofemoralis muscle, the lateral femoropatellar ligament, the lateral patellar ligament and a portion of the tensor fascia lata muscle.

A second longitudinal skin incision was made on the medial aspect of the stifle, using the same landmarks as for the lateral incision. The exposed fibrous capsule of the femoropatellar joint was imbricated with seven interrupted vertical-mattress sutures of USP 0 polydioxanone, incorporating the tendon of the sartorius muscle and the medial patellar ligament. A polypropylene mesh, 3 cm wide $\times$ 7 cm long, was placed, over the imbricated tissue and sutured to the fibrous capsule of the femoropatellar joint with simple-interrupted sutures of USP 0 polydioxanone (**Fig 1**).

The filly suffered from several post-operative complications including dehiscence of the lateral incision, a subcutaneous abscess on the medial aspect of the stifle and synovial sepsis of the femoropatellar joint. Bacterial culture of fluid from the infected surgical wounds yielded colonies of multiresistant *Enterobacter cloacae*. Infection of the femoropatellar joint



Fig 1: Intraoperative image of the medial aspect of the left stifle. A polypropylene mesh has been sutured to the imbricated parapatellar tissue with USP 0 polydioxanone sutures inserted in a simple-interrupted pattern. The mesh is indicated with an asterisk (*) in the image.

was treated by arthroscopic lavage. The filly was hospitalised for a total of 10 weeks. Ten months after surgery, the filly was sound at the walk, the patella was located in a normal anatomical position and no osseous abnormalities were noted on radiographic examination of the left stifle.

Key points

- Surgical repair of congenital lateral patellar luxation through transection of the lateral parapatellar fascia and imbrication of the medial parapatellar fascia may be improved by suturing a polypropylene mesh to the imbricated fascia.
- The use of a polypropylene mesh in the repair of congenital patella luxation in large breed foals has the potential of improving the success rate in this group of horses.
- Several post-operative complications can be encountered and should be kept in mind before undertaking this procedure.



Case Report

Lateral patellar instability in Standardbred horses at the weanling age: clinical and morphological features in four cases (2017-2019)

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Keywords: horse; developmental disorder; patellar luxation; computed tomography; anatomic angles measurements

Summary

A total of 222 weanling Standardbreds were examined between June 2017 and December 2019 for presales examination, and lateral patellar instability (LPI) was identified in four horses (1.8% of the weaning population). The mean age at the time of diagnosis was 6.7 months (range 4–9 months). All four horses were colts and presented with 'moderate' to 'severe' unilateral femoropatellar effusion. The affected limb was the right hindlimb in Cases 1 and 2 and the left hindlimb in Cases 3 and 4. Except for a stiff gait in the affected limb, overt lameness was not observed at a walk or during trot in a straight line. Three horses showed an intermittent audible patellar 'slap' during in hand walking on firm and soft surfaces.

The cranioproximal–craniodistal oblique views of the affected stifles confirmed lateral luxation of the patella out of the intertrochlear groove (IG) and obvious incongruity of the articular surfaces (**Fig 1**). All weanlings presented with an abnormal patellar shape characterised by a rounder profile and a less pronounced sagittal crest. Measurement of the IG angle was wider compared to the unaffected stifle only in one case.

One horse was euthanised due to worsening of the lameness and the irreducible patellar luxation (Engelbert' grade 4/4). Computed tomography examination was performed on the entire length of both hindlimbs. The affected femur showed an increased angle of anteversion of the femoral neck and a smaller anatomical lateral and distal

femoral angle with a valgus deviation of the distal femur in comparison with the unaffected limb. The angle of tibial torsion in the affected limb was more than twice the angle calculated on the unaffected limb.

None of the affected horses entered a training programme for racing. Three of four cases were used for leisure activity and the effusion of the femoropatellar joint increased mildly over a 2-year period.

LPI prevents Standardbreds affected from fulfilling an athletic career, and no effective treatments are currently reported.

Key points

- Lateral patellar instability seems to occur with a high prevalence in Standardbred weanling populations
- Lateral patellar instability could be identified in the first 6 months of life of the foals by the presence of a consistent femoropatellar effusion, an audible patellar 'slap' at walk, and the ability to manually displace the patella when the stifle is kept in moderate flexion.
- The findings of the study suggest that lateral patellar instability is related to a combination of epiphyseal dysplasia and rotational and angular abnormalities of the affected limb.

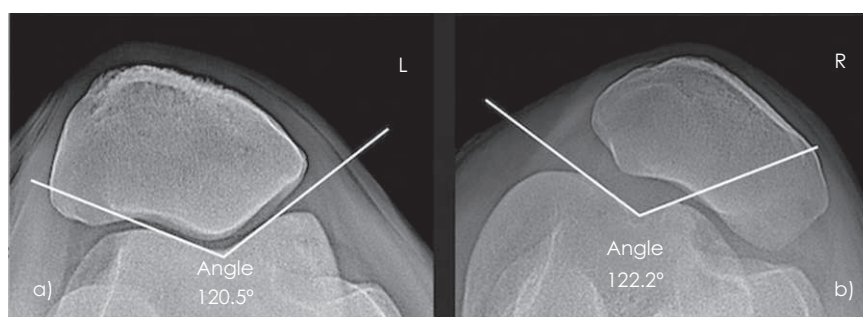


Fig 1: Cranioproximal–craniodistal oblique views of the right and left stifles of Case 2 are shown. a) Left normal stifle. b) Right stifle presenting lateral patellar instability. There is a consistent lateral displacement of the patella when the stifle joint is in full flexion. The patella presents an abnormal shape with an elongated profile and a less pronounced sagittal crest.



Clinical Commentary

Patellar instability/patellar luxation in horses: Potential risk factors and treatment options

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Keywords: horse; patellar instability; patellar luxation; surgical treatment; risk factors

Patellar instability/luxation in horses is an uncommon condition and a good understanding of the mechanism behind the condition and the potential risk factors is lacking as is highlighted in the report by Pagliara *et al.* (2022). A variety of treatment options are available and some of these have been described in the report by Abu-Seida and Shamaa (2022) in a donkey foal and in a larger Arabian foal by Gustafsson *et al.* (2022). The aim of this commentary is to describe the clinical signs, potential risk factors and a variety of treatment options, including surgical options for larger foals, associated with patellar instability/luxation.

The report describing lateral patellar instability in young Standardbred horses by Pagliara *et al.* (2022) will hopefully provide further understanding of the diagnosis and treatment of this uncommon disease. The description of the clinical and morphological features described by Pagliara *et al.* (2022) highlights the need to understand the mechanism associated with this disease and to try to identify the risk factors, with the ultimate aim to recognise the disease early and explore potential treatment options.

The general definition of patellar instability is the inability of the patella to remain located within the trochlear groove throughout the full range of motion of the stifle. In veterinary medicine this is most commonly reported as patellar luxation, divided into different grades of severity (from grade 1 to grade 4) and grouped into traumatic, developmental and congenital causes (Busschers 2009). Post-surgical patellar instability after medial patellar ligament desmotomy has also been described (Baccarin *et al.* 2009), but this commentary will focus on developmental and congenital patellar luxation.

Clinical signs and potential risk factors

Congenital patellar luxation has mainly been reported in miniature horses and ponies, and now has been documented, and treated successfully, in a donkey foal as well (Abu-Seida and Shamaa 2022). Foals can present with unilateral or bilateral disease and if the patella is luxated they commonly present with stifle effusion and a typical crouched position. However, if the patella is not completely luxated, then a stiff gait can be observed. Clinical signs of developmental patellar luxation are similar and will vary depending on the severity of the disease. Horses and ponies with less severe developmental patellar luxation largely present with a stiffness in gait, a reluctance to flex the limb, a potential audible 'slap' at walk and femoropatellar joint effusion (Walmsley 2010; Pagliara *et al.* 2022). Lameness only becomes apparent in the later stages when degenerative changes of the joint are present, and most horses will present

with unilateral disease. Radiographs are helpful to further determine the position of the patella and identify any bony abnormalities.

Pagliara *et al.* (2022) discuss that the aetiopathogenesis of lateral patellar instability remains unclear in their cases. It is possible that abnormalities of the soft tissues and/or bony structures associated with the quadriceps mechanism were present at birth which subsequently progressed into more significant pathology. However, a developmental cause seems more likely considering the lack of obvious clinical abnormalities at birth. The underlying cause of patellar instability in other species (i.e. dog and human) is still not completely understood, but malalignment of the quadriceps mechanism seems to play a key role in the development of this disease. The quadriceps mechanism includes the quadriceps muscle group, patella, medial and lateral femoropatellar ligaments, patellar ligaments (medial, middle and lateral), trochlear groove and tibial tuberosity. Any abnormality of this mechanism, resulting in different contact pressures during the growth period, can lead to morphological changes of the distal femur, patella and proximal tibia with subsequent patellar instability. However, it is well known that pre-existing malpositioning of the patella (i.e. patella alta [more proximally positioned patella] or patellar instability/patella luxation) influences the development and results in flattening of the trochlear groove and flattening of the patella (Huri *et al.* 2012; Kaymaz *et al.* 2013; Niu *et al.* 2017; Dona *et al.* 2018; Tanaka 2018). This effect has been shown to be reversible if the patella is realigned early in the growing phase (Wang *et al.* 2016). These concepts are well recognised and there is no reason to believe this will be different for the equine species.

Previously, developmental patellar luxation in horses has been primarily associated with severe dysplasia of the lateral trochlear ridge, but additional bone abnormalities have been identified in other species and in the report by Pagliara *et al.* (2022). Various anatomic features such as valgus or varus deviation and patella alta have been described as risk factors for recurrent patellar instability in people and dogs (Johnson *et al.* 2006; Chotel *et al.* 2015; Niu *et al.* 2017; Parikh *et al.* 2019; Schlichte *et al.* 2019) and it is possible these abnormalities play a role in horses as well. In ponies and young horses presented with patellar luxation/instability a clearly abnormal conformation is rare, but Pagliara *et al.* (2022) identified a valgus deviation of the distal femur and a rotational effect of the tibia in one case at post-mortem examinations. It is likely that these anatomical abnormalities are associated with malalignment of the patella. Minor conformational abnormalities may play a role in the development of this disease but they might go unrecognised

as the diagnostics most commonly used (clinical and radiographic examination) might not be sensitive enough to detect minor abnormalities. Additional risk factors including increased tibial tubercle to trochlear groove distance, shape of the patella and patellar tilt have been described in human medicine (Chotel *et al.* 2014; Schlichte *et al.* 2019). Pagliara *et al.* (2022) identified an abnormally shaped patella with a more rounded appearance in all four cases and in three cases a shallow intertrochlear groove was identified; these could be the result of abnormal contact pressures during growth. At this stage, it appears that there is uncertainty in most species as to whether or not primary changes in the quadriceps mechanism result in secondary bone changes and patellar instability, or whether the bone changes are the primary cause of the patellar instability.

Treatment

In cases of congenital patellar luxation surgical treatment is recommended, but this category is usually amenable to simpler surgical techniques and overall has a good prognosis. In foals, it is rare that there are major osseous abnormalities and soft tissue techniques (lateral release and medial imbrication) are usually sufficient to realign the patella. A single, large, incision at the craniomedial aspect will provide exposure for both the lateral release and medial imbrication. Lateral release can usually be accomplished by carefully transecting the lateral patellar attachments without transecting the joint capsule and pulling the patella medially will help determine when the release is complete. Medial imbrication can be accomplished by performing a medial arthrotomy (which will transect the medial femoropatellar ligament) and closing the tissue by overlapping the caudal tissue on top of the more cranial tissue. Sutures should be preplaced, after which they can be pulled all together and each tied tightly. An abnormally shaped patella combined with insufficient width and depth of the trochlear groove are not necessarily reasons to perform more aggressive osseous surgical techniques. After surgery when normal patellar tracking is re-established, remodelling of the trochlea and the patella will likely occur. In the rare cases where there is obvious flattening of the trochlear ridges, a recession wedge sulcoplasty can be considered. In larger foals, lateral release and medial imbrication is less successful (Leitch and Kotlikoff 1980), and reinforcement of the medial imbrication is recommended. A mesh can be used as reinforcement as performed in the case report by Gustafsson *et al.* (2022), but in larger foals and weanlings placement of an artificial implant mimicking the function of the femoropatellar ligaments could be considered (Busschers 2009). The implant used needs to be strong (high molecular weight polyethylene cable or similar) and correct placement through the patella and fixation on the femoral epicondyle is extremely important. The implant needs to be isometrically placed so its length is preserved during the range of motion of the stifle and selecting the femoral attachment point is critical. The ideal attachment point is the anatomical origin of the femoropatellar ligaments, which is just proximal from the medial femoral epicondyle (medial femoropatellar ligament) and on the lateral femoral epicondyle just proximal to the lateral collateral ligament (lateral femoropatellar ligament). The approximate insertion through the cranial aspect of the patella is less critical but should be at the anatomical

insertion site of the lateral or medial femoropatellar ligament. After placing the implant through the patella, the isometric femoral attachment site can be found. A mesh, as used by Gustafsson *et al.* (2022), is more elastic and a lack of isometry can be overcome, but an isometric implant will be stronger and likely result in increased stability if placed appropriately and should be considered for larger patients.

Other major skeletal deformities resulting in abnormal conformation and thus abnormal alignment of the patella (such as a valgus deviation or abnormal positioning of the tibial tuberosity) are rare. As discussed previously, Pagliara *et al.* (2022) reported that one case had mild conformational abnormalities on post-mortem examination. It is possible that these abnormalities are present, but not detected, at birth or that they develop with time due to abnormal pressures and malalignment of the quadriceps mechanism. If surgical treatment is considered it should aim to restore the normal alignment of the quadriceps and the patella with the entire limb; the recommended procedure depends on the type of abnormalities present. Tibial tuberosity transposition is commonly performed in dogs and people with abnormal conformation and could be considered. This procedure is more challenging in the horse due to the complex anatomy of the patellar ligament insertions in this region and the presumed higher risk of mechanical failure in larger animals.

After any surgical procedure providing patellar realignment, evaluation of patellar tracking within the trochlear groove during flexion and extension of the stifle should be performed before closure. A full limb bandage is recommended to limit flexion during recovery.

In human medicine, insufficiency of the vastus medialis muscle is thought to contribute to lateral patellar instability and a cadaver study showed that reduction of the tension of this muscle resulted in significant increases in lateral patellar tilt and translation, elevated lateral/reduced medial articular contact pressures and reduced patellar stability (Stephen *et al.* 2018). These findings provide rationale to support the role of quadriceps strengthening in patients with normal femoropatellar anatomy and patellar instability. Further research is required to investigate whether similar rehabilitation principles apply to patellar instability in the horse.

In the report by Pagliara *et al.* (2022), the three surviving horses had limited athletic ability but were able to be used for leisure activity. However, these horses did not receive any specific treatment for the condition, and it is possible that additional surgical techniques as described could result in a more successful outcome in affected horses. Early recognition of the disease and early surgical intervention will improve the success rate for a variety of reasons; firstly, our patients will weigh less which improves the chance of surgical success, and secondly, early treatment allows for remodelling of the trochlea and the patella once normal contact pressures are re-established. Early intervention will mitigate negative effects of the condition on growing bone and finally will limit development of degenerative joint disease.

Author's declarations of interest

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Clinical Commentary

Luxation of the patella in foals: A treatment challenge

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Keywords: horse; medial imbrication of the joint capsule; recession trochleoplasty; stifle joint; trochlear ridge

Luxation of the patella is uncommon in equids, and is most commonly an inherited disorder in foals. It is usually seen in the miniature breeds, particularly in ponies. The article in this issue by Gustafsson *et al.* (2022) illustrates the successful diagnosis and surgical treatment of a congenital lateral luxation of the patella in an Arabian filly. The authors report on the success of treatment after transecting the lateral parapatellar fascia, imbricating the medial parapatellar fascia and suturing a polypropylene mesh to the imbricated fascia. The filly recovered 10 months after surgery with no osseous abnormalities at that time. Further studies are needed to understand the aetiology and benefits of different surgical corrections of this condition in foals.

The case reports by Gustafsson *et al.* (2022) and Abu-Seida and Shamaa (2022) describe the diagnosis and surgical repair of congenital lateral luxation of the patella in foals.

The authors of the first report discuss the diagnosis and treatment of a congenital lateral luxation of the patella in a 3-h-old Arabian filly (Gustafsson *et al.* 2022). The luxation was surgically repaired by releasing, medial imbrication and suturing a polypropylene mesh to the imbricated fascia (Gustafsson *et al.* 2022). While the authors of the second report describe, for the first time, the diagnosis and treatment of a congenital lateral patellar luxation in a 6-month-old female donkey foal (Abu-Seida and Shamaa 2022). The donkey foal was successfully treated by releasing, recession trochleoplasty and medial imbrication of the joint capsule.

Congenital luxation of the patella in donkey foals has not been recorded prior to the report by Abu-Seida and Shamaa (2022), but it has been observed in horses (O'Meara and Lischer 2009; Ghasemi *et al.* 2015; Ogden *et al.* 2017; Gustafsson *et al.* 2022).

Luxation of the patella is probably an inherited disorder in equids, particularly in ponies of the miniature breeds (Hart *et al.* 2009). Alternatively, traumatic luxation of the patella is also recorded, particularly in adult equids (O'Meara and Lischer 2009; Ogden *et al.* 2017).

There are several types of patellar luxation reported in foals including lateral, medial or distal, unilateral or bilateral and intermittent or persistent (Hall *et al.* 2010). The patellar luxation has four grades: grade 1: the patella is luxated manually but able to reduce itself; grade 2: the patella is located in the trochlear groove and luxated intermittently; grade 3: the patella is usually luxated but can be manually reduced; and grade 4: the patella is luxated and cannot be manually reduced (Arnoczky and Tarvin 1980).

Patellar luxation in foals can usually be diagnosed by the case history, clinical signs and physical examination. The affected foals usually show a crouched position, with swelling of the stifle joint, muscle atrophy, slight femoropatellar joint effusion and pain, moderate to severe lameness, reluctance to flex the diseased hindlimb at a walk, dragging the toe of

the affected limb during exercise and inability to back-up (Abu-Seida and Shamaa 2022). The luxated patella is palpated at the lateral, medial or distal aspect of the stifle joint, and it may be reducible or irreducible into its normal anatomical site. Moreover, the affected foals respond painfully to forced stifle flexion (Gustafsson *et al.* 2022; Abu-Seida and Shamaa 2022).

In the articles by Gustafsson *et al.* (2022) and Abu-Seida and Shamaa (2022), the lateral luxation of the patella of both foals was confirmed by radiography. Radiography helps to identify the degree of degenerative joint disease, depth of trochlear groove, shape and position of the patella, degree of ossification of the trochlear ridges and other bony changes (Engelbert *et al.* 1993). Lateromedial and flexed skyline radiographs of the femoropatellar joint are necessary to assess trochlear ridge hypoplasia (O'Meara and Lischer 2009; Ghasemi *et al.* 2015).

Regarding the treatment of patellar luxation in foals, various surgical repairs have been applied. Surgical repair for patellar luxation in equids falls into two techniques, as described by Hart *et al.* (2009), fascial release and imbrication techniques in cases with minor or no anatomical changes, while reconstructive techniques such as a modified recession trochleoplasty (Hart *et al.* 2009) and recession sulcoplasty (Abu-Seida and Shamaa 2022) can be applied in combination with releasing and imbrication techniques in foals with major anatomical changes such as a shallow trochlear groove and hypoplastic trochlear ridge. In lateral luxation of the patella, the release technique is applied to the lateral retinacular structures and the medial side of the joint capsule is imbricated, while in medial luxation of the patella, the procedures are reversed.

Surgical treatment of lateral patellar luxation through lateral release and medial imbrication has reportedly produced good results in miniature horses (Engelbert *et al.* 1993); however, in larger breeds, the same technique was reported to be less successful (Leitch and Kotlikoff 1980). Therefore, the report of Gustafsson *et al.* (2022) is important because the authors used a polypropylene mesh in the repair of patella luxation in large-breed horses that has not been previously described. This modification has the potential of improving the success rate in this group of horses.

The potential complications of releasing and imbrication techniques include a subcutaneous abscess, recurrent luxation, septic arthritis, degenerative joint disease, wound dehiscence, muscle atrophy, septic arthritis and impaired stifle extension (Engelbert *et al.* 1993; Ghasemi *et al.* 2015).

The incomplete wedge recession trochleoplasty reported by Hart *et al.* (2009) presents a logical variation to the traditional trochlear wedge recession technique used in dogs with patellar luxation, while the traditional technique, complete wedge recession trochleoplasty reported by Abu-

Seida and Shamaa (2022), was used successfully, in combination with releasing and medial imbrication, in the treatment of congenital lateral patellar luxation in a donkey foal. The theoretical advantages of incomplete over complete wedge recession technique or chondroplasty are the smoother articular surface proximally and more stability of the construct as a whole. Technically, the modified recession trochleoplasty appears more demanding than other techniques, and more time-consuming compared with the standard wedge trochleoplasty.

A combination of releasing, recession trochleoplasty (sulcoplasty) and medial imbrication of the joint capsule is an innovative and promising technique for repair of lateral luxation of the patella in foals, particularly those with trochlear ridge hypoplasia and shallow trochlear groove (Abu-Seida and Shamaa 2022). No complications or recurrence after surgery were reported in the donkey foal recorded by Abu-Seida and Shamaa (2022).

A recent technique for repair of lateral luxation of the patella in a foal involved transecting the lateral parapatellar fascia, imbricating the medial parapatellar fascia and reinforcing the imbrication with a polypropylene mesh by suturing the mesh to the imbricated fascia (Gustafsson *et al.* 2022). Although several complications such as septic arthritis and wound dehiscence were recorded after surgery, none of them was related to the polypropylene mesh.

Although the anatomy of the stifle joint is similar among equids, and there is no difference in the surgical repair of this condition between horses and donkeys, the outcome of treatment is generally better in donkeys, probably due to their small size compared to those of horses (Abu-Seida and Shamaa 2022).

Like in dogs, lateral luxation of the patella in foals has usually been resolved by using recession trochleoplasty and medial imbrication of the joint capsule (Kobluk 1993). Thus, the more elaborate surgical techniques used to treat patellar luxation in dogs may be necessary when treating this condition in foals.

Luxation of the patella is uncommon in foals; therefore, a comparison of different surgical repairs will prove difficult, as few cases are treated and even fewer are likely followed-up.

Based on the currently available literature, miniature horses are the most predisposed breed to patellar luxation. Therefore, the prognosis for future athletic use in larger-breed horses remains unknown. The aetiology of the problem remains also unknown. Although the recorded cases in foals provide us with an optimistic outcome for this problem, we

should turn our attention to preventing this condition by discouraging breeding of the treated foals.

Author's declaration of interests

No conflicts of interest have been declared.

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Case Report

Large placental area of degeneration in a twin pregnancy in a mare (*Equus caballus*)

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Keywords: horse; fetal membranes; PAD; mummification; type C twinning

Summary

A primiparous mare foaled a small but healthy foal and a mummified twin (the live foal attained the same size as its peers over the next several months). The mummy and its fetal membranes were necrotic and had been invaginated within the fetal membranes of the live foal. The mummy was estimated to have died at around 6 months of gestation, most likely due to growth retardation (i.e. intrauterine growth restriction), which would have developed as a result of low nutrient and oxygen exchange caused by limited access to the endometrium. Near the mummy, the fetal membranes of the live foal had a clear demarcation between a 'white' and a 'red' region. The white region was touching the mummy, and some of its features were similar to those of a fetal-foot placental area of degeneration (PAD): it was ischaemic and degenerate (as indicated by hypoplasia, hyaline degeneration, multifocal squamous metaplasia, cell swelling and basement membrane sclerosis) with villi that were shorter than normal and limited in number. However, the PAD in this case was thinner than those in previous reports, and it was much larger, as it surrounded the entire mummy. The red region, which was touching the maternal endometrium, was hyperaemic, but in other respects, it was similar to the fetal membranes in the other uterine horn. Invagination of the dead foal with the allantochorion of the live foal may have helped the live foal to survive in two ways. First, it created a physical barrier between the decaying mummy and

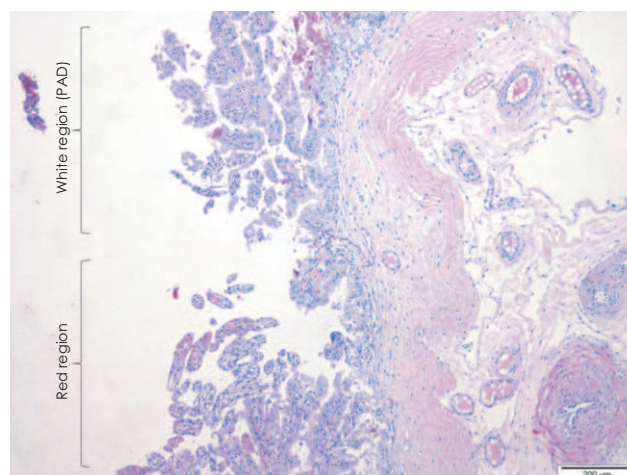


Fig 2: Micrograph of the line of demarcation between the white and red regions. Placental area of degeneration (white region) on top and red region on the bottom. HE staining.

the live foal; the presence of cell swelling and hyaline droplet degeneration in the PAD suggests that this barrier was processing fluids and protein from the mummy. Second, invagination provided more contact area for nutrient and oxygen exchange between the allantochorion of the live foal and the endometrium. To the authors' knowledge, this is the first extensive report on the histology of type C twinning (i.e. with a mummified foal) in which the death of one foal had not been induced (Figs 1 and 2).

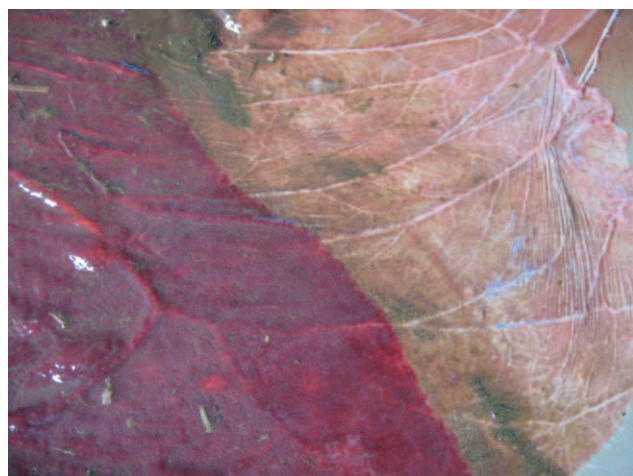


Fig 1: Demarcation of the allantochorion. Red region to the left and white region (placental area of degeneration) to the right.

Key points

- In cases of type C twinning, the live foal's allantochorion can invaginate the mummy; the part of the allantochorion touching the mummy can display features of a placental area of degeneration (PAD).
- This large PAD can have features similar to fetal-foot PADs often observed in singleton pregnancies.
- Invagination of the dead foal and creation of a PAD may help the live foal to survive by creating a physical barrier that processes fluids and protein from the mummy, and by providing more contact area for nutrient and oxygen exchange between the allantochorion of the live foal and the endometrium.



Clinical Commentary

Love thy neighbour – unless they are sharing your uterus

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Keywords: horse:fetus; placenta; twin pregnancy

Twinning in the mare is an undesirable occurrence, unless one is undertaking embryo transfer, and rarely results in the birth of two viable foals since the equine placenta requires the entire surface of the uterus from which to derive enough nutrition to support a fetus to term. Before the advent of routine ultrasonography in the early 1980s (Chevalier and Palmer 1982; Simpson *et al.* 1982; Allen and Wilsher 2018), twin pregnancies frequently went undetected and were the commonest cause of abortion in Thoroughbreds (Jeffcott and Whitwell 1973). Although natural post-fixation embryo reduction of twins occurs before Day 40, the rate is significantly influenced by whether fixation of the twins is unilateral or bilateral (**Fig 1**). Ginther (1988) reported that post-fixation reduction of bilaterally fixed twins is minimal, with just 6% (1/18) resolving naturally, versus 83% (34/41) of unilateral twins. Death of one unilateral twin usually results from abutment of the yolk sac against the co-twin rather than the endometrial surface depriving the developing conceptus of nutrition (**Fig 1b**). Nevertheless, the ultrasonographic recognition of twins in early gestation provides the opportunity to manually reduce one embryonic vesicle while leaving a singleton to go to term, without taking the risk that natural reduction may or may not occur. The success rate of this procedure in experienced hands is high (>90%) when carried out before Day 16 or 17 of pregnancy (Pascoe *et al.* 1987a,b; Ginther 1988; Morris and Allen 2002; Allen *et al.* 2007) and there is no increase in pregnancy loss throughout the remainder of the gestation for the remaining singleton (Davies Morel *et al.* 2012). There are also options for reducing twins at later stages of gestation, although as the gestational stage at which they are detected increases, the success rate decreases (Macpherson and Reimer 2002; Wolfsdorf and Macpherson 2010).

The Case Report in this issue entitled 'Large placental area of degeneration in a twin pregnancy in a mare (*Equus*

caballus)' (Rapacz-Leonard and Paździor-Czapula 2022) illustrates the case of a co-twin surviving to term along with its mummified sibling. The twin placentation described in this case is Type C where one twin undergoes mummification and occupies on average only 15% of the uterus whilst the other twin occupies the remaining 85% encompassing all of one uterine horn, the body and part of the other uterine horn with the fetal membranes of the mummified twin enveloped in a large invagination (Jeffcott and Whitwell 1973). In the aforementioned seminal paper by Jeffcott and Whitwell (1973) on twinning as a cause of fetal and neonatal loss in Thoroughbred mares, Type C twin placentation accounted for 10% of the 62 sets of twin fetal membranes examined. All 6 of these Type C pregnancies went to term after gestations of normal length (333–352 days). One foal was born alive in each instance although only three of these survived past 2 weeks of age. However, the reduction in the size of the allantochorion of the surviving twin, albeit only by approximately 15%, resulted in lower birthweights of the foals compared with singleton conceptuses. Similarly, the Case Report in this issue reported a smaller than expected birthweight and estimated the villous surface of the allantochorion to be about 85%, with the remainder, mostly avillous area, enveloping the mummified twin and its membranes. In addition, it reiterates the findings of Ball *et al.* (1993) that although the placenta may be able to partially extend into a previously occupied area of uterine space, following death of a co-twin, the development of the microcotyledons on its surface will be sub-standard or absent, indicating that development of the microcotyledons is a stage-specific event during pregnancy.

In most cases of twin placentation, as one would expect, it is the larger twin that has the greater chance of survival, given that there is a close correlation between chorionic surface area and fetal weight (Allen *et al.* 2002).

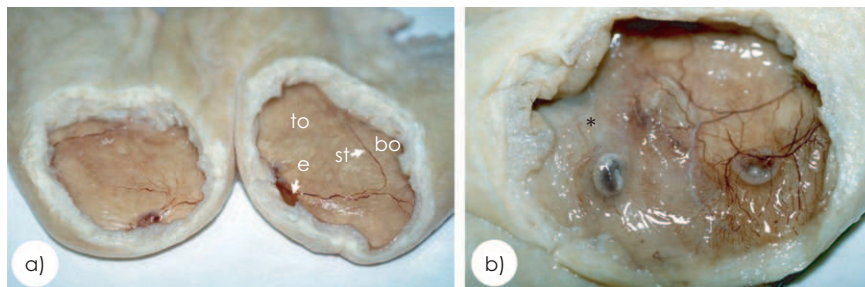


Fig 1: Perfused fixed, post mortem specimens showing (a) Day 24 bilateral and (b) Day 26 unilateral twins. a) In the bilateral twins normal development of the conceptus is seen with both embryos (e) showing the vitelline vessels and the sinus terminal (st) delineating the vascularised trilaminar (to) and bilaminar (bo) omphalopleures. b) In the unilateral twins one conceptus is dying (asterisk) as it is unable to obtain histotrophic nutrition from the endometrial gland secretions through the absorptive yolk sac which is abutted to its co-twin.

Nevertheless, Jeffcott and Whitwell (1973) reported that placental insufficiency leading to fetal death was not always the whole story. Hence, in 20% of Type A twin placentas, where there is marked discrepancy between the size of the allantochorions, the smaller twin was born alive or had only recently died, whereas the larger one was autolysed. Likewise, Prickett (1970) also noted that on occasion the smaller twin may be the survivor. However, death of the larger twin may be attributable to its larger size and the fact it runs out of placental area to support it before the smaller co-twin (**Fig 2**). In addition, despite no evidence for bacterial infection, Jeffcott and Whitwell (1973) also noted that the area where the twin allantochorions abut frequently shows a chronic inflammatory reaction with plasma cells infiltrating the interface, foci of inflammatory cells are seen in the liver of twins, and small quantities of gamma-globulin in their serum, findings not observed in non-infective abortions or stillbirths of singletons (Jeffcott and Whitwell 1973). Taken together these observations support the idea that an adverse inter-twin immunological response may contribute to some twin deaths (Whitwell 2011). Furthermore, placental insufficiency does not explain why twins are often aborted in early gestation before the uterus has reached its maximum size (Whitwell 1980).

Reports of twin placentation, such as the one in this issue, allow a better understanding of placental function and morphology in unusual pregnancies and may also provide clues to enable the formulation of hypotheses concerning aspects of placental and fetal development in normal singleton pregnancies. For example, the role of uterine space in the development of the umbilical cord, and fetal malformations. In this respect, hypoplasia of one umbilical artery was reported to be common in twins but not in singletons (Whitwell 1984), but the length of the umbilical cord in twin versus singleton pregnancies has not been investigated in the mare. In women, where the scenario is somewhat different, and the majority of twin pregnancies

make it to term, the umbilical cord has been reported to be significantly shorter in singletons (Soernes and Bakke 1987) or, conversely, to show no statistical difference in length (Katsumata *et al.* 1991); the first study gives credence to the theory, but the other not, that intrauterine constraint reduces fetal movement and hence limits tensile forces on the cord which, in part, may dictate cord length. Furthermore, one theory on skeletal deformities and malformations in the horse is mechanical moulding pressure exerted on the fetus by the uterine wall, given the unusual and cramped shaped space that many twins experience prior to abortion or birth. Therefore, it is somewhat surprising that twin fetuses are not commonly reported as suffering from these conditions, although, Whitwell (1980) did mention a co-twin with contracture of the forelimbs and another case with torticollis of one twin.

The relatively large number of twin placentae that Jeffcott and Whitwell (1973) studied is a situation unlikely to be repeated since few equine pathology laboratories will have access to this number of twin placentas to examine, given that, nowadays, manual reduction of twins in early pregnancy in well-managed populations of mares is undertaken routinely. However, there may well be increasing opportunities to study twins, albeit with a different type of twin placentation. Equine twins are almost always dizygotic, originating from the fertilisation of two individual oocytes. And, although occasional reports of naturally occurring monozygotic twins (Rooney 1970; Govaere *et al.* 2009) and triplets (Meadows *et al.* 1995) do exist in the literature, monozygotic multiple pregnancies are considered rare in most animals. Reports also exist of monozygotic twins occurring following embryo transfer of a single embryo flushed from a donor mare (McCue *et al.* 1998; Mancill *et al.* 2011; Sper *et al.* 2011). However, with the increasing production of embryos from oocytes recovered from puncture of ovarian follicles and their fertilisation by



Fig 2: A set of twins aborted at approximately 8 months of gestation. The twin placentas have a Type B arrangement, where each allantochorion has a more or less equal share of the uterine space (Jeffcott and Whitwell 1973). Note how the larger twin on the right is already showing advanced degeneration and its allantochorion is pale and bloodless, compared with that of the smaller twin.

intracytoplasmic sperm injection (ICSI), several authors have reported monozygotic twin, or even triplet, pregnancies after transfer of such in-vitro produced (IVP) embryos (Li *et al.* 2001; Roberts *et al.* 2015; Dijkstra *et al.* 2020). The same phenomenon has been described following *in-vitro* production of human embryos (Edwards *et al.* 1986; Blickstein *et al.* 1999, 2003; Sills *et al.* 2000; Alikani *et al.* 2003; Aston *et al.* 2008). What is particularly interesting about such cases is that the two fetuses usually develop within a single allantochorion, but have separate umbilical cords and amnions, therefore being classified as monochorionic and diamniotic. In women, monochorionic and diamniotic twins make up about 20% of all twin placentas and this is the most common form of placentation found in monozygotic twins. Such pregnancies are compatible with survival of both fetuses due to the very different placental structure in women compared to the mare (Baergen 2005).

As with any twin pregnancy in the horse, the limited placental area from which two fetuses can derive enough nutrition to get them to term makes the live birth of one or both fetuses in cases of monochorionic placentation unlikely. So, might twin reduction be an option in these pregnancies, as it is in dichorionic twin placentation in the mare? Certainly in women, survival of one twin is possible following death of its co-twin with a monochorionic placenta. In a recent study in women, looking at the pregnancy outcome following spontaneous death of one fetus in monochorionic twin pregnancies, 89% (62/70) resulted in a live birth although such pregnancies were complex and high-risk, often further complicated by twin-twin transfusion syndrome (Morris *et al.* 2020). Preterm births and prematurity also occurred frequently (Morris *et al.* 2020). In addition, selective reduction of one fetus in complicated monochorionic twin pregnancies in human medicine has also resulted in live births (Yinon *et al.* 2015). However, from a practical point of view, in equine monochorionic twin pregnancies the chance of a successful outcome following reduction of one twin is low. Notwithstanding, reduction of one twin in a monochorionic equine pregnancy has been attempted. For example, Dijkstra *et al.* (2020) compressed the thorax of one fetus at 50 days of gestation and successfully stopped its heart beating, although one week later the pregnancy had failed.

From the Type C twin placentation described by Rapacz-Leonard and Paździor-Czapula (2022), in the present issue, to the increasing appearance of reports mentioning monochorionic twin placentation in the horse, such anomalies are both intriguing and worthy of discussion to better understand the tribulations of the fetus *in utero*. They also provide a timely reminder that there is no room for complacency when undertaking ultrasound pregnancy examinations in the mare as there is always the possibility of a twin pregnancy, even when only a single ovulation has been noted, or a single *in vivo* derived or IVP embryo has been transferred to a recipient mare.

Author's declarations of interest

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this clinical commentary.

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Case Report

Multicavitary septic effusions associated with actinobacillosis in an adult Tennessee Walking Horse with weight loss**K. Means, K. Townsend  and P. Johnson* **

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Keywords: horse; peritonitis; pleuritis; actinobacillosis; ultrasonography**Summary**

An 18-year-old Tennessee Walking Horse gelding was presented with weight loss of 6 months' duration. Weight loss without other signs of systemic illness had progressed in spite of an excellent appetite, regular deworming, routine dentistry and dietary alterations to promote weight gain. Although vital parameters were within normal limits, auscultation indicated decreased bronchovesicular sounds bilaterally below the level of the gelding's shoulders and mild ventral subcutaneous oedema. Mild anaemia was evident on haematology, but the white blood cell and neutrophil counts were within reference intervals. Plasma biochemical abnormalities included marked hyperproteinaemia, hyperglobulinaemia and hypoalbuminaemia. Results of serum protein electrophoresis were consistent with nonspecific chronic inflammation. Plasma serum amyloid A was elevated, but the plasma fibrinogen concentration was within the reference interval. Severe bilateral thoracic effusion, severe peritoneal effusion and mild pericardial effusion were evident on ultrasonography. Fibrin was extensively adhered to the visceral and parietal surfaces of the peritoneal cavity (**Fig 1**). Thoracocentesis and abdominocentesis yielded yellow, opaque fluid. Marked septic neutrophilic inflammation with phagocytised rod bacteria was visualised on cytological analysis of fluid from both cavities (**Fig 2**). An *Actinobacillus* sp., likely *A. lignieresii*, was cultured from both peritoneal and pleural fluid and was susceptible to most tested

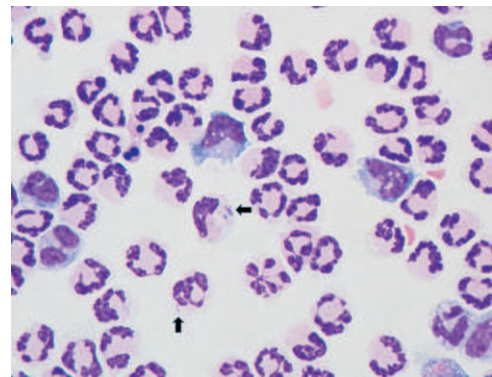


Fig 2: Microscopic appearance of peritoneal fluid following cytopsin preparation depicting numerous polymorphonuclear granulocytes and phagocytised bacterial rods (arrows). Wright-Giemsa stain, magnification 100 $\times$.

antimicrobials. Following the institution of intravenous fluids, a substantial volume of yellow, opaque fluid was aseptically drained from both cavities. The gelding was initially treated using intravenous antibiotics, flunixin meglumine and omeprazole. Seven days following admission, the gelding was discharged for treatment at home using trimethoprim-sulphamethoxazole for 4 weeks. The gelding's body condition was normal 4 weeks following discharge. Follow-up physical and ultrasonographic examinations at 7 months following initial presentation yielded normal findings and the gelding had gained 75 kg of body weight.



Fig 1: Ultrasonographic image obtained (3.5 MHz curvilinear frequency probe) from the right hemithorax depicting both pleural and peritoneal effusions at intercostal space 9. Dorsal is at the left side of the image. PF = pleural fluid; D = diaphragm; PeF = peritoneal fluid; F = adherent fibrin.

Key points

- Actinobacillosis should be considered in cases of weight loss associated with multicavitary effusion, minimal signs of systemic illness and a paucity of haematological indications of inflammation.
- Septic peritonitis and pleuritis resulting from actinobacillosis may respond well when conservative therapy is instituted, including cavitory drainage, intravenous fluids and appropriate antimicrobial therapy.
- Ultrasonography and cytologic analysis of peritoneal and pleural fluids can be useful diagnostic tools in weight loss cases with nonspecific clinical signs.



Original Article

Transfusion with 2 litres of hyperimmune plasma is superior to transfusion of 1 litre for protecting foals against pneumonia attributed to *Rhodococcus equi*

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Keywords: horse; foal; *Rhodococcus equi*; pneumonia; plasma transfusion; passive immunity

Summary

Background

Transfusion of plasma hyperimmune against *Rhodococcus equi* (REHIP) is used to reduce the incidence of foal pneumonia caused by *R. equi* at endemic farms, but the optimal volume to transfuse is unknown.

Objectives

To determine whether transfusion of 2 L of REHIP to foals was superior to transfusion of 1 L for reducing the incidence of pneumonia attributed to *R. equi* in foals.

Study design

Retrospective cohort design.

Methods

Medical records of 158 foals from two breeding farms in Saratoga Springs, New York, were reviewed. Information collected from mares and foals included the date of birth, volume of REHIP transfused to foals and whether the foal developed pneumonia attributed to *R. equi*. Data were analysed using random effects logistic regression with pneumonia as the outcome variable and farm modelled as a random effect to account for clustering of foals within farm.

Results

There were 77 foals with evidence of clinical ($n = 75$) or subclinical ($n = 2$) pneumonia. The odds of pneumonia were 2.5-fold greater (95% confidence interval [CI], 1.1–5.8; $P = 0.0319$) for foals transfused with 1 L than for foals transfused with 2 L. The odds of pneumonia were 2.7-fold

(95% CI, 1.4–5.5; $P = 0.0046$) greater for foals born in April or May than for foals born before April. Accounting for the effects of birth month, the odds of pneumonia were 2.4-fold (95% CI, 1.1–5.6; $P = 0.0457$) higher for foals transfused with 1 L of REHIP than for foals transfused with 2 L.

Main limitations

The major limitations of this study are the observational study design and that diagnosis of *R. equi* pneumonia was presumptive.

Conclusions

Transfusing foals with 2 L of REHIP is likely superior to transfusing 1 L for reducing the incidence of *R. equi* pneumonia and appeared safe.

Clinical relevance

- Pending results of a well-designed clinical trial, evidence indicates that transfusion of 2 L is superior to 1 L for reducing the incidence of presumed *R. equi* pneumonia at breeding farms in North America
- Transfusion of 2 L to foals appeared to be safe and effective
- Many farms likely under-dose plasma when transfusing foals to prevent *R. equi* pneumonia
- Odds of *R. equi* pneumonia are greater for foals born in later months at some farms in North America



Original Article

Comparison of the efficacy of rifampin/azithromycin and rifampin/tulathromycin for the treatment of foals affected with pneumonia

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Keywords: horse; foal; pneumonia; macrolid antibiotic

Summary

Background

There is a lack of data on treatment protocols of moderate-to-severe pneumonia in foals.

Objectives

The aim of the study was to compare the effectiveness of two antibiotic combinations, rifampin/azithromycin and rifampin/tulathromycin, and to find out which one leads to faster healing of pulmonary abscesses in foals and long-term treatment success.

Study design

The study was designed as a prospective, randomised and blind study.

Methods

A total of 160 foals older than 4 weeks of age with moderate-to-severe pneumonia from a Warmblood stud were included in the study. An abscess score of ≥ 15 cm was chosen as the start of treatment to rule out possible spontaneous healing of foals with ultrasonographic pulmonary findings. Foals with moderate-to-severe pneumonia were randomly assigned to one of two groups and treated with different antibiotic combinations. The foals assigned to group R/T ($n = 87$) were treated with rifampin (10 mg/kg orally once daily) and tulathromycin (2.5 mg/kg dose once weekly intramuscularly/intravenously). The foals in group R/A ($n = 73$) were treated with rifampin and azithromycin (each 10 mg/kg orally once daily). The effect of treatment was evaluated twice weekly based on the findings of the clinical examination and the sonographically determined abscess score. Additionally, the white blood cell count of the foals was determined once weekly.

Results

The recovery rates (group R/T 89.6% and group R/A 91.7%) did not differ significantly between treatment groups. Most foals needed 3 weeks of treatment to recover.

Main limitations

As the pneumonia was diagnosed in an early stage, it is questionable whether the results can be transferred to clinical cases with more severe lesions.

Conclusion

In our study population, both antimicrobial combinations were effective in treating foals with moderate-to-severe bronchopneumonia in 3 weeks of time.

Clinical relevance

- The efficacy of rifampin/azithromycin and rifampin/tulathromycin for the treatment of foals affected with moderate and severe pneumonia was compared. Both antibiotic combinations led to an effective reduction and healing of pulmonary abscesses in foals within the first 2 weeks of treatment. Furthermore, long-term treatment success was good in both treatment protocols.
- It was also shown that the highest percentage of the foals in the study recovered after a treatment period of 3 weeks. Therefore, an initial treatment duration of 3 weeks seems to be adequate to lead to the recovery of moderate and severe bronchopneumonia, however, whether this can be extended to clinical cases found later in the course of pneumonia is uncertain.





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Original Article

What is equine hoarding and can 'motivational interviewing' training be implemented to help enable behavioural change in animal owners?

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Keywords: horse; animal hoarding; equine hoarding; motivational interviewing; behaviour change; training

Summary

Animal hoarding is one of the most complex, costly and difficult to manage animal welfare issues, but it is poorly understood and little researched. In addition to the considerable welfare issues and animal suffering, animal hoarding has a significant impact on the humans involved, as well as their communities and the environment. The hoarding of equines is not uncommon, but it is not specifically recognised or addressed in the published literature. There is also very little information published about any interventions that can be successful with those who are, or are at risk of, animal hoarding. One intervention that has been briefly mentioned is Motivational Interviewing, a well-researched and evidenced intervention used across a range of difficult to change human health behaviours, including substance misuse and other addictions. This paper describes the evaluation of motivational interview training which was delivered after a preliminary exploration of equine welfare officers' experiences of complex multi-horse cases which confirmed that equine hoarding occurs. The training taught motivational interviewing skills and theory to equine welfare officers, in order for them to be able to use this approach during their general duties as well as more specifically in equine hoarding cases. The findings indicate that, for many equine welfare workers these skills can be beneficially applied to their caseload and can have good outcomes in the most difficult of areas, that of equine hoarding.

Introduction

The hoarding of animals leads to the 'starvation, illness and death of animals, neglect of self and others and household destruction' (Patronek and Nathanson 2009), with consequences for communities and agencies. The pathological keeping of companion animals in large numbers was first identified by Worth and Beck (1981) but subsequent investigations have been undertaken by only a handful of researchers, mainly in America. The keeping of a large number of animals is not in itself indicative of hoarding, rather it occurs when there are a number that are not being cared for adequately, in an environment that is not appropriate, with animals whose basic needs are unmet, who are ill and who are not receiving veterinary attention and treatment. Patronek *et al.* (2006) suggest four characteristics of animal hoarding. Firstly, there will be a failure to provide minimal standards of sanitation, space, nutrition and

veterinary care for the animals. Secondly, people hoarding will be unable to recognise the effects of this failure on the welfare of the animals, human members of the household and the environment. Thirdly, there will be obsessive attempts to accumulate or maintain a collection of animals in the face of progressively deteriorating conditions and finally, those hoarding will deny or minimise problems and the living conditions for both humans and animals.

It is also not uncommon for dead animals to be kept, decomposing (Berry *et al.* 2005) and deliberately stored (Patronek and Nathanson 2009), sometimes in freezers (Vaca-Guzman and Arluke 2005). Small companion animals (most often cats and then dogs) are the species most commonly hoarded but other animals can also be found including other small mammals, reptiles, birds, farm animals (Arluke and Frost 2002), wild animals (Steketee *et al.* 2011) and hazardous exotic species (Patronek and HARC 2001).

Three main types of animal hoarding behaviour have been proposed (Patronek *et al.* 2006; Frost and Steketee 2010) but these are recognised as not being definitive (Patronek *et al.* 2006). 1. *Overwhelmed Care Givers* acquire animals passively, often due to a lack of neutering or spaying of the original animals. The owner may be aware of problems, with a gradual decline caused by changes in circumstances, but there is a tendency to minimise the issues and they can have a strong emotional attachment to the animals. The person may be known in their community for taking in unwanted or stray animals and others may bring unwanted animals to them (Patronek and Nathanson 2009). In type 2. *Rescuing* (Patronek *et al.* 2006) or *Mission-driven* hoarding (Frost and Steketee 2010) there is an active acquisition of animals combined with a determination not to euthanise any, often described by those involved as having a 'no kill' policy (Patronek *et al.* 2006). They may depict themselves as running an animal shelter and may have networks of supporters. They can have more social contacts than those in type 1. With type 3. *Exploitive Hoarding* (Patronek *et al.* 2006), there tends to be a lack of any empathy for both animals and humans, although the individual can come across as initially very charming and plausible but this is underpinned by a distinct lack of guilt or remorse. More animals are actively sought and the individual is likely to overrate their own expertise and be controlling in manner.

Prosecution and banning those who hoard from keeping animals appears to have little impact as there is a very high

level of recidivism; often more animals are obtained within days of the originals being removed (Frost *et al.* 2015). For the hoarded animals, there is physical and psychological damage, long term suffering, disease or death. The animal hoarding literature highlights that most animals do not do well after removal from hoarded situations (Patronek and Nathanson 2009) and often the best outcome is euthanasia (Berry *et al.* 2005).

There is an increasing recognition of the need to support behaviour change in those who have responsibility for animals in order to aid their welfare. From the animal hoarding literature (Frost *et al.* 2015), it is clear that legal interventions may be the only resort, but do not appear to work. Therefore, other possible ways of working with owners who are currently hoarding animals, or who may be at risk of sliding into it needed to be explored. However, there are few recognised interventions that work with those undertaking the hoarding.

Motivational Interviewing (MI) has a long, well-researched and evidence-based history (Miller 1983; Project MATCH Research Group 1999; Rubak *et al.* 2005), as being a method of working with people who have some of the most difficult, entrenched human health behaviours, including all types of substance misuse, gambling and other addictions. MI is described as 'a collaborative conversation style for strengthening a person's own motivation and commitment to change' (Miller and Rollnick 2013). A current behaviour may be uncomfortable, bringing risks and difficulties but it can be easier to continue with, as making change which whilst often beneficial, takes time energy and personal resources. This is termed ambivalence and the key to making change is resolving ambivalence (Miller and Rollnick 2013). Through the use of MI, structured and focused conversations about behaviour and change can be had which allow the individual to generate their own reasons for change. It is not easy to learn but, when workers are able to master it and integrate it into their work, it can have significant outcomes and supports people to make self-determined behaviour changes that last (Miller and Rollnick 2013).

Motivational Interviewing (MI) has been used in human health for over 30 years to support behaviour change (Miller and Rollnick 2013) although not specifically with respect to animal owners. However, one researcher (Bard *et al.* 2017) has started to document the use of MI by UK veterinary surgeons, to support behaviour change by cattle farmers to improve the welfare of their farmed animals. Bard *et al.*'s research suggested that veterinarians who used a 'directive style', or told others what they needed to do, were less likely to see required positive behaviour changes with farmers they worked with, whereas veterinarians who could have more empathic conversations with 'tuned and sharp listening' (Bard 2018) had better outcomes.

Finally, within the literature some studies have found multiple species kept within a hoarding environment but, although horses are sometimes mentioned, there is no literature evaluating equines as a specific hoarded species. This prompted the lead author to hypothesise that whilst the hoarding of equines does occur it is not recognised. This may be because the focus has been on small animals, particularly cats and dogs, but also because horses are regarded as herd animals and therefore it is not unexpected to find them in groups.

Therefore, this project aimed to 1) Explore the experiences of equine welfare officers in the UK of cases, involving

multiple equines and to consider these findings against the current understanding of animal hoarding situations as documented in the literature, in order to confirm whether equine hoarding does exist as an entity or not. 2) Evaluate the potential for MI training to help those working the field with difficult welfare cases including those associated with equine hoarding.

Preliminary study one

The preliminary study was qualitative in approach, using Grounded Theory to underpin the methodology. A small project group oversaw the study and was formed of both human health and animal welfare professionals experienced in undertaking such research projects as well as individuals seen as national experts in UK equine welfare.

Participants and data collection

Qualitative interviews were undertaken with six Field Officers (FOs) from World Horse Welfare, by the lead author, in order to explore their experiences of welfare cases in which multiple equines had been involved. These experiences were then evaluated in order to see how these might fit with the literature on animal hoarding. Emerging themes were noted and explored as saturation was achieved. The themes were then further explored in a focus group of seven participants, two of whom had been individual participants in the earlier interviews and five who had not previously been interviewed.

All World Horse Welfare FOs were invited to participate and the subjects that agreed to do so were given written and verbal information about the study before and during the interviews and focus group. Consent was given by each individual and they were aware that they could withdraw this at any time. The interviews were semi structured and digitally recorded. Open questions were used to support participants to explore their experiences of multi-equine welfare cases and direction was only given when descriptions were of cases that did not involve equines. As themes emerged, several open questions were formulated for later participants and the focus group.

Data analysis

All the interviews and focus group recordings were transcribed by the lead author and the transcripts were then interrogated and coded using N-Vivo. The transcripts, codes and themes were then reviewed, by a member of the project group who was a researcher with a background in both human and animal health, to confirm correct deductions had been made from the data available. The initial findings were presented to the participants and their colleagues at their bi-annual training event, by the lead author, for respondent validation to check the accuracy of the themes.

Results

This preliminary work indicated that many of the cases described by the participants did indeed meet both the characteristics for animal hoarding as outlined by Frost and Steketee (2010) and Patronek *et al.* (2006) and demonstrated the presence of the key types of hoarding; Overwhelmed Caregiving, Rescuing or Mission Driven and Exploitative. In addition, several new themes that were more specific to the keeping of large animals, especially horses, were identified.

The first, *Indiscriminate Breeding*, was the deliberate, undiscerning breeding of animals without care. A second, *Naïve Owners/Helpers* fitted across both the *Overwhelmed Caregiving* and *Rescuing/Mission-driven* hoarding types. Another theme that emerged was that equines were often 'contained' in hoarding situations, segregated into small areas within buildings or outdoor areas.

Study 2 training project

Course delegates

World Horse Welfare offered the training to a number of their employees. The training was delivered to two cohorts with a total of 26 people completing the course. In addition to the 13 FOs who attended, others from the charity took up places, including those working with welfare calls, rehoming issues and dealing with the general public. One place was taken up by a RSPCA Equine Specialist Officer. Of those trained, 9 had been participants in Study 1, and their experiences therefore had supported the design and delivery of the course.

Delegate consent

All participants were given written and verbal information about the project, consent was sought from each for their evaluation data and feedback to be used anonymously, and they were aware that they could withdraw their evaluations at any time. Only the lead author had sight of and access to the individual evaluations.

Course design and delivery

Prior to the course, delegates were sent information about the training and asked about the issues they encountered when requiring people to change or amend behaviour, their experiences with possible or actual equine hoarding behaviour, and examples of their current approaches. The information, in addition to the original information gathered in the preliminary study was used to support the final design of the course.

The course was bespoke, delivered over 5 days, adapted from a training blueprint that the lead author had designed and delivered for 15 years for human health and social care professionals. A sixth, follow-up day, brought all the FOs from both cohorts together as well as some of the other workers who had received the training. This day, held several months after the initial course, allowed the FOs to present their use of MI skills to each other, using a structured reflective framework.

Included in the course were active listening skills; essential for the successful use of MI, and the content was adapted to include basic information about mental health and mental illness, belief systems, different thinking patterns, childhood attachment and the effects of childhood trauma. These were included to support the understanding of what may lead people to have problematic issues with, and attachments to, animals, and to be unable to care for them adequately. Information about hoarding behaviour in general and animal hoarding specifically, was added including the findings from the qualitative preliminary work in equine hoarding previously undertaken with some of the FOs. The course also gave information and allowed discussion about personal wellbeing, maintaining mental health, burnout and compassion fatigue in animal welfare workers.

A core feature of the course design was attitudinal change to help delegates understand how difficult any behaviour change is for all humans and to allow them to increase, often already evident, empathy for those they worked with and the difficulties animal owners found themselves in. This was done by inviting those undertaking the training to consider changes that they might make in their own lives and to allow the techniques to be applied to their own behaviours by their colleagues when practicing skills in the training room.

Course evaluation and assessments

A frequently used and well-recognised model, Kirkpatrick's Four Level Evaluation Model (Kirkpatrick 1994), was used to frame the evaluation process. **Table 1** shows the four levels of Kirkpatrick's model, what they measure and how each level was achieved in the MI course reported on here.

At the start of the course, a self-assessment questionnaire was used, looking at knowledge and confidence, where the delegates scored themselves against the main course learning objectives, using a Likert scale ranging from 0 (no knowledge or confidence) to 5 (a good deal of knowledge and very confident).

The delegates' original questionnaires were returned to them at the end of day 5 and they were asked to rescore themselves. The key elements of the questionnaire were extracted and are shown in **Table 2**.

Written and verbal evaluation were sought at the end of each day. The written evaluations asked about satisfaction with the training that day, the pace, content and training delivery and style.

TABLE 1: Kirkpatrick's four level evaluation model

Kirkpatrick's four level evaluation model	What Kirkpatrick's model measures	How this was done for evaluation of this training project
Level 1	The reaction of the student – what they thought and felt about the training	Evaluation sheets from each participant at the end of each day and verbal feedback
Level 2	The learning – the resulting increase in knowledge or capability	Pre and postcourse self-assessment (undertaken at the beginning of day one and at the end of day 5)
Level 3	The behaviour – extent of the required behaviour and the capability improvement and implementation/application	Pre and postcourse questionnaires (undertaken prior to attending day one and after attending day 5). Trainer observations
Level 4	The results – effects on the business or the environment resulting from the trainee's performance	Postcourse questionnaires and other written feedback from those trained Day 6 case presentations Trainer observations

TABLE 2: Results of the delegates self-assessment pre and post the training: numbers of delegates reporting each grade of knowledge for each question asked

Grade Question	No knowledge or confidence Score 1		A little knowledge or confidence Score 2		Some knowledge and some confidence Score 3		Good knowledge and good confidence Score 4		A good deal of knowledge and very confident Score 5	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Understanding how MI can be used in equine welfare work to support owners and others to make changes	12	0	13	0	0	5	0	19	0	1
Able to adapt and incorporated MI skills to own work	18	0	4	0	3	3	0	17	0	3
Can identify the three main types of animal hoarders	8	0	11	0	3	7	2	10	2	7
Skilful in exploring and discussing beliefs	12	0	13	0	6	9	2	14	0	2
Can understand own and others frame of reference and how we and others see the world	8	0	9	0	3	6	3	10	0	3

Finally, a short post-course qualitative evaluation questionnaire was sent out to all delegates asking how they had used the skills and during the course delegates were asked to email with any interesting experiences they had in using the new ideas and skills.

Statistics

A Wilcoxon Sign test was applied (JASP.0.11.1, 2019) to four of the main self-assessment questions to test for the difference between the median confidence scores (1-5) picked by participants before and after training.

Results

Self-assessment

The self-assessments showed a general shift in confidence, knowledge and skills across the elements of the course. Containing both quantitative and qualitative data they showed people were generally satisfied with the training and that it fitted with the skills they already had.

Table 2 shows the results of the delegates' level of knowledge and confidence self-assessment for a few key questions that met the main learning objectives pre and post-training. The least confidence pretraining was shown for Q 2 (Able to adapt and incorporate MI skills into own work), with a median result of 1 (No knowledge or confidence) chosen by 72% of delegates.

Overall the outcomes were positive with all reporting improved skills especially in active listening and an understanding of, and confidence in using MI. All but three of those trained increased their ability to identify different types of animal hoarding; two of these three already had significant knowledge and confidence in this area.

All but three people became more confident and knowledgeable in exploring and discussing an individual's beliefs. Two who made no change already had some knowledge and confidence in this area and felt there was no difference for them. One felt they already had good knowledge and confidence, and that remained the same pre and post-training. The rest of those trained showed significant increases in knowledge and confidence in this area.

Statistically significantly greater confidence was shown after the training for each question asked ($P < 0.001$, Wilcoxon Sign test, $n = 23-25$, JASP 2019), with the median moving from Score 2 (a little knowledge or confidence) to 4 (good knowledge and good confidence) as illustrated in **Fig 1**.

Field Officer reported outcomes

A number of specific examples of how the training helped real-life cases were presented on the sixth, follow-up day and met Kirkpatrick's Level 4 evaluation criteria. These included a *Rescuer/Mission-driven* case of which welfare agencies had been aware of for some time, the use of MI facilitated the owner to relinquish ownership of all but three equines and closed the rescue operation. This was a decision that the owner came to themselves, having been allowed to explore the impact that the situation was having on their family. In another case, a 'stud' or *Indiscriminate Breeding* was being operated where other welfare agencies had not been allowed on the property, the use of MI by an FO enabled the person to accept assistance to help clear the land and part with five equines but the owner then recanted on parting with the equines.

Field Officers in general reported that the use of MI had given insights and increased their understanding of how owners had behaved as welfare issues had first started to develop and how owners had begun to struggle prior to the situation coming to welfare agencies' attention. FOs felt that they were learning about the possible motivations behind individuals' hoarding behaviour. In one case, a 'stud', that would meet the definition of animal hoarding, the FO supported the owner to explore how they arrived in the situation with insufficient resources and facilities to adequately meet the needs of the equines. It turned out that this owner had not been allowed to have a pony when growing up, whilst other children had them. This owner's beliefs were that now as they were an adult, they would make their own decisions and no one could stop them doing what they wanted.

Some of the FOs who could integrate MI successfully and consciously into their practice started to report good outcomes with cases that would meet the definitions of animal hoarding. They described engagement with these



Fig 1: Median scores ($\pm$ s.d.) across all the questions asked pre and post-training.

owners being easier, more consistent and more collaborative with some reports of owners being more willing and able to sign over their equines and reduce numbers. They reported that discussions about euthanasia, when it was the required outcome, could be had with more ease and owners could make difficult decisions earlier than they might have before.

One FO described a welfare case that would meet the criteria for hoarding where a very elderly owner had previously hidden a stallion from another welfare agency.

'I didn't do my normal action of the first question being 'can I see the stallion you have previously hidden away?', instead...listening and waiting so much so in the end I didn't need to ask and they showed me. The stallion hadn't been out the stable for 3 years and had very long feet'

Discussion

This project aimed to initially explore the experiences of those involved in welfare cases involving multiple equines and to consider these findings against the current understanding of animal hoarding situations as documented in the literature. This confirmed that despite the hoarding of equines being little recognised in the literature, it appears to be a significant issue for those working in equine welfare. A number of new more specific types of equine hoarding were identified, which may help to inform future ways of working with certain types of cases.

The possible new types of animal hoarding included *Indiscriminate Breeding*, the deliberate, undiscerning breeding of animals without care would possibly fit with *Breeder Hoarders*, of which there is only one mention in the literature, described by Patronek *et al.* (2006). The second, new type, *Naïve Owners/Helpers* fitted across both the *Overwhelmed Caregiving* and *Rescuing/Mission-driven* hoarding types. Some owners or keepers in the multi-equine cases described appeared to be simply naïve; not understanding the needs of equines and the level of care and resources required for their wellbeing. They are potential

targets for others who want to dispose of their own unwanted, unhealthy or aged animals.

Another theme that emerged from the preliminary study was that equines were often 'contained' in hoarding situations: they, for example, might be housed within stables or in pens created in larger sheds or other buildings, or within segregated areas outside. This type of containment appears to be similar to that often found in small animal hoarding, where animals may be found in crates, often stacked on top of each other. Like small animals that are crated, contained equines often have little or no space to move, living in their own and others' waste products, having poor air quality and lack of daylight, which all has a profound psychological effect.

The findings of this preliminary study were then used to inform the design and delivery of the main training. This training was undertaken to develop equine welfare Field Officers' (FOs) existing skills and personal styles for working with some of the most difficult and hard to reach equine owners, and to support their ongoing work in a wide range of cases, not just those that involved equine hoarding. The Kirkpatrick's evaluation model offered a systematic method (Shelton and Alliger 1993) of training evaluation and was particularly useful for this study as Level 4 seeks outcomes for an organisation, in this case increased knowledge and skills for World Horse Welfare staff in human behaviour change to improve equine welfare with particular relevance to equine hoarding. Animal hoarding is very expensive in terms of time and resources for any agency involved (Castrodale *et al.* 2010) therefore evidence that training transferred in to practice and had outcomes for the organisation would be essential when balanced against the cost of staff receiving training.

Animal hoarding has a huge impact on the animals and humans involved (Patronek and HARC 2001; Reinisch 2008), but the interventions required take considerable resources in terms of time, personnel, multi-agency collaboration (Castrodale *et al.* 2010), assessment, euthanasia or treatment and rehabilitation, and the monitoring of ongoing situations

and, finally, prosecution (Patronek and HARC 2001). Recidivism is almost certain (Reinisch 2008; Frost and Steketee 2010), meaning significant time and resources are invested for the situation to only be recreated, often immediately.

More recent literature suggests that animal hoarding may have similarities with addictive behaviours such as gambling (Patronek and HARC 2001; Reinisch 2008) and as MI has been used to help people with such addictions (Miller and Rollnick 2013) it may have a useful role in interventions for animal hoarding. MI is not easy to learn but, when workers master it and integrate it into their work, it can produce significant outcomes as it supports the making of self-determined lasting behaviour changes. In equine welfare, behaviour change on the part of the owners is pivotal, yet it is one of the most difficult elements of the work.

The training course was designed to increase knowledge about human behaviour change, and to help develop skills, building on the existing experience and professional and technical know-how of the delegates. It involved a full 5 days MI training with additional elements relevant to understanding behaviour change and animal hoarding plus a sixth follow-up day, required a significant amount of time out of the field for each worker and considerable investment from the employing charity. However, Bard noted that 'longer training would be needed for take up of more complex skills' in the use of MI and 'coaching and feedback was necessary for maintenance' as the intervention is a very practical skill. Indeed, Rollnick *et al.* (1999) stated that MI is not a 'magic bullet' and requires 'subtle alterations to a repertoire which needs gradual and ongoing fine tuning'. The training reported here appears to demonstrate Bard's findings and Rollnick *et al.*'s understanding: that investment in longer training can have better outcomes.

Whilst this initial investment in training may be high, it needs to be balanced with the current approaches taken in animal hoarding cases, or animal welfare situations which are at risk of developing into hoarding cases. The usual interventions for animal hoarding do not work and hoarded animals are often psychologically damaged and many require euthanasia (Berry *et al.* 2005) or are not suitable for rehoming. The preliminary study carried out by the lead author with some FOs, which explored their experiences of animal hoarding, showed that banning people from keeping animals often did not work. They typically went on for example to hoard a different species from that which they were banned from keeping, or they ignored the ban altogether, continuing to gather and keep the banned species.

This project was novel, in that it looked at developing skills using an evidence-based human health behaviour change intervention to improve the welfare of animals, and then more specifically for animal hoarding cases or where there was a risk of hoarding developing. When teaching MI in human health and social care it is common for there to be a variance in the level of how the skills are learnt and transferred into individuals' practices (Rollnick *et al.* 1999), and it appeared to be the same for the cohort reported on here. It was evident that the FOs had considerable people skills at the start and that MI added to these. However, those who implemented the new skills quickly and repeatedly after the training had the best outcomes. Some recognised that as soon as they altered their way of working, and their own behaviour, owners changed theirs. One identified that if they had used their previous

approach, the outcomes to their newer cases would have been different and less positive.

A few of those trained had difficulty in synthesising the approach and skills with their usual ways of working. These FOs were more likely to struggle to keep conversations flowing and structured, resorted back to 'telling', or reported outcomes consistent with those they described prior to the training. Other FOs could absorb and integrate to a deep level (Biggs 2003) the skills, tools and, most importantly, the philosophy, or what Miller and Rollnick (2013) call the 'spirit' of the approach. These FOs tended to have good outcomes and noted that they needed to use the skills consciously, making shifts in their attitudes to incorporate the 'spirit' of MI, and they could keep a neutral curiosity leading to increased confidence, allowing conversations to flow. Many described using what Schön (1987) called 'reflection-in-action', where the worker can think and react in the moment, and so, fluidly and subtly adapt moment to moment.

Bard (2018) found that, with brief training, veterinarians could learn MI skills and were shown to have greater empathy with the farmers they were working with and that they were much more able to use active listening. All the FOs trained described spending more time listening, and many said they did less 'telling' and that MI gave a structure to their conversations. This matches Bard *et al.*'s (2017) findings about which veterinarians had more successful conversations with farmers. Many FOs described listening differently and being more able to hear an owner's story, even if the owner's beliefs were very different from their own. One FO said they would never have asked in the past why the situation was like this and what had happened for them to have '100 starving horses' in their field. When they asked these types of questions they discovered a very different quality, as well as quantity, of information, that enabled them to better understand and then work with the individual. Many of the FOs could understand more about the beliefs and cultural issues for an owner and hearing a person's story allowed FOs to identify that owners often just stopped doing tasks or avoided doing them when the situation started to become overwhelming.

Field Officers found that their use of structured listening allowed the owner themselves to identify what the welfare issues were, and to formulate their own plan. One FO said that in the past they would have come up with a plan for the owner, but now they were enabling the person to devise their own strategy, which had better outcomes all-round, especially as a plan devised by the person who needs to make the behaviour change is more likely to work and to be sustained (Miller and Rollnick 2013).

The lead author had thought it likely that the *Overwhelmed Caregiving* type of hoarding was the most likely behaviour for those trained to use MI with, but the results reported by a number of the FOs show that *Rescuer/Mission-driven* hoarding behaviours could also be beneficially worked with, as well as the *Naïve Owners/Helpers*.

The FOs were highly skilled, however, with those people displaying hoarding behaviour, FOs' approaches used prior to the training, were often not enough to enable these people to make meaningful welfare improvements. From the cases presented, many of those trained described better outcomes for all involved, including for World Horse Welfare as an organisation. Those who could embrace MI as a way of working talked about feeling more confident, more positive

and being less exhausted and stressed in their work life. There was generally less emotional impact from the work on the FOs who used the techniques, and cases took less time in the long run. FOs described increased job satisfaction when they could engage with owners and find out more about them. Using MI allowed some FOs to think about, and look for, more positive things that helped them, as well as the owners. This matched what the lead author has observed in human health and social care; that those who routinely and successfully embed MI into their practice are more robust and effective in their work and the work has less personal impact. In animal hoarding cases, long-term involvement is required by agencies and this can be gruelling. Anything that helps to reduce the impact on the worker must be welcomed. The relationship built in one case allowed the owner to become a potential contact to allow the organisation to engage with a hard to reach marginalised group.

There was a recognition that time spent early on getting alongside an owner, understanding their situation and their view of it, was a good investment, as this led to better and more positive outcomes in cases in the long run. In some cases, owners made changes rapidly, which sometimes surprised the FOs involved.

For some of the other staff trained alongside the FOs, the skills were successfully integrated into their work with the public, both in person and over the phone. There were better outcomes with serial welfare callers and sometimes these calls now had less of an impact on the worker dealing with them. It was reported that MI could be used to help give better information and guidance to some of these individuals, as well as to those who had equines on loan from the charity and were required to make some alterations to their management of loaned animals.

An interesting outcome of the training was how owners, with whom the FOs had to become involved due to welfare issues, could sometimes remain positive about World Horse Welfare through the relationships that were built. Some owners proactively remained in contact with the FOs, offering updates and photographs. A key issue with animal hoarding is that owners and others involved tend to become very secretive and avoid contact with agencies. Keeping communication open and owners engaged is a powerful tool in hoarding situations, or where there is a risk of a slide into hoarding.

It is common for a 'quick fix' technique to be sought to change others' behaviours whether that be in human health or animal welfare, but these are rarely, if ever, successful. The case of the 'stud' with *Indiscriminate Breeding* where the owner accepted help and agreed to sign over five equines but then recanted, highlighted that MI is not quick fix but a technique that will likely require regular engagement to support some owners to change over time. It is important that those learning or commissioning training in MI understand it is not a set of tricks, techniques or tools to get the outcomes that we want from others. The philosophy of the approach was demonstrated by a trained FO when they said that animal welfare workers should not use the relationships they build with others to manipulate them. This illustrates the stance that, although using the skills allow workers to find out a lot very quickly about people, they should not be used to manipulate, but rather to help workers operate with transparency. Miller and Rollnick (2013) are clear that MI

should not be used as a manipulative method for making people do what others want or think it would be best for them to do.

Going forward it might be useful for animal welfare agencies to consider who might be best able to learn MI skills and the all-important underpinning philosophy or 'spirit' of the approach, and to integrate it into their practice. This would allow MI training to be directed to those who could potentially make best use of the skills and who would have opportunities to transfer them into practice. Some workers might be better delaying their training until personal and work circumstances are more conducive, in order to give them a better opportunity. Organisations might also give their workers the opportunity to undertake the training rather than those in particular roles being expected to undertake it. On the other hand, there is also the benefit of an agency taking a whole organisation approach and adopting MI as a philosophy rather than a skill available to just some. Ensuring that skills 'stick' and are maintained over time will require organisations to plan how to support those trained to maintain and develop their MI skills, which is well recognised as a requirement (Rollnick *et al.* 1999; Bard 2018).

Conclusion

This training, the first of its kind to attempt to develop skills for equine welfare workers in working with those who are hoarding equines or who are at risk of doing so, has shown some promising outcomes. Many of those trained could integrate the philosophy, knowledge and skills of MI with their already skilful approaches with animal owners, which improved outcomes in general equine welfare issues as well as potential and actual animal hoarding cases.

It is important to recognise that MI is not easy to learn (Miller and Rollnick 2013) but when individuals can use it with fluidity and fluency, merging it with their own skills, approaches and knowledge, it can lead to less stress for the worker and improved outcomes for the animals, the workers, organisations and the owners involved. This was highlighted in this training project.

The consequences of animal hoarding are costly in time, finances and resources for many agencies across not just animal welfare, but also human health, environmental health and other agencies such as police and fire and rescue services. Therefore, investing in robust training that can transfer across into practice for animal welfare workers, to prevent some animal hoarding cases developing, or even with cases that would meet the definition of animal hoarding, could be seen to be a good investment.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Consent was sought and given by all those trained.

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Authorship

B. Williams designed and delivered the training reported, including the evaluation methods, and prepared the manuscript. P. Harris assisted with the design of the training project, its evaluation and helped with the manuscript. C. Gordon supported the training programme, assisted with the evaluation of the training and final approval of the manuscript.

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Zimeta® (dipyrone injection)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

See Product Insert for complete Adverse Reaction information.

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

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

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

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

Refer to the Product Insert for complete Effectiveness information.

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

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

Approved by FDA under NADA # 141-513 NDC 17033 905-10

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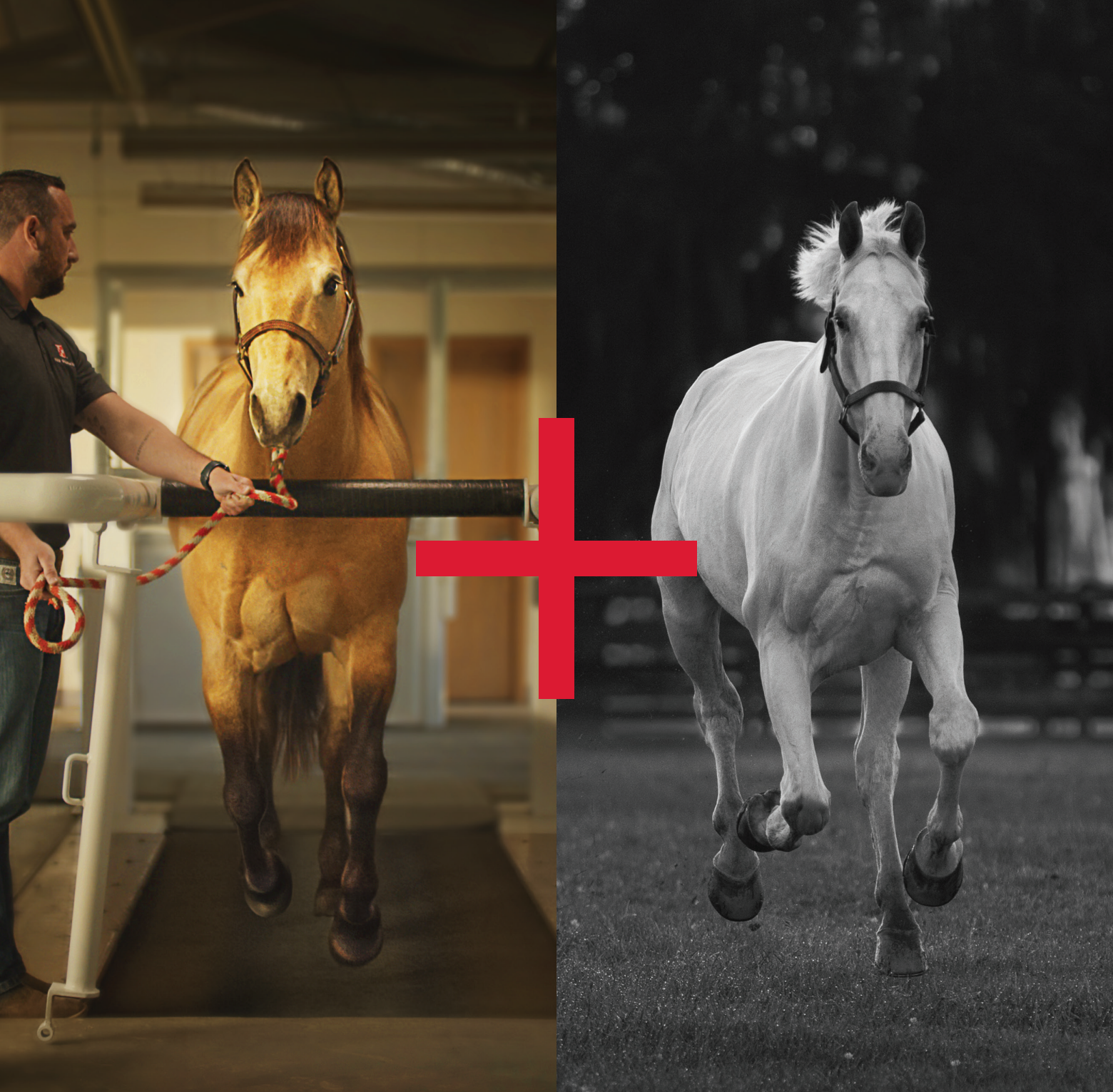
Zimeta® (dipyrone injection) should not be used more frequently than every 12 hours. For use in horses only. Do not use in horses with a hypersensitivity to dipyrone, horses intended for human consumption or any food producing animals, including lactating dairy animals. Not for use in humans, avoid contact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

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

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

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Review Article

Haematogenous septic arthritis, physitis and osteomyelitis in foals: A tutorial review on pathogenesis, diagnosis, treatment and prognosis. Part 2

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Keywords: horse; foal; septic arthritis; osteomyelitis; physitis

Summary

Haematogenous septic arthritis, physitis and osteomyelitis are manifestations of a potentially debilitating or even life-threatening disease entity encountered in all types of foals from neonates to approximately 7 months of age. Correct and complete diagnosis and successful treatment requires collaboration across specialties; medicine, anaesthesia, diagnostic imaging, surgery, and rehabilitation. 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.

Introduction

Haematogenous septic arthritis, physitis and osteomyelitis (SAPO) are manifestations of a potentially debilitating or even life-threatening disease entity encountered in all types of foals from neonates to approximately 7 months of age. Part one of this review provided an overview of the aetiology and presenting complaints as well as all aspects of how to diagnose SAPO in foals (Lindegaard *et al.* 2021). Part two will review all aspects of treatment including surgical options, antimicrobial and analgesic recommendations, rehabilitation, and reports on short- and long-term prognosis for foals affected with SAPO.

Treatment options

As with many other bacterial infections, a successful outcome depends on a combination of antimicrobial treatment and adequate surgical removal of as much infectious and inflammatory material as possible (Vos and Ducharme 2008; Hall *et al.* 2012; Wright *et al.* 2017; Richardson and Stewart 2019). It is therefore crucial to identify the septic nidus based on the type of SAPO described in Part 1, in order to pursue appropriate treatment. Removal of infectious material (bacteria, necrotic tissue, inflammatory cells) will allow the administered antimicrobials to be more effective as many antimicrobials have limited penetration into necrotic tissues and into cells, and some also have reduced action in purulent and acidic environments (Simmen *et al.* 1993; Maurin and Raoult 1994; Debets-Ossenkopp *et al.* 1995; Falagas *et al.* 1997; Barcia-Macay *et al.* 2006; Baudoux

et al. 2007; Ford and Cassat 2017). The removal of infectious material can shorten the time needed to treat with antimicrobials and attenuate the ongoing inflammatory response, which is deleterious to the joint. In addition to reducing the time needed for the foal's own macrophages to debride the infected area, the removal of infectious and inflammatory debris will also reduce the amount of inflammatory mediators and catabolic enzymes in the joint, and therefore speed up recovery and convalescence of the foal. The authors are strong advocates for a more aggressive combination of antimicrobials and surgical removal of infectious and inflammatory foci; however, it must be acknowledged that some foals can survive and resolve the infection with antimicrobial administration alone.

Antimicrobial treatment

Antimicrobial treatment should be guided by the results of culture and sensitivity analysis. Until these results are available, choice of systemic antimicrobial therapy should be based on empirical knowledge. As SAPO can be caused by Gram-positive and Gram-negative bacteria (see Part 1; Lindegaard *et al.* 2021), and there is no reliable way to determine the infectious agent until culture results become available, it is safest to initially choose broad-spectrum antimicrobial coverage.

Furthermore, the antimicrobial choice is dictated by:

Distribution in bone and synovial structures

Most antimicrobials penetrate well into bone and joint tissues, exceeding the minimum inhibitory concentrations (MIC) values of common bone and joint pathogens (Thabit *et al.* 2019). Penicillin and metronidazole, however, have shown a lower than optimum penetration into bones (Thabit *et al.* 2019). Furthermore, the presence of conditions limiting blood flow to the joint, such as ischaemia, may affect the extent of diffusion into the tissues.

Activity of the antimicrobial agent in a septic environment

In vitro sensitivity does not necessarily equal *in vivo* sensitivity. For example, trimethoprim-sulfonamides do not work well in purulent material, and acidic environments markedly decrease MIC values of macrolides and gentamicin (Simmen *et al.* 1993; Maurin and Raoult 1994; Debets-Ossenkopp *et al.* 1995; Falagas *et al.* 1997; Barcia-Macay *et al.* 2006; Baudoux *et al.* 2007).

Route of administration

Several days of intramuscular injections are not ideal, and oral medication might not be possible or reliable in a foal with concurrent gastrointestinal tract infections. Although it is a common belief that oral antimicrobials are inferior to intravenous antimicrobials, literature does not support this for bone and joint infections (Li *et al.* 2019; Thabit *et al.* 2019).

Potential toxicity

In foals, the main toxicity concerns include nephrotoxicity and arthropathy. The fluoroquinolone class has been associated with arthropathy, especially enrofloxacin (Vivrette *et al.* 2001; Giguère *et al.* 2013). However, a recent study has failed to induce arthropathy following enrofloxacin administration in foals (Ellerbrock *et al.* 2020), and anecdotally clinicians have used marbofloxacin without development of musculoskeletal problems. Nephrotoxicity is mainly caused by antimicrobials from the aminoglycoside class, but also oxytetracycline has been reported to cause nephrotoxicity in a foals (Vivrette *et al.* 1993). Moreover, several other antimicrobials have been described to cause nephrotoxicity in humans, such as polymyxin B, sulfonamides, fluoroquinolones and some cephalosporins (Downes *et al.* 2020).

Antimicrobial stewardship

Use of critical antimicrobials should be restricted to cases that demonstrate resistance to noncritical groups based on culture and sensitivity. The European Medicine Agency (EMA) has also released a recommendation for categorisation of antibiotics for use in animals for prudent and responsible use (https://ec.europa.eu/health/sites/health/files/antimicrobial_resistance/docs/2015_prudent_use_guidelines_en.pdf and https://www.eceim.info/sites/default/files/documents/ca_tegorisation-antibiotics-use-animals-prudent-responsible-use_en.pdf). Correct dosage and timing intervals should be respected, and unnecessarily long treatments should be avoided. Several countries have legislation in place concerning antimicrobial stewardship, supporting restrictive use of critical antimicrobials. Please refer to your local guidelines for further information.

Knowledge of the local geographic bacterial isolates

Reviewing previous bacteriology and sensitivity results can assist with the empirical antimicrobial choice until culture results for the specific patient becomes available.

Common systemic antimicrobials include the following: penicillin/gentamicin, penicillin/ampicillin, trimethoprim-sulfonamides and tetracyclines. Cephalosporins are mentioned frequently in the literature on foals with SAPO but as pointed out above, they belong to the critical category. Because of physiological differences between neonates and adult horses, some antimicrobials have different dosing recommendations in foals to ensure adequate plasma levels, for example gentamicin (Table 1).

Local antimicrobial therapy can be added to any systemic antimicrobial treatment. Due to the strong connection between SAPO and systemic sepsis, a local antimicrobial treatment should not be solely relied upon. Local antimicrobial therapy may consist of intra-synovial injections, poly-methyl-methacrylate (PMMA) antibiotic impregnated beads, intravenous regional limb perfusion (IVRLP), or intra-synovial constant rate infusion with a balloon catheter injection system (Hall *et al.* 2012; Richardson and Stewart 2019).

Lavage options

Distinction between S-, E- and P-type infections is important in order to institute adequate treatment as early as possible (Hardy 2006; Richardson and Stewart 2019). In cases of 'S-type only' infections, joint lavage with or without arthroscopic visualisation and debridement is generally sufficient and carries a good prognosis for short- and long-term survival (Wright *et al.* 2017). The most simple form of lavage is 'through-and-through' lavage, which should be performed with the foal sedated or lightly anaesthetised in recumbency (Fig 1). Lavage can be further facilitated by predistending the joint with mepivacaine (post-sampling since mepivacaine has antimicrobial potency Adler *et al.* (2017)). Based on simple flow dynamics, large gauge needles (14-16 gauge) are preferable, and should be placed as far apart as possible to ensure lavage of the entire joint. Ideally, the lavage fluid should flow from dorsal/cranial to palmar/plantar/caudal compartments to ensure flushing of the narrow regions of the joint between the two opposing articular surfaces (Richardson and Stewart 2019). Lavage is often performed with 0.5-2 L of isotonic, physiological crystalloid fluids under aseptic conditions. Flexible extensions can be placed on the needle in order to avoid movement or potential withdrawal of the needle in case of unintended movement of the patient (or veterinarian). At the end of the procedure, it is advisable to evacuate as much fluid as possible and to inject local antibiotics, analgesics and opioids followed by application of a sterile bandage. Needle lavage has the obvious advantage of low cost, but due to the relatively small size of the needles, large conglomerates of pus, fibrin or other debris might not be removed from the joint (Fig 2).

Arthroscopic lavage is considered gold standard (Wright *et al.* 2003; Richardson and Stewart 2019) (Fig 3). Correctly placed portals on different sides of the joint will allow for thorough lavage and manual and/or motorised debridement of infectious and inflammatory debris (Richardson and Stewart 2019). Furthermore, arthroscopic lavage allows for better evaluation of all accessible articular margins, providing information about prognosis and possible identification of additional infectious foci to be debrided. Arthroscopic visualisation will also allow for guided placement of intra-articular catheters for continuous delivery of antimicrobial agents (Lescun *et al.* 2006). In the authors' opinion, extensive motorised debridement of the synovial membrane is not advised, since the trauma created and subsequent bleeding may generate an environment favouring bacterial regrowth.

Other surgical interventions

Osteolysis and destruction of the physis are common sequela if E- and P-type infections are not detected and treated properly, which can often lead to deleterious consequences for the patient. In addition to joint lavage and systemic broad-spectrum antibiotics, E- and P-type infections require a more aggressive approach with debridement of lytic and infected bone and/or cartilage at the specific site of infection (Hall *et al.* 2012). This can be performed with various methods depending on the type and location of the lesion. E-type lesions can be approached either directly from the joint cavity, if there is already lysis of the adjacent cartilage and subchondral bone, or from the physis without going through the articular cartilage (Fig 4). The latter can be

TABLE 1: Antimicrobial drugs for equine foals (Corley and Stephen 2008; Giguère et al. 2013; Orsini 2014)

Drug	Dose	Frequency	Route	Spectrum	Penetration in bone and synovia	Side effects	WHO classification*	EMA classification on veterinary use†
Amikacin sulfate	<1-week-old: 25-30 mg/kg 2-4 weeks old: 20-25 mg/kg	q. 24 h	IV or IM	Gram-negatives, incl gentamicin resistant bacteria and <i>Pseudomonas aeruginosa</i> .	Yes	Nephrotoxic	2	C
Ampicillin sodium	50-100 mg/kg	q. 6-8 h	IV or IM	<i>Staphylococcus</i> Gram-positive and Gram-negative spectrum	Yes	Rare (anaphylaxis, haemolytic anaemia)	2	D
Azithromycin	10 mg/kg	q. 24 h for 5 days, then q. 48 h	PO	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, good intracellular penetration	Diarrhoea in foal and mare	1b	C
Ceftiofur	5 mg/kg 10 mg/kg CRI: 1.5 mg/kg/h	q. 12 h q. 6 h	IV or IM	Gram-positive and Gram-negative spectrum, some anaerobes Higher doses: broader Gram-negative spectrum	Yes, but poor penetration in necrotic tissue	Rare (anaphylaxis, haemolytic anaemia)	1b	B
Cefquinome	1-4 mg/kg	q. 6-12 h	IV or IM	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, but poor penetration in necrotic tissue	Rare (anaphylaxis, haemolytic anaemia)	1b	B
Chloramphenicol	50 mg/kg	<5 days old: q. 12 h >5 days old: q. 6h	PO	Gram-positive and Gram-negative spectrum, some anaerobes	Yes	Public health concerns around idiosyncratic nonregenerative anaemia	3	C
Clarithromycin	7.5 mg/kg	q. 12 h	PO (absorption considerably reduced by concurrent rifampin)	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, good intracellular penetration	Diarrhoea in foal and mare	1b	C
Doxycycline	10 mg/kg	q. 12 h	PO	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, good intracellular penetration	Nephrotoxic, chronic bone toxicity	3	D
Enrofloxacin	5 mg/kg 7.5 mg/kg	q. 24 h	IV PO	Gram-positive and Gram-negative spectrum	Yes	Chondropathy and arthropathy	1b	B

TABLE 1: Continued

Drug	Dose	Frequency	Route	Spectrum	Penetration in bone and synovia	Side effects	WHO classification*	EMA classification on veterinary use†
Erythromycin stearate	25 mg/kg	q. 6-8 h	PO	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, good intracellular penetration, but acid environments decrease MIC values	Diarrhoea in foal and mare; hyperthermia	1b	C
Gentamicin	<14 days old: 12 mg/kg >14 days old: 6.6 mg/kg	q. 24-36 h q. 24 h	IV	Gram-negative spectrum, some Gram-positives	Yes, but acid environments decrease MIC values	Nephrotoxicity	2	C
Metronidazole	10-25 mg/kg 35 mg/kg	q. 8-12 h	PO or IV Per rectum	Anaerobes	Suboptimal	Inappetence, neurological signs	4	D
Oxytetracycline	5-10 mg/kg	q. 12 h	IV administer slowly	Gram-positive and Gram-negative spectrum, some anaerobes	Yes, good intracellular penetration	Nephrotoxic, chronic bone toxicity	3	D
Na or K penicillin	20,000-50,000 IU/kg	q. 6 h	IV	Gram-positive spectrum, most anaerobes	Suboptimal, also poor penetration in necrotic tissue	Immune mediated haemolysis, anaphylaxis	3	D
Procaine penicillin	20,000-50,000 IU/kg	q. 6 h	IM	Gram-positive spectrum, most anaerobes	Suboptimal, also poor penetration in necrotic tissue	Pain at injection site, neurological signs when administered in blood; rare side effects include anaphylaxis and haemolytic anaemia	3	D
Rifampin	5 mg/kg	q. 12 h	PO	Gram-positive and Gram-negative spectrum, anaerobes. Many Gram-negatives have resistance	Yes	Red orange coloration of saliva, tears and urine, hepatitis (rare)	2	A
Trimethoprim-sulfonamide	30 mg/kg (dose/kg is combined trimethoprim and sulfonamide)	q. 12 h	PO, IV (slow and not with alpha2 agonists)	Gram-positive and Gram-negative spectrum, some anaerobes	Yes but does not work well in necrotic and purulent material	Nephro- and hepatotoxicity (rare)	3	D

With decreasing importance, the following categories of antimicrobials for use in humans are recognised by WHO: (1) Critically Important and Highest Priority. The 2 sub categories should be called 1a and 1b (a) reserved for human use only (b) only when culture and sensitivity testing demonstrate necessary use of these drugs in animals (orange); (2) Critically Important and High Priority; (3) Highly Important; (4) Important; (5) Currently not used in humans. *

The following categories are recognised by the EMA: (colours as chosen by EMA) A: Avoid – not authorised in the EU (Dark orange / red). B: Restrict – use should be considered only if there are no antimicrobials in category C and D and should be based on antimicrobial susceptibility testing (Orange). C: Caution – use should be considered only if there are no antimicrobials in category D (Yellow). D: Prudence – use as first line, but only when medically needed (Grey). †

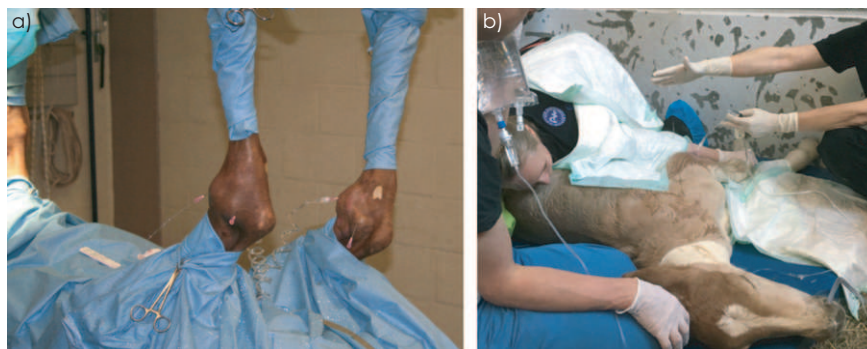


Fig 1: Through-and-through lavage can be performed in various ways. Either under full general anaesthesia in a surgical theatre (a) or in a less advanced setting in the stable with the foal in a short-term heavy sedation/ general anaesthesia (b – Image courtesy of Professor Stine Jacobsen, University of Copenhagen). Regardless of the method, focus on asepsis is of utmost importance. In the authors' opinion, all procedures should be initiated with local intra-articular analgesia (mepivacaine) and terminated with injection of antimicrobials in combination with morphine.

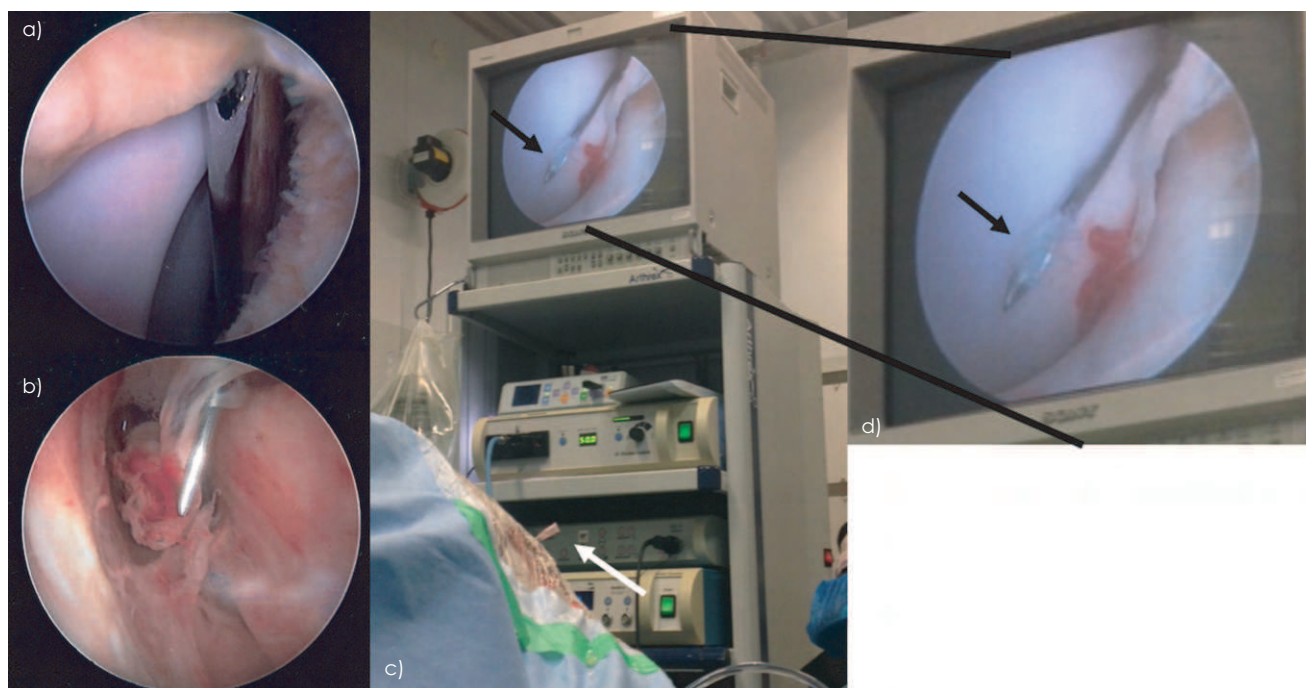


Fig 2: Arthroscopic lavage aims at removing bacteria, inflammatory mediators and as much debris (b) as possible. This can be performed either with forceps or a motorised synovial resector ('shaver') (a). c) shows a set up from an arthroscopic lavage of an infected joint with a hypodermic needle placed in the joint. There is no flow from the needle (white arrow) since it has been clogged with a very small piece of debris (black arrow, enlarged in (d)).

facilitated by use of preoperative radiography or, preferably, CT and intraoperative ultrasonography (Wright *et al.* 2018). Due to the potential damage to the articular cartilage, the necessity of, and approach to, debridement should be evaluated carefully. With P-type lesions, the affected region can be identified preoperatively with radiography or CT and further localised with intraoperative ultrasonography. When the specific affected region is identified, needles are placed in the physis, a stab incision is made through the skin, and the soft infectious and necrotic material is carefully debrided using small size curettes (Hall *et al.* 2012). It is important to realise that the physis of a foal is relatively soft, and debridement should only include the infected, inflamed and

necrotic tissue which is softer and more grey than normal physeal tissue (Hall *et al.* 2012). After debridement, the curetted area is flushed, the skin is closed for primary healing with a monofilament nonabsorbable suture material in a simple interrupted pattern, and a sterile bandage is applied. The authors prefer placement of dialkylcarbamoyl chloride-coated dressings (DACC dressings/Sorbact®) as a primary layer followed by an absorbent secondary layer. DACC dressings form a bacterial binding barrier between the surgical portal and the bandage, decreasing the likelihood of recontamination and have shown to be particularly useful in the prevention of surgical site infections in humans (Chadwick and Ousey, 2019). Placement of antimicrobial beads or a

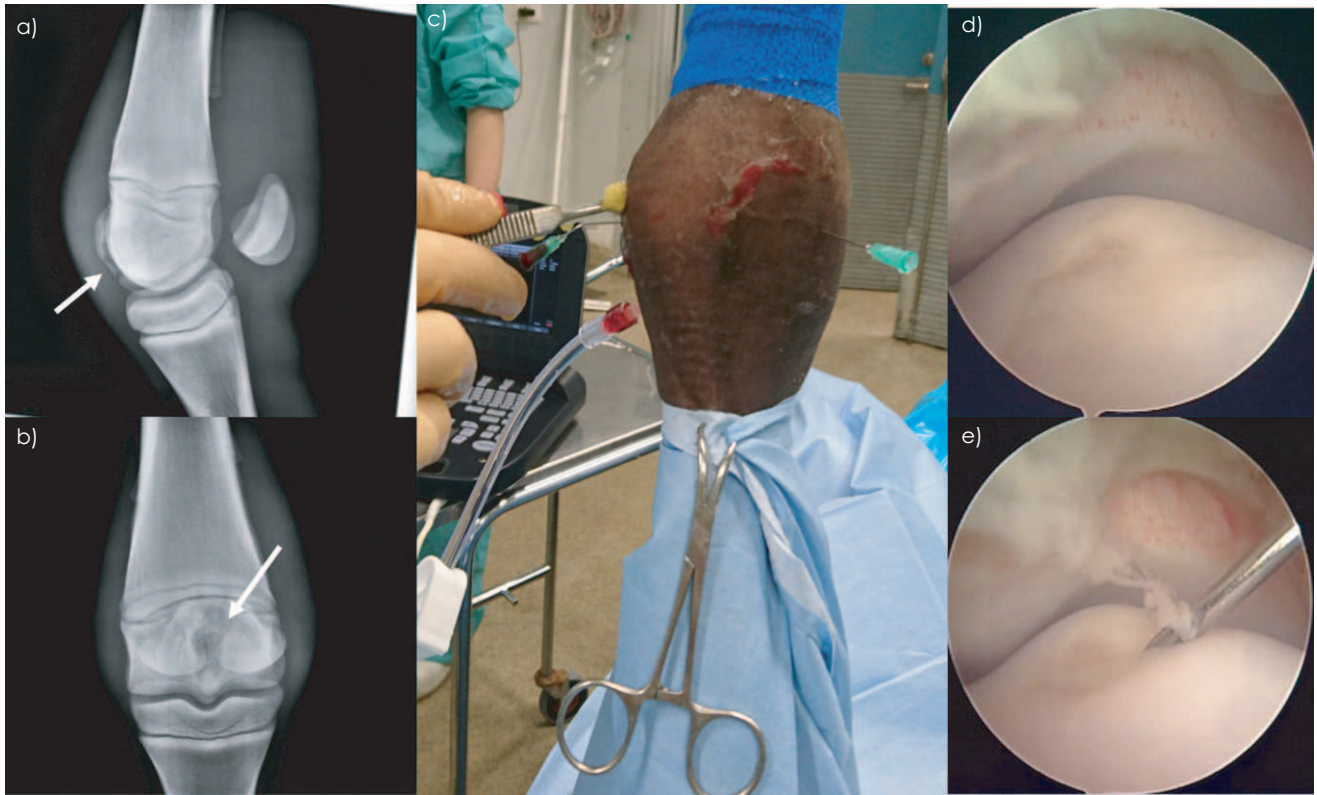


Fig 3: Three-month-old foal with severe E-type septic arthritis of a metacarpophalangeal joint originating from the central distal MC3 epiphysis. Extensive loss of bone seen in both lateral and dorsal radiographs (a and b, white arrows point at defect). The joint is filled with pus exiting the joint at first incision (c). On arthroscopy, the defect of the central epiphysis has created an obvious cartilage covered defect of the dorsal sagittal ridge of MC3 (d). The subchondral bone is necrotic and has been phagocytosed to an extent that the overlying cartilage voids to the pressure from a hypodermic needle (e).

small subcutaneous catheter to allow for repeated antimicrobial injections can be considered (Richardson and Stewart 2019).

Concurrent analgesic and anti-inflammatory treatment

Foals with SAPO show various degrees of lameness, stiffness and depression due to pain, fever and inflammation. In the authors' opinion, all foals with SAPO should receive systemic treatment with nonsteroidal anti-inflammatory drugs (NSAIDs) to provide pain relief and suppress the systemic and local inflammatory state and its potentially deleterious and catabolic effects. Admittedly, successful treatment of the infection should lead to reduced pain, lameness and fever; however, until this effect is fully accomplished, administration of NSAIDs ensures that the foal is comfortable, allowing ambulation and nursing, thus avoiding a negative energy balance and a catabolic state. In very young foals of 0-1 days old, maintaining normal nursing activity is also a primordial need to support passive transfer of immunity, which is critical to fight bacterial infections. Considering the higher risk of side effects of NSAIDs (such as nephro- and gastrointestinal toxicity) in compromised neonates (Cook and Blikslager, 2015), NSAID treatment dose and duration should be judicious and renal function should be monitored carefully with prolonged treatment. Furthermore, COX-selective drugs,

such as meloxicam, should be used. Healthy foals tolerate meloxicam well, and in contrast to findings for other NSAIDs, foals appeared more resilient to the renal and gastrointestinal adverse effects of this drug at repeated dosing and high dosages than observed in adult horses (Raidal *et al.* 2013). It is the authors' opinion that phenylbutazone should not be used in foals due to the increased risk of side effects (Traub *et al.* 1983; Geor *et al.* 1989; Mozaffari *et al.* 2010).

For optimal local analgesia and anti-inflammatory effect, morphine can be administered intra-articularly together with local antimicrobials at the end of any joint lavage or sampling (Lindegård *et al.* 2010; Lindegård *et al.* 2021). Local analgesics can also be administered at the end of an arthroscopic procedure. Mepivacaine is the drug of choice, since lidocaine and bupivacaine are more likely to cause articular cartilage damage (Adler *et al.* 2020). It is worth noting that local analgesics also have some antimicrobial effects (Adler *et al.* 2017). No studies have evaluated potential negative effects of combining gentamicin or amikacin with morphine and mepivacaine. In human medicine, it is common practice to use corticosteroid treatment for septic arthritis. Although defined as low quality evidence since only derived from limited trials and case numbers, a recent Cochrane review on steroid use for children with septic arthritis showed some benefit of intravenous use of dexamethasone for 4 days as adjunctive therapy (Delgado-Noguera *et al.* 2018). The conclusion of that Cochrane review was that 'corticosteroids

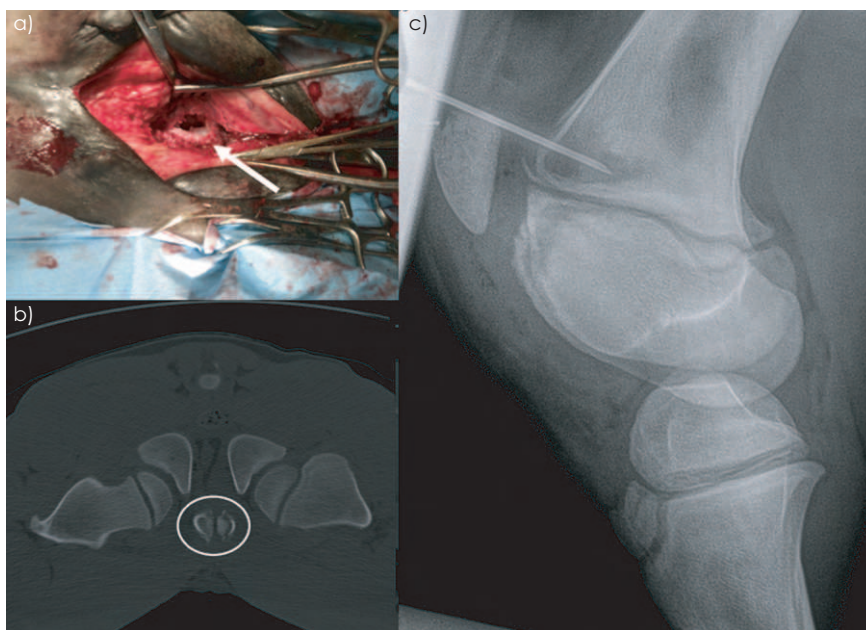


Fig 4: E- and P-type SAPO can potentially benefit from surgical debridement of bacteria and inflammatory debris. **a)** The infected pelvic symphysis (white arrow) of a 14-day-old foal could be approached specifically through a ventral midline approach to perform surgical debridement of the infected area due to planning from computed tomography (CT). **b)** Transverse computed tomography image of the foal in image (a). Dorsal is up and the infected pelvic symphysis (irregular edges) is surrounded by a white oval. Just adjacent to the infected symphysis is the paired coxo-femoral joints. X-ray or ultrasonography might also be helpful for identifying the area to be debrided. Image **c)** shows a needle placed inside a large osteolytic defect in a distal femoral type P defect (not same foal as a and b). The needle will then guide the incision needed to introduce a curette to debride the defect.

may increase the proportion of patients without pain and the proportion of patients with normal function of the affected joint at 12 months, and may also reduce the number of days of antibiotic treatment'. Currently, no data are available on this use in foals with SAPO.

Additional treatment

In addition to antimicrobial and analgesic treatments, foals with SAPO require monitoring for nutritional and immune status. Failure of passive transfer is common in foals with SAPO (Steel *et al.* 1999), and reduced milk intake, inadequate levels of immunoglobulins or increased usage of immunoglobulins due to infection can place them at risk for developing additional or more severe disease and delay recovery. Measuring IgG concentrations is therefore warranted.

Increased recumbency can easily cause decubital ulcers, and increased recumbency times and reduced ambulation or reduced use of a single limb can lead to muscle atrophy, or laxity or contraction in tendons. This may ultimately compromise musculoskeletal function and development. Thick and clean bedding and close monitoring of the skin is therefore warranted. Yet, too thick bedding, especially with straw, can unwillingly complicate and restrict the foals' movements in the stall (Hardy and Latimer 2003; Wilkins and Santschi 2004).

If the foal is systemically compromised, it requires additional supportive care and treatments, but these are beyond the scope of this paper. It is worth noting that systemic compromise can increase the risks of complications and death during general anaesthesia for surgical lavage

options and treatment may need to be delayed until the foal is stable (cardiovascular and respiratory). Therefore, a modified treatment plan may be necessary including less ideal treatment plans in the initial phase (e.g. initial needle lavage under short sedation, or only antimicrobial treatment without lavage), followed at a later stage by more thorough arthroscopic treatments.

Evaluation of treatment progress

Careful and close clinical assessment (vital parameters, lameness, swelling) remains key to evaluation of the treatment progress. But since clinical assessment is not always clear, and in order to avoid waiting too long to change or stop treatment, or risk discontinuing treatment too early, additional tools are warranted to assess evolution in many cases.

Although the infection may have subsided, residual lameness can still be present due to unhealed damage to joint surfaces, physis and/or other soft tissue trauma instituted by the disease itself or as sequelae to the treatments (personal experience). However, the contrary is also valid, and even with unresolved infection, overt lameness may still be absent. Also, in the authors' experience, some foals that have experienced pain in the affected limb will avoid proper use for some time after resolution until they unlearn this behaviour.

Use of serial synovial fluid (SF) analysis has been suggested to evaluate local response to treatment. Synovial total protein and neutrophil percentage may not be good indicators for detecting eradication of bacterial infection as they remained elevated on average 10 days after

eradication of infection caused by *E. coli* from infected and subsequently treated joints in adult horses (Koziy *et al.* 2019). Synovial SAA concentrations have shown promise in monitoring response to lavage in adult horses (Sanchez-Teran *et al.* 2016). Synoviocentesis itself, however, increases the risk of recontamination of the joint, and careful consideration should be taken to avoid iatrogenic sepsis in treated cases.

On a systemic level, accurate follow-up of WBC count, fibrinogen and SAA concentrations in blood in comparison with earlier concentrations can be used to monitor resolution of infectious and inflammatory processes. There is currently no literature in foals with SAPO, but serial measurements of plasma SAA were found to be a valid tool for monitoring treatment response in otherwise healthy horses presented with injuries penetrating synovial structures (Haltmayer *et al.* 2017), thus avoiding the risk associated with serial synoviocentesis. Even though scientific data are lacking on SAA in foals with SAPO, it is the authors' clinical experience and impression that serial evaluation of blood SAA concentrations are helpful in monitoring treatment progress and disease development, including spread of infectious foci to other parts of the body in SAPO foals.

Follow-up imaging is typically not indicated in foals that are improving clinically. However, repeat radiographs or CT are certainly indicated in patients that suffer from persistent clinical signs (lameness, joint effusion or fever) and a continued elevated SAA concentrations despite treatment. Repeat imaging may help to identify progression of previously identified lesions or identify new lesions (e.g. development of osteomyelitis in foals previously diagnosed with septic arthritis; an E- or P-type lesion could have been mistaken for an S-type lesion). Interpretation of follow-up images should be correlated with any surgical debridement that has been performed, keeping in mind that regions of surgical debridement should have well-defined, smoothly marginated borders and that regions of poorly defined lysis are indicative of new or ongoing infection (Hall *et al.* 2012; Lindegaard 2018).

Rehabilitation

The aims of a rehabilitation plan for SAPO foals are to avoid laxity and contracture of the affected and other limbs, ensure compression/expansion of articular cartilage, maintain overall mobility and prepare the foal for normal exercise when its general condition improves and pasture turnout becomes possible. It is well established that exercise is essential for correct development of the musculoskeletal system in foals (Dowling and Dart, 2005; Kurvers *et al.* 2006; Rogers *et al.* 2012), and the rehabilitation plan should mobilise the foal as much as possible within the limits of the overall treatment plan.

First, it is important to identify what the rehabilitation programme should accomplish and discuss likely prognostic outcomes with the owners. Second, the rehabilitation plan must prevent further injury and support a successful short-term outcome, while also limiting long-term consequences to the athletic future of the foal. Little attention has been placed on rehabilitation protocols in the reported cases, so there may be an unexplored opportunity to further improve the outcome in these foals.

Very limited data are available on rehabilitation in foals with orthopaedic conditions other than angular limb deformities, where physiotherapy is an integrated part of

treatment (Levine 2015; Caldwell 2017; Gaughan 2017). Typically, the rehabilitation follows a modified protocol from mature horses, mostly stall rest followed by access to a small paddock before normal turnout. A few reports include physiotherapy, but none for septic arthritis (Mykkänen *et al.* 2011; Ebben 2013; Levine 2015; Tatarniuk *et al.* 2019). Human literature on rehabilitation after septic arthritis is also sparse, but the consensus focuses on the importance of preserving joint mobility and cartilage health (Donatto 1998).

Rehabilitation starts when the diagnosis is made and should be adjusted to the individual patient throughout the entire recuperative period (Donatto 1998; Konin and Jesse 2012). The rehabilitation protocol should include a combination of passive and active range-of-motion exercises, stretching, massage, weightbearing exercises and proprioceptive stimulation (L.C. Berg, personal communication – 'Experiences with rehabilitation of foals'). Additional adjunctive therapies can be added, including cryotherapy, hydrotherapy and neuromuscular stimulation (Konin and Jesse 2012).

Passive range of motion (PROM), stretching exercises and massage therapy can be used if the foal is nonweightbearing, as long as they can be done safely without risking infection in lavage portals or other complications (Mykkänen *et al.* 2011; Ebben 2013; L.C. Berg – personal communication). Joint mobilisation will help to maintain joint range of motion by stretching collagen fibres and fascia networks surrounding the joint, and improve cartilage health through the cyclic loading and unloading that leads to compression and expansion of the cartilage and thus ensures distribution of nutrients to the chondrocytes (Jones *et al.* 2003; Konin and Jesse 2012; Liao *et al.* 2016). Stretching and massage can improve tissue elasticity, circulation, and alleviate muscle soreness and tension (Konin and Jesse 2012). Stretching exercises have also been shown to reduce pain (Corey *et al.* 2012). PROM exercises include gentle movement of the joint(s) within the range of normal movement. If the foal has to undergo multiple lavages over several days, PROM exercises while the foal is anaesthetised may be considered if possible. This technique has been described in a human patient who returned to full athletic ability (Naylor *et al.* 2013).

As the foal becomes weightbearing and more mobile, assisted active ROM (AAROM), active ROM (AROM), proprioceptive and strengthening exercises should be added to the protocol, so that correct movement, balance and strength are regained by active muscles, tendons, ligaments and fascia (Table 2).

The foal should be returned to normal pasture turnout as soon as possible based on an individual assessment of the temperament of the mare and foal, the progress of the condition and rehabilitation, and the home facilities. As discussed by Lescun (2018), foals change their exercise behaviour significantly when confined, and pasture turnout may ensure a more continuous low-impact strain on their musculoskeletal system, as opposed to the less controllable bursts of high impact strain sometimes seen when foals are confined in a stall or only turned out for shorter periods of time (Valk and Schumacher 2020). However, if long periods of confinement have been necessary, unrestricted pasture turnout should be introduced carefully, as catastrophic fractures of the sesamoid bones have been described in recovered foals or foals that run to exhaustion trying to keep

TABLE 2: Rehabilitation of foals recovering from septic arthritis (Mykkänen *et al.* 2011; Ebben 2013; Levine 2015; Berg 2020)

When	What	How
Early	• Passive range of motion (PROM) • Stretching • Massage • Proprioceptive stimulation	• Gentle movement (flexion/extension) of affected joints as well as nonaffected joints within normal range of motion without causing discomfort for the foal or disrupting wounds/portals • Gentle massage of entire body to release tension in muscles and fascia and maintain overall mobility • Cyclic compression of articular surfaces to maintain nutrient supply
Later	• Assisted active range of motion (AAROM) • Active range of motion (AROM) • Weightbearing exercises • Strengthening exercises • Proprioceptive stimulation	• When the foal can stand, start assisted weightbearing and assisted or free active movement • Slowly, gently rock the foal side-to-side and forward-backward to engage stabiliser muscles, train balance, and stimulate proprioceptors • Gentle assisted stretching exercises within normal range of motion • Controlled exercise together with mare on different, nonslippery surfaces • Paddock turnout with mare as soon as deemed safe and if facilities allow to avoid sudden bursts of high energy movement, but rather encourage continuous low-impact movement

up with the dam (Reesink 2017). If facilities permit, a stable with open access to a small paddock with level footing will provide the mare and foal with access to low-impact exercise during the earlier phases of treatment, and thereby may reduce the risk of returning the foal to pasture.

Prognosis

Survival

Studies have reported short-term survival of foals with SAPO between 42 and 84%. Of those foals, long-term survival has been reported to be up to 92%, and euthanasia after discharge was often unrelated to the SAPO diagnosis (Steel *et al.* 1999; Vos and Ducharme 2008; Neil *et al.* 2010; Wright *et al.* 2017).

Early initiation of treatment in foals with SAPO is positively correlated with survival (Vos and Ducharme 2008). In Vos and Ducharme's study, 93% of foals that were treated at the hospital within 24 h of recognition of clinical signs survived, while only 66% of foals whose treatment was delayed survived. After 24 h, the time to initiation of treatment after onset of clinical signs was not significantly different between survivors and nonsurvivors, suggesting that the first 24 h after onset of clinical signs is the critical time frame. In human medicine, studies have shown that in the absence of clinical sepsis immediate joint drainage does not appear to reduce the risk of sequelae compared with delaying drainage 24 h post-admission (Lauper *et al.* 2018). Since the actual onset of infection might not be certain in foals, it is the authors' opinion that treatment should be initiated as early as possible in order to avoid potentially debilitating sequelae.

Several other prognostic factors for lower survival in foals with SAPO have been identified including <30 days of age at time of diagnosis (Neil *et al.* 2010), critically ill foals (Steel *et al.* 1999; Neil *et al.* 2010) and involvement of multiple bones or joints (Steel *et al.* 1999; Vos and Ducharme, 2008; Neil *et al.* 2010; Hepworth-Warren *et al.* 2015). Degenerated neutrophils (Vos and Ducharme, 2008) or high SF neutrophil count (Steel *et al.* 1999) were also negatively associated with short-term survival, while fibrinogen concentration was positively associated with survival in septic arthritis with a 25%

increase of probability of survival to discharge for every 1 g/L increase in plasma fibrinogen concentration (Hepworth-Warren *et al.* 2015).

Detection of intra-articular Gram-negative bacteria (Vos and Ducharme, 2008), mixed bacterial infection (Vos and Ducharme 2008), or culture of *Salmonella* from SF (Steel *et al.* 1999) are also negative prognostic factors. Sick foals with positive blood cultures (not specifically SAPO foals) have a better outcome when they are started with an empirical antimicrobial therapy that the isolates are sensitive to (Theelen *et al.* 2019, 2020), highlighting the importance in knowing typical infection patterns in the local patient population. Moreover, adult horses with a positive bacterial culture from a septic synovitis have a poorer prognosis for survival to discharge from hospital and overall long-term return to function than horses that yielded no bacterial growth (Taylor *et al.* 2010). It is unknown whether this is translatable to foals.

Athletic function

Depending on type and location, SAPO may lead to destruction of articular cartilage, thickening of the joint capsule, reduced range of motion, and may eventually lead to osteoarthritis, which will decrease the foal's chance of a future athletic career.

In P-type cases, damage to the physis may lead to uneven growth (varus or valgus deformities, impingement of the spinal cord, etc.) (Glass and Watts 2017). T-type infections may lead to deformation of the cuboidal bones of the carpus or tarsus. These changes might lead to altered limb conformations which might not be compatible with future athletic performance.

Overall, prognostic outcome for full athletic function following septic arthritis in foals has previously been described as guarded (Steel *et al.* 1999; Smith *et al.* 2004; Sanchez *et al.* 2008; Neil *et al.* 2010). However, a recent study evaluating athletic performance in horses treated for SAPO as foals reported an overall prognosis for entering athletic work to be 62%, comparable to results seen in adult horses treated for septic arthritis (Wright *et al.* 2017). The presence of multiple septic joints, but not multiple bone involvement, had an

TABLE 3: Overview of outcomes reported for foals with SAPO, published in the last 10 years

Authors	Year of publication	n	Number of foals survived to discharge (%)	Follow-up
Rinnovati <i>et al.</i>	2018	16	11 (69%)	11 clinically normal at 6 months
Hall <i>et al.</i>	2017	17	15 (88%)	15 clinically normal at 9 months
Wright <i>et al.</i>	2017	60	48 (80%)	40 (67%) survived long term Overall prognosis for athletic soundness 37/60 (62%) Not mentioned
Hepworth-Warren <i>et al.</i>	2015	83	47 (57%)	
Kay <i>et al.</i>	2012	8	6 (75%)	6 long-term survival and clinically normal (15-month to 4-year follow-up)
Neil <i>et al.</i>	2010	108	87 (80%)	52 or 48% had a documented racing career

unfavourable prognosis for racing (Neil *et al.* 2010) (**Table 3**). In a sport horse population, only 28% of treated foals eventually performed as intended as adults. Those with synovial cell counts at admission exceeding 60,000 WBC/mm³ were significantly less likely to eventually perform (Haspeslagh *et al.* 2020).

Discussion and conclusion

All types of SAPO are severe and with potential grave consequences to the foal. Part 1 of this review summarised all aspects of clinical signs and diagnostic decision making, emphasising the relevance of reaching a specific diagnosis as soon as possible in order to initiate an aggressive treatment and rehabilitation plan as early as possible. This includes early and prudent use of broad-spectrum antimicrobials, administered systemically, regionally and locally, and when possible combined with thorough mechanical reduction of bacteria and inflammatory debris through joint lavage and surgical debridement of adjacent infected skeletal structures as indicated. Treatment progress should be monitored by clinical evaluation combined with a focus on inflammatory parameters in blood and synovial fluid. Supportive analgesic therapy and physiotherapy will help the foal maintain normal ambulating activity and potentially improve the chances for a future athletic career. Overall prognosis for survival and future athletic performance is good; however, it declines when more joint structures (cartilage, subchondral bone and or collateral ligaments) or other organs are affected.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Authorship

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

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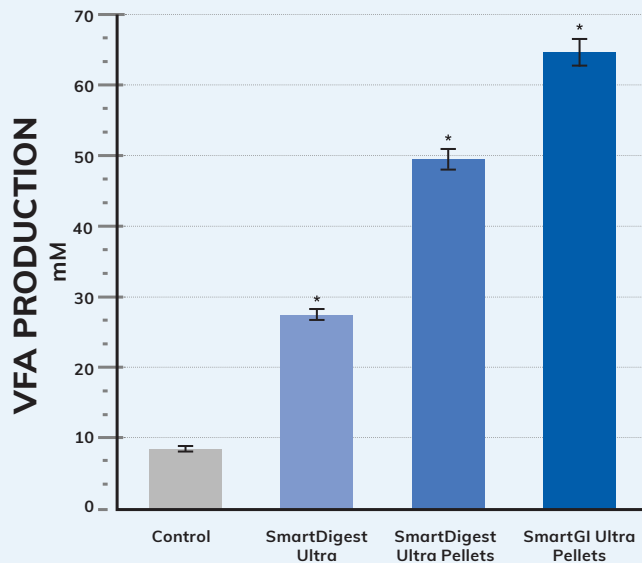
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Review Article

Systemic antimicrobial therapy in foals

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Summary

Antimicrobial agents are commonly used in neonatal foals for the treatment or prevention of sepsis. However, due to concerns about the development of antimicrobial resistance and increasing pressure on veterinarians to rationalise antimicrobial use, we should be trying to reduce the unnecessary use of antimicrobials. This article reviews many of the important considerations when selecting an antimicrobial for use in neonatal foals. Firstly, we consider general differences in neonatal pharmacology and physiology. Secondly, we review common antimicrobial drugs and their indications. Finally, we review antimicrobial stewardship.

Part 1: General considerations for antimicrobial selection in foals

There are several important differences between foals and adult horses which must be considered when selecting antimicrobial drugs for use in foals. Neonatal foals have a proportionally greater body water content than adult horses. In the first week of life, foals have a body water content of 71–83% compared to 60–70% in adult horses (Andrews *et al.* 1997; Fielding *et al.* 2011). Fluid dynamics differ further between mature horses and foals as a result of foals having a relatively smaller intracellular fluid compartment and larger extracellular fluid compartment as well as higher blood and plasma volumes (Carlson *et al.* 1979; Fielding *et al.* 2003; Fielding *et al.* 2011). This greater body water content means higher dosages of hydrophilic drugs such as aminoglycosides are necessary in foals whereas the dosages of lipophilic drugs are less affected (Corley and Hollis, 2009).

Drug metabolism also alters as organ function matures. The rate of hepatic metabolism and renal excretion generally increases with age. This means that protocols that are extrapolated from adult dosing may not always be appropriate, especially for young foals. For example, standard oral dosing of trimediazine sulphadiazine at 24 mg/kg achieved higher plasma levels in 1- to 10-day-old foals than would be achieved in adult horses (Swain O'Fallon *et al.* 2020). The rate of elimination of intravenous chloramphenicol has been shown to increase in foals over the first 6 weeks of life, with more prolonged elimination times in premature foals (Adamson *et al.* 1991).

Foals also differ from adult horses with regard to their gut flora as they are not yet hindgut fermenters. In foals, a healthy gastrointestinal tract with appropriate microbiota is important to allow the foal to transition into a healthy weanling. Recent studies have tracked the changes in faecal microbiota as the gut transitions from a diet of milk to

becoming a hindgut fermenter (De La Torre *et al.* 2019; Lindenberg *et al.* 2019). In the first 7 days of life, the gut microbiota of foals is very transient with large inter-individual variability. A more uniform composition between foals is established by Day 20, with an increase in fibre fermenting species developing between Day 20 and Day 50 (Lindenberg *et al.* 2019). These studies suggest that the composition of bacterial populations in the foal's gut changes gradually in an age-dependent manner. These differences in microbiota allow foals to tolerate a wider range of antimicrobials, such as the macrolides, that would result in severe colitis in adult horses. However, currently no literature is available in horses regarding potential long-term effects on gut microbiota composition as a result of antimicrobials administered in early life.

The majority of pharmacokinetic studies are performed in healthy foals. The bioavailability of drugs can be altered in sick foals where disease processes, organ dysfunction, hypovolaemia and administration of other drugs can affect drug absorption and metabolism. In septic foals, for example enteral absorption of antimicrobials is often reduced as a result of hypoxic damage and reduced perfusion of the gut (Corley and Hollis 2009). Furthermore, some antimicrobials used in adult horses such as enrofloxacin are unsuitable for use in foals due to specific toxicities. The impact of these factors on the risk of antimicrobial toxicity and the steps that can be taken to monitor for these side effects will be discussed later in this article.

Common bacterial infections in foals and considerations for antimicrobial selection

Sepsis is the most common cause of foal death during the first 7 days of life. Failure of passive transfer of colostral immunity is an important risk factor. The 'open gut' of the foal which enables pinocytosis of colostral antibodies also allows direct access for bacteria from the environment and the gastrointestinal tract into the circulation. Sepsis is the result of failure of the immune response to respond adequately to infection with downstream sequelae including conditions such as septic arthritis, phylitis, osteomyelitis, meningitis and umbilical infections in some foals. Antimicrobial therapy is central to the treatment of sepsis along with intravenous fluid therapy and other supportive care. When initially selecting antimicrobials for the treatment of sepsis, it is important to select broad spectrum, intravenously administered bactericidal drugs (Magdesian 2017). Empirical selection of broad-spectrum antimicrobials is necessary initially for septic foals as there is a time delay of several days until blood culture results are reported and false-negative results are

often obtained (Wilson 1989). Bactericidal drugs are necessary due to septic foals having a naive immune system compared to adults. The route of administration affects the plasma concentrations of antimicrobial drugs. The intravenous route is recommended as sick foals are often haemodynamically compromised leading to reduced perfusion of the gut and muscle and reduced absorption of drugs administered via the oral or intramuscular routes. The importance of rapid antimicrobial administration in sepsis is well recognised in humans, with earlier administration of antimicrobials associated with an improved outcome (Puskas *et al.* 2011). Delaying the initiation of antimicrobial treatment in these foals while awaiting culture results is clinically recognised to increase the likelihood of septic shock or the sequelae described above developing. Survival rates have been shown to be improved when an empirically selected antimicrobial regime includes an antimicrobial to which isolated bacteria are susceptible (Theelen *et al.* 2019).

A number of studies have been published summarising the most common bacterial isolates in neonatal foals with sepsis and their susceptibility patterns (Brewer and Koterba 1990; Marsh and Palmer 2001a,b; Corley and Hollis 2009; Theelen *et al.* 2014a,b; Theelen *et al.* 2019). Both Gram-negative and Gram-positive bacteria are often isolated from foals with sepsis. The most common isolate obtained from septic foals is *Escherichia coli*. Other Gram-negative bacteria that are often identified include enterics such as *Enterobacter* spp. and *Klebsiella* spp. Nonenteric Gram-negative bacteria commonly isolated include *Actinobacillus* spp. and *Pasteurella* spp. Gram-positive bacteria that are frequently reported in septic foals include *Streptococcus* spp., *Enterococcus* spp. and *Staphylococcus* spp. (Magdesian 2017). Polymicrobial infections occur frequently in foals with sepsis, and it is possible to have mixed infections of Gram-negative and Gram-positive bacteria (Brewer and Koterba 1990; Gayle *et al.* 1998).

There is evidence from a study in California comparing isolates in neonatal septic foals at one hospital over a period of 30 years that while Gram-negative bacteria remain the most common isolates, the prevalence of Gram-positive bacteria is increasing. *Enterococcus* spp. isolates were also cultured more frequently in recent years (Theelen *et al.* 2014b). The increase in *Enterococcus* spp. prevalence is concerning as they can act as a donor of antimicrobial resistance genes to other bacteria. Hospitalisation also appears to have an impact upon the bacteria isolated and the susceptibility of the strains. When cultures were compared between hospital admission samples and those taken after 48 h of hospitalisation, there was found to be an increase in the prevalence of several bacterial species including species often involved in healthcare-associated infections such as *Acinetobacter* spp., *Klebsiella* spp., *Pseudomonas* spp. and *Serratia* spp. These results provide a rationale for repeating bacteriological culture and susceptibility testing of hospitalised foals and emphasise the importance of hospital hygiene in equine neonatal intensive care units (Theelen *et al.* 2020). It is clear from the studies already published that bacterial susceptibility is also region- and hospital-dependent, therefore local monitoring of this information to guide antimicrobial selection is recommended (Marsh and Palmer 2001a,b; Theelen *et al.* 2014a).

Despite the necessity of antimicrobial treatment in neonates to avoid septic shock, there are currently no studies investigating the long-term implications of administering antimicrobials to foals. In human medicine, studies have shown an association between the use of antimicrobials in children and the development of allergies, arthritis, inflammatory bowel disease, asthma, multiple sclerosis, obesity and diabetes (Schulfer and Blaser 2015). There is a recognition that the first year of life is vital for the development of a child's intestinal microbiota and that early exposure to antibiotics alters the microbiota and increases the risk of developing inflammatory bowel diseases in later life (Ponder and Long 2013). Alterations in gut microbiota have been noted in adult horses after antimicrobial administration but this has not been investigated in foals (Costa *et al.* 2015). Despite the lack of studies examining the long-term implications of early antimicrobial administration in foals, these results from humans and mature horses support careful consideration when prescribing antimicrobials in foals.

Part 2: Specific antimicrobial drugs – indications and considerations

Beta-lactams: penicillin and ampicillin

Beta-lactam antimicrobials are time-dependent, bactericidal drugs that inhibit cell wall synthesis. These drugs are hydrophilic which means they distribute widely throughout plasma but do not penetrate lipophilic cell membranes well. In general, they have good Gram-positive spectrum of activity, with lesser Gram-negative and anaerobic coverage. They are often used synergistically with the aminoglycosides to provide broad-spectrum coverage (Haggett 2008).

Procaine penicillin G can be administered intramuscularly. However, this route of administration is associated with a risk of penicillin reactions (Olsen *et al.* 2007) and is often poorly tolerated due to low muscle mass. Procaine penicillin G also achieves low plasma concentrations in adult horses (Uboh *et al.* 2000), and this problem is likely worsened in foals with poor perfusion leading to reduced drug absorption from the tissue. Intravenous salts (sodium or potassium) of penicillin G are better suited to use in foals as they achieve higher and more reliable plasma levels.

The aminopenicillin, ampicillin, generally provides slightly better Gram-negative coverage than penicillin G (Magdesian 2017) and has the added advantage that sensitivity to *Enterococcus* spp. is generally better (Theelen 2014a). Ampicillin is generally considered to be the first-line choice for treatment of neonatal sepsis in combination with an aminoglycoside (Theelen 2014a).

Anti-pseudomonal penicillins

These drugs can penetrate the outer cell wall of Gram-negative bacteria, including *Pseudomonas* spp. They can also overcome β -lactamase inactivation when administered with clavulanic acid. They can be considered an alternative for treatment of foals with sepsis or Gram-negative infection in which the use of aminoglycosides is contraindicated due to renal dysfunction. Ticarcillin clavulanate has been used widely but is no longer commercially available. The authors have used piperacillin G tazobactam in neonatal foals but there are no published reports of the use of this drug and the dosage has been extrapolated from other species.

Oral penicillins

Amoxicillin clavulanate can be used orally for the treatment of bacterial infections in young foals (up to 4 months of age) as it can attain adequate plasma levels (Love *et al.* 1981). This drug can be considered to be good oral treatment for specific infections such as neonatal pneumonia.

Beta-lactam antimicrobials: carbapenems

These drugs have probably the widest spectrum of activity of all antimicrobials and imipenem has been studied in horses (Orsini *et al.* 2005). This drug is of critical importance to human health and should not be used in neonatal foals unless in exceptional circumstances and only after bacteriological culture and susceptibility testing has proven no other alternatives for treatment.

Cephalosporins

These drugs are bactericidal and time-dependent with a broad spectrum of activity. They distribute widely throughout plasma and the extracellular compartment but have poor intracellular penetration. These drugs have been widely used in neonates due to their broad spectrum of activity, ease of administration and lack of major side effects. However, these drugs are classified as 'highest priority critically important antimicrobials' by the World Health Organization, and consequently, there is increasing pressure to reduce their usage in equine practice. There are five generations of cephalosporins. All generations have good Gram-positive coverage with increasing Gram-negative activity in the later generations.

Ceftiofur

Ceftiofur, a third-generation cephalosporin approved for use in horses in some parts of the world, is the cephalosporin most widely studied in neonatal foals. It is indicated for the treatment of neonatal sepsis when other nonprotected drugs are inappropriate, usually in the case of renal dysfunction. A significant proportion of isolates from foals with neonatal sepsis are reported to be resistant to ceftiofur, and hence, ampicillin and gentamicin or amikacin is generally a better first-line choice (Marsh and Palmer 2001a; Sanchez *et al.* 2008). The label dose of ceftiofur (2.2 mg/kg) is appropriate for the label indication of treatment of respiratory disease caused by *Streptococcus zooepidemicus*, a highly susceptible organism. A dose rate above 2 mg/kg is required to ensure that adequate blood MIC concentrations are obtained to exceed the MIC for less susceptible organisms such as *E. coli* (Meyer *et al.* 2009). Ceftiofur has the added advantage that it can achieve adequate plasma levels after intramuscular or subcutaneous injection (Slovic *et al.* 2006).

Other third-generation cephalosporins with a slightly broader Gram-negative spectrum can be used as an alternative to ceftiofur when culture and susceptibility results dictate. Examples include ceftriaxone and cefotaxime. Both these drugs cross the blood brain barrier and are indicated for the treatment of meningitis (Magdesian 2017).

Cephalosporins are suited to constant rate infusion due to their time-dependent mechanism of action, and this route of administration may improve efficacy by maximising time above MIC. Studies have evaluated continuous infusion of ceftiofur and cefotaxime, and this route of administration should be considered over bolus administration for hospitalised

neonatal foals when cephalosporins use is indicated (Hewson *et al.* 2013; Weam *et al.* 2013).

Aminoglycosides

Aminoglycosides are bactericidal, concentration-dependent antimicrobials with a predominantly Gram-negative spectrum. They are indicated for the treatment of specific Gram-negative infections or neonatal sepsis when used in combination with a beta-lactam. The main concern regarding their use is their potential to cause nephrotoxicity due to concentration of the drug in the renal tubular cells. This side effect occurs when repeated dosing occurs prior to excretion of the previous dose. Therapeutic drug monitoring (TDM) is recommended to reduce this risk. This relies on measuring a peak concentration to ensure drug efficacy and a trough concentration to ensure excretion (Magdesian 2017). Suggested target levels are shown in **Table 1**. If TDM is not available, then careful attention should be given to ensure an adequate dosing interval and normal renal function. Hydration status, urine output and serum creatinine concentration should be monitored closely.

Due to the high body water content of foals and the high volume of distribution, a high dose of aminoglycosides is required to reach therapeutic levels (see **Table 2**). Amikacin is less likely to be associated with renal side effects compared to gentamicin. The proportion of bacterial isolates that are susceptible to gentamicin is lower when compared to amikacin in some geographic regions (Theelen *et al.* 2019). From an antimicrobial stewardship point of view, gentamicin is preferred over amikacin. Therefore, making an informed decision on which aminoglycoside to use should be based on the local information obtained by ongoing monitoring of susceptibility results.

Aminoglycosides are also ideal drugs for regional use due to their concentration-dependent effect. Intra-articular medication or intravenous regional perfusion should be considered for foals with localised limb sepsis (Glass 2017).

Tetracyclines

Tetracyclines are bacteriostatic time-dependent antimicrobials which inhibit protein synthesis (Haggett 2008). They generally have a broad spectrum of activity but lack efficacy against some important Gram-negative bacteria and *Enterococcus* spp. Tetracyclines are lipophilic and penetrate well into tissues. This is a major advantage when treating localised infections such as septic arthritis, pharyngitis or omphalophlebitis.

Oxytetracycline can be administered intravenously as a first-line antimicrobial for foals with localised bacterial infections. It is generally not considered an ideal first-line choice for the treatment of sepsis. At supra-therapeutic doses, oxytetracycline is used to treat flexural limb deformities in foals (Madison *et al.* 1994). Even at antimicrobial doses

TABLE 1: Suggested target plasma aminoglycoside concentrations for therapeutic drug monitoring

Drug	30-min peak (ug/mL)	8-h level (ug/mL)	20-h trough (ug/mL)
Amikacin	>53–60	15–20	<2
Gentamicin	>30–40	3–5	<1

TABLE 2: A list of antimicrobials commonly used in neonatal foals

	Dosage (mg/kg unless otherwise stated)	Route of administration	Frequency of administration (h)
Procaine penicillin G	20	IM	12
Sodium penicillin	20,000–44,000	IV	6
Sodium ampicillin	20	IV	6
Piperacillin tazobactam	30*	IV	6
Amoxicillin clavulanate	30	PO	8
Ceftiofur sodium	5–10	IV, IM, SC	12
Cefotaxime	40	IV	6
Ceftriaxone	25	IV	12
Amikacin	25	IV	24
Gentamicin	12	IV	36
Oxytetracycline	5 - 10	IV	12
Doxycycline	10	PO	12
Marbofloxacin	2	IV	24
	4	PO	
Clarithromycin	7.5	PO	12
Rifampin	5	PO	12
	10	PO	24
Trimethoprim sulfadiazine	5/25	PO	12
Metronidazole	10	IV, PO	12

* Dosage extrapolated from other species.

limb ligament laxity can occur and this can limit the use of this drug particularly in dysmature individuals. Oxytetracycline can cause acute kidney injury in foals, especially at high doses, and this drug should be used cautiously in foals with poor renal perfusion or evidence of reduced renal function (Ellero *et al.* 2020).

Doxycycline is well absorbed after oral administration to young foals and due to its relatively broad spectrum of activity and good tissue penetration is an excellent choice for the treatment of localised infections such as pneumonia and omphalophlebitis (Corley 2009).

Fluoroquinolones

Fluoroquinolones are considered 'protected' drugs in equine practice and should not be used for first-line therapy (British Equine Veterinary Association 2012; World Health Organization 2019). In general, the fluoroquinolones have limited Gram-positive activity (predominantly *Staphylococcus spp*) with excellent Gram-negative coverage. They are lipophilic drugs with excellent tissue penetration.

The main limitation of their use in neonates is their propensity to cause toxicity to developing articular cartilage (Vivrette *et al.* 2001). This effect is thought to be less when using marbofloxacin compared to enrofloxacin.

Due to their excellent tissue penetration, the main indication for the use of marbofloxacin is the treatment of localised infections when culture and sensitivity results show no alternative options for treatment. Marbofloxacin has also been used to treat macrolide-resistant *Rhodococcus equi* infections.

Macrolides

The main indication for the use of macrolides is for the treatment of *Rhodococcus* infections (Giguère 2017). These drugs have a narrow, predominantly Gram-positive spectrum of activity but are highly lipophilic with excellent intracellular penetration. They can occasionally be used for the treatment of other localised infections, but only in the absence of other options based on culture and sensitivity. These drugs should be administered carefully as there is a risk of severe or fatal enterocolitis in the mare if they ingest small amounts of the drug. This risk seems to be greatest when using earlier generation macrolides such as erythromycin (Båverud *et al.* 1998). Enterocolitis can also occur as a side effect of treatment with any macrolide (Giguère 2017). This risk is greater in older foals with a more mature gut flora. Macrolides use is also associated with a reduced ability to sweat (anhidrosis or hypohydrosis). Foals undergoing treatment should be kept cool in hot weather as they are unable to thermoregulate effectively (Stieler *et al.* 2016).

Rifampin

Rifampin has a narrow spectrum of activity which is predominantly Gram-positive. The drug is highly lipophilic and penetrates well into tissues. The drug is most often used in combination with a macrolide antimicrobial for the treatment of *Rhodococcus equi* pneumonia (Giguère 2017) but can also be used to treat other localised infections. Co-administration of rifampin with clarithromycin leads to decreased plasma and pulmonary epithelial fluid cell concentrations of clarithromycin (Peters *et al.* 2012) due to inhibition of intestinal uptake transporters. This has caused debate about whether this combination of drugs is appropriate. However, as co-therapy is thought to reduce the chance of bacteria acquiring rifampin resistance and because plasma levels above the MIC for most common pathogens can still be reached, combination therapy should be used. Drug interactions between other macrolides and rifampin are variable and when gamithromycin and rifampin are combined, plasma concentrations of gamithromycin are actually increased (Berlin *et al.* 2018). Rifampin should not be used as a sole agent due to rapid acquisition of resistance (Haggett 2008) and can be combined with other oral medications such as doxycycline or trimethoprim sulfadiazine for treatment of osteomyelitis or umbilical infections. Historically, rifampin has been administered twice daily but a recent study suggested that once daily administration may be adequate (Berlin *et al.* 2017).

Potentiated sulphonamides

Trimethoprim sulfadiazine is a broad-spectrum bacteriostatic drug. Levels of resistance are relatively high in some geographic regions (Theelen 2019). The drug has lack of efficacy against *Enterococcus spp.* (Magdesian 2017) and is poorly active in purulent material (Haggett 2008). The drug is useful for first-line treatment, for example in cases of mild pneumonia. Trimethoprim sulfadiazine, however, is not a good choice in foals with suspected sepsis.

Metronidazole

Metronidazole is indicated for the treatment of anaerobic infection including clostridial infections. The drug has a longer elimination half-life in foals compared with adults and should be used at a lower dose (Swain *et al.* 2014).

Discontinuation of therapy

Once antimicrobial treatment has been started, it is important to evaluate whether or not the treatment is effective. Clinical improvement of the foal and improvement of laboratory test results are the most reliable indicators. Besides repeated clinical evaluation of the patient, repeated blood analysis, such as white blood count, serum amyloid A and fibrinogen, or repeated diagnostic imaging to monitor disease resolution can be helpful in determining when antimicrobial treatment can be discontinued. In cases that fail to improve, collection of follow-up samples for bacteriological culture and susceptibility testing can be useful. Isolation rates and antimicrobial susceptibility profiles from bacteria isolated from foals with sepsis after > 48h of hospitalisation differ significantly from those collected at hospital admission (Theelen *et al.* 2020). This demonstrates that previous test results should not be used for selection of alternative drugs for treatment if initial treatment is unsuccessful. This study also showed it was not possible to predict antimicrobial susceptibility of bacteria isolated from foals after > 48h of hospitalisation and, therefore, no general empirical recommendation could be made for treatment of foals with sepsis which did not respond well to the initial antimicrobial therapy. Repeated bacteriological culture and susceptibility testing is necessary in these cases to make an informed decision in each individual patient.

Part 3: Surveillance of antimicrobial drug use and development of resistance

Frequent use of antimicrobial drugs leads to the development of antimicrobial resistance over time, and this trend is also observed for bacteria isolated from foals with sepsis (Sanchez *et al.* 2008; Theelen *et al.* 2014). The opposite was also seen: susceptibility to 'older' drugs that were no longer used increased over time (Theelen *et al.* 2014). This supports the central notion in antimicrobial stewardship programmes that reduced use of an antimicrobial drug can contribute to maintaining the efficacy of that antimicrobial drug over time. Antimicrobial stewardship programmes are being developed and implemented in human as well as veterinary medicine in order to sustain the efficacy of antimicrobial drugs in the light of increasing development and spread of resistance. Surveillance of antimicrobial drug use and development of resistance are key concepts in any antimicrobial stewardship strategy. Since antimicrobial drug prescription varies between different geographic regions, based on common practices and local regulation, development of antimicrobial resistance also varies between different geographic regions. Susceptibility patterns from bacteria isolated from (neonatal) foals also differ between geographic regions (Brewer and Koterba 1990; Gayle *et al.* 1998; Marsh and Palmer 2001a,b; Russell *et al.* 2008; Sanchez *et al.* 2008; Hollis *et al.* 2008; Theelen *et al.* 2014; Hytychová and Bezdeková 2015; Toombs-Ruane *et al.* 2016). Utilising studies obtained from different countries with different antimicrobial usages and over different time periods to make decisions regarding antimicrobial treatment in individual patients may therefore result in inappropriate treatment and potentially poor corresponding outcome. This highlights the importance of incorporating continuous surveillance of antimicrobial drug use and development of resistance in each practice or hospital.

For surveillance of antimicrobial drug use, procurement or prescription data can be used. The former is easier to obtain but does not allow for differentiation between patient types or, in mixed practices, species. Prescription data can be obtained from many patient management systems and allows for detailed analysis of prescription policy between species, different types of patients and even between different veterinarians. Systematic collection of these data also allows for benchmarking between practices which can stimulate veterinarians to further reduce the use of antimicrobials in their practice.

Monitoring development of antimicrobial resistance starts with implementing the policy of collecting samples for bacteriological culture and susceptibility testing in each case and not only in refractory cases. Furthermore, systematic recording of bacteriological culture and susceptibility testing results is essential in order to be able to detect changes in prevalence and antimicrobial susceptibility over time. It is therefore advisable to assign this task to a designated person within the practice and to discuss trends on a regular basis within the entire team to increase awareness and engagement.

Two different methods for antimicrobial susceptibility testing are used: disk diffusion (Kirby Bauer) or microdilution susceptibility testing. In disk diffusion susceptibility testing, antibiotic discs are placed on agar plates inoculated with bacteria. Interpretation criteria for inhibition zones are used to determine antimicrobial susceptibility. The results of this method of testing are reported as S (susceptible), I (intermediate) or R (resistant). In microdilution susceptibility testing the wells in the microtiter plates are inoculated with a broth containing the bacteria as well as varying concentrations of the antimicrobial drugs of interest. After the incubation time, each well is checked for bacterial growth. By using this procedure, it is possible to determine the Minimum Inhibitory Concentration (MIC; the lowest concentration of antimicrobial drug that inhibits bacterial growth) for each antimicrobial drug that was tested. Interpretation breakpoints are used to determine susceptibility. If the MIC is below the breakpoint, an organism is considered to be susceptible (S); if the MIC is above the breakpoint, an organism is considered to be resistant (R). Microdilution is currently considered the gold standard of susceptibility testing. This method allows for early detection of increasing MIC values, which might still be well below the breakpoint meaning the isolate is still susceptible but are an early indicator of development of antimicrobial resistance (Theelen 2014). From a surveillance point of view, microdilution susceptibility is therefore preferred over disk diffusion susceptibility testing.

Practical guidelines for antimicrobial stewardship in foals

Antimicrobial stewardship involves the judicious use of antimicrobials balanced against the requirement to treat the presenting clinical condition (Raidal 2019). The same principles apply to human medicine as well as veterinary medicine, including equine medicine. This requires a multifactorial approach combining reduction of resistant reservoirs, improved diagnostic techniques for bacterial infection, improved infection control measures, improved preventative health measures and greater insight into the aetiology of infections to reduce dependence on antimicrobials and limit the emergence of antimicrobial

resistance. Recently, several excellent papers have been published on antimicrobial stewardship in equine medicine (Raidal 2019; Prescott 2021). In these papers, guidelines are formulated that can be applied in equine practice. A recent study on antimicrobial stewardship in small animal medicine clearly demonstrated the positive effect of implementing an antimicrobial stewardship programme in small animal clinics by reducing the total amount of antimicrobials used and showing a shift in type of drugs used from 'protected' antimicrobials such as cephalosporins and fluoroquinolones to more 'first-line' antimicrobials such as penicillins (Hopman *et al.* 2019). Developing and incorporating an antimicrobial stewardship strategy are therefore important for all veterinary practices in order to reduce the use of antimicrobial drugs. Future research and development of new improved diagnostic techniques will hopefully contribute to a decreased need for use of antimicrobials. In the meantime, many aspects related to antimicrobial stewardship can be applied in daily practice. In the following paragraph, we will discuss how antimicrobial stewardship guidelines can be applied practically in (neonatal) foal medicine.

Antimicrobial stewardship starts with prevention of disease. Hygiene protocols, both at farms and in the hospital, should be optimised to prevent infections, thereby decreasing the need to use antimicrobials to treat infections. This is especially important in the perinatal period as foals are susceptible to sepsis. Hygiene protocols should include hand hygiene, aseptic protocols and isolation of patients with contagious conditions. Furthermore, bacterial infections can be avoided by preventative medicine measures, such as excellent prepartum and foaling management, assuring adequate colostrum intake in neonatal foals and by vaccination. Once infection has occurred, it is important to make an evidence-based decision about whether or not a foal should be treated with antimicrobials in each individual case. Many cases do not need antimicrobial treatment, such as mild cases of diarrhoea or foals with colic. Recently, a study demonstrated that a policy change to treat foals with *Rhodococcus equi* pneumonia in the later stage of the disease reduced antimicrobial usage without increasing mortality (Arnold-Lehna *et al.* 2020). Appropriate aseptic sample collection technique is also important in this light to avoid sample contamination and overtreatment. The duration of antimicrobial therapy should be appropriate. Excessive duration of treatment should be avoided. Clinical and blood parameters can be used to evaluate the need for continuation of treatment. Removal of the infected source can reduce the need for long-term antimicrobials. For example, abscess drainage or surgical removal of infected tissue can take away the need to treat a foal with antimicrobials. Antimicrobials must only be used with veterinary involvement. Owners should not have access to antimicrobial drugs without consulting a veterinarian. As discussed previously, continuous monitoring of bacteriological culture and sensitivity results in each practice is essential to collect information on the local situation regarding prevalence and susceptibility of bacteria. Antimicrobials should be classified as 'first line', 'alternative' and 'protected' options, based on local culture and susceptibility results. Documents ranking antimicrobials based on risk management of antimicrobial resistance are available and should be used as guidance for selection of antimicrobial drugs for treatment in veterinary medicine, such as the World

Health Organization 'List of Critically Important Antimicrobials for Human Medicine' and the PROTECT ME toolkit developed by the British Equine Veterinary Association (British Equine Veterinary Association 2012; World Health Organization 2019). Antimicrobials that are of critical importance to human health, such as 3rd-, 4th- and 5th-generation cephalosporins, fluoroquinolones and carbapenems (World Health Organization 2019) should be classified as 'protected' and their use should always be justified by bacteriological culture and susceptibility testing results demonstrating that no other alternatives are available. Treatment should be modified based on culture and susceptibility results for individual patients, when possible. Dose and route of administration should be appropriate to the condition being treated to make sure antimicrobials reach sufficiently high concentrations to be effective at the location of the infection. Local delivery methods (e.g. intra-articular administration in a septic joint) can be used to allow for high antimicrobial concentrations at the site of infection, which is especially useful in cases where concentration-dependent antimicrobials are used as bacterial killing is directly proportional to the ratio of peak drug concentration to the MIC of the infecting bacteria. Isolation of patients infected by multi-drug resistant bacteria is important to reduce the risk of spread of resistance. Monitoring antimicrobial drug use in a practice provides the opportunity of comparing data between individual years and/or veterinarians within a practice or even between practices (benchmarking). Benchmarking can have a positive effect on reducing the total amount of antimicrobials used (Hopman *et al.* 2019). Post educational training for veterinarians on antimicrobial resistance and practice-wide discussions on guidelines should be organised in order to improve alignment. Client education on antimicrobial resistance can assist in reducing client pressure on veterinarians to prescribe antimicrobials. This can be achieved through sharing information by the use of posters or leaflets for clients.

Prophylactic use of antimicrobials in foals in the first few days of life has been advocated in the past to prevent infections but given the current rise of antimicrobial resistance and the worldwide call for reducing antimicrobial use, should not be used. Antimicrobial prophylaxis should not be used as a substitute for good animal health management. Prevention of infections by improving hygiene on breeding farms is key. In each case, the requirement to treat the presenting clinical condition with antimicrobials should be balanced against the potential for development or spread of resistance (Raidal 2019). Empirical use of antimicrobials is justified in initial treatment protocols for rapidly progressive, life-threatening conditions such as sepsis in foals, while awaiting the results of culture and susceptibility tests to increase the chance of survival (Theelen *et al.* 2019). Selection of antimicrobial drugs in these cases should be based on knowledge of the bacterial agents most likely involved with the disease process and knowledge of local resistance patterns combined with antimicrobial guidelines favouring antimicrobial drugs with the lowest risk of development and spread of resistance.

Conclusions

It is important to realise that results of bacteriological culture and susceptibility testing may differ between geographic regions. Temporal trends in susceptibility and resistance also

occur. Continuous local monitoring of culture and susceptibility results is therefore of utmost importance to ensure that empirical selection of drugs for treatment is based on contemporaneous and locally applicable susceptibility results. Bacteriological culture and susceptibility testing in individual cases therefore might not only benefit the individual patient, but also provides the basis for empirical drug selection in future cases.

Foals treated at NICU facilities are at risk for healthcare-associated infections (Theelen *et al.* 2020). Hygiene is important to prevent infection and spread of resistant bacteria. Repeated bacteriological culturing and susceptibility testing is advisable in hospitalised foals to detect ongoing or healthcare-associated infections at an early stage to provide guidance for potentially changing antimicrobial therapy.

Choosing antimicrobials for treatment of equine neonates is complex. Selecting antimicrobial drugs is more complicated than matching 'drugs and bugs'. Knowledge about the drugs, the microbiological aspects and the clinical situation of the patient are all necessary to make an appropriate decision and improve the chance of a positive outcome for the foal. The challenge is not to always play it safe, just because it is easy, but to make a well-considered decision in each individual case. Judicious use of antimicrobials is important to prevent development of resistance. In order for the veterinary profession to take responsibility and contribute to the worldwide battle against antimicrobial resistance, all veterinary practices should develop and implement a practice-wide antimicrobial stewardship strategy.

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