EQUINE VETERINARY EDUCATION/AMERICAN EDITION

VOLUME 33 NUMBER 8

AUGUST 2021

EQUINE VETERINARY EDUCATION

American Edition | August 2021

BEVA

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

IN THIS ISSUE:

IN A WORLD OF ITS OWN

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References:
[1] Nogradi N, Couetil LL, Messick J, Stochelski MA, Burgess JA. Evaluation of an Omega-3 Fatty Acid Containing Feed Supplement in the Management of Horses with Chronic Lower Airway Inflammatory Diseases. J Vet Intern Med 2015; 29:299-306.
[2] Couetil LL, Cardwell J.M, Gerber V, Lavoie J.-P, Leguillette R, Richard E.A. Inflammatory Airway Disease of Horses. ACVIM Consensus Statement J of Vet Intern Med 2016; 30:503-515 p. 508-510.

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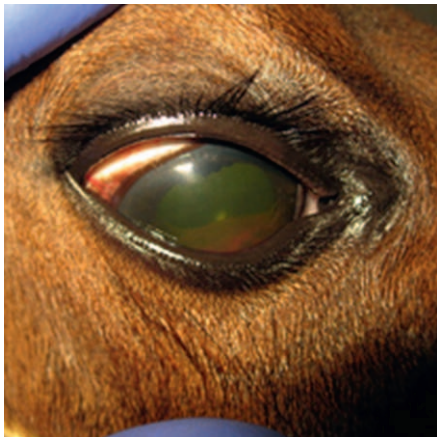

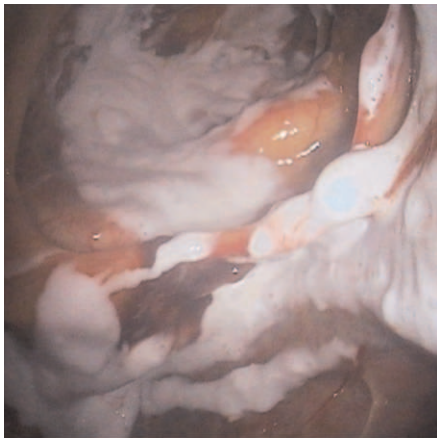

AAEP NEWS In this issue

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

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

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Celebrate
EQUINE PRACTICE
AAEP®
67th Annual Convention & Trade Show
Dec. 4-8, 2021 | Nashville, TN
REGISTRATION KIT

Come together with Horse Doctors from around the world to celebrate equine practice at the **AAEP's 67th Annual Convention**.

Write the next verse of your career in Music City USA by reestablishing relationships across the industry and reconnecting to your passion for equine practice.

The much-anticipated return to an in-person event brings both the full convention experience and all Nashville has to offer, including its vibrant live music scene.

In Nashville, it is said country is a way of life. So, too, is equine practice, whether you are an inquisitive intern or seasoned partner, or your practice has four walls or rolls down country roads on four wheels.

This December, all roads lead to downtown Nashville, where your AAEP community is excited to welcome you home!

While we welcome the much-anticipated pivot back to an in-person event, a virtual component will be available soon after conclusion of the live convention if you are unable to attend. *See page 3 for details.*

Download the AAEP Convention App

Enhance your meeting experience with the AAEP Convention App. Browse sessions and speakers, create a personal itinerary and take notes; search, filter and contact exhibitors; create your own profile and message other attendees; contact and schedule a time to meet with exhibitors; view and post to the event stream on Twitter; and access *Proceedings* papers closer to the event. Search "AAEP Education" at your app store to download.

Sponsored by Zoetis, "For Animals. For Health. For You."

New: Member Roundtables

Join us on Saturday afternoon, Dec. 4, for a series of informal member roundtable discussions on timely industry topics, including emergency coverage, retirement planning, euthanasia alternatives to pentobarbital and others in development. The complete schedule of topics and times will be available at convention.aaep.org, on the AAEP Convention App and in the convention program on-site.

Can't Make It to Nashville?

If unable to join your colleagues in Nashville, you can still discover the latest diagnostic and treatment solutions through a virtual convention option.

The virtual option enables:

- participation in a slate of 12 Table Topics that will be re-offered live via Zoom during the week of Dec. 13; and
- indefinite access to on-demand recordings and supporting resources of educational sessions (excluding Table Topics) presented in Nashville. CE credit for on-demand sessions will be available for three months following the live convention.

The virtual convention option is available to AAEP members for $450. **Register for the on-site convention and receive the virtual option at no additional cost,** enabling you to watch recordings of and claim credits for educational sessions you may miss on-site. For more information or to register for the virtual convention option, visit convention.aaep.org.

EDUCATIONAL PROGRAM

Speakers, times, and topics are subject to change.

Denotes a core concept for new graduates. *Denotes a Table Topic being re-offered live post-convention via Zoom.*

SUNDAY December 5

Morning

8:00 a.m. **Opening Session**
Moderator: Emma Read

9:00-10:00 a.m. **Keynote: Zap the Gap: Generational Differences Examined**
Meagan Johnson (see next page)
Sponsored by Merck Animal Health.

10:15 a.m. **Kester News Hour**
Enabled by a grant from the estate of Dr. Wayne O. Kester, the Kester News Hour highlights the latest scientific papers in specific areas of equine medicine. Presenters listed below and pictured from left.

Anchors: *Regina M. Turner and Katherine S. Garrett*
Forecaster: *Amy L. Johnson*
Sportscaster: *Sherry A. Johnson*
Field Reporter: *Eric Mueller*

Afternoon

How to Maximize the Use of Ultrasound in the Field

Moderator: Katherine S. Garrett
Sponsored by Antech, SOUND®, Your Worldwide Equine Diagnostic and Imaging Partner. Visit Booth 423 for more information.

1:30 p.m. How to Evaluate the Foal Abdomen and Thorax Ultrasonographically in the Field – *William F. Gilsenan*

1:50 p.m. Adult Abdomen and Thorax – *Tracy E. Norman*

2:10 p.m. Musculoskeletal Ultrasound of the Foal – *Katherine S. Garrett*

2:30 p.m. Ultrasound of the Hind Suspensory Ligament – *Caitlyn R. Horne*

2:50 p.m. Ultrasound of the Pastern Region – *Kate Chope*

3:10 p.m. Reproductive and Urogenital Ultrasound of the Mare – *Maria R. Schnobrich*

3:30 p.m. How to Perform Plantar Non-Weight Bearing Ultrasonographic Evaluation of the Equine Hind Proximal Suspensory Ligament – *Kimberly D. Trolinger-Meadows*

3:50 p.m. Review of Non-Weight Bearing Proximal Suspensory Ligament Ultrasound for Alterations in the Muscle/Fat Indicating Pathologic Change – *Natasha Werpy*

4:10-5:00 p.m. Panel/Q&A

Back to Basics: Wound Management

Moderator: Dean A. Hendrickson
Sponsored by Akorn Animal Health. For over 45 years, Reliable, Trusted, Predictable!

1:30 p.m. Controlling Wound Bacteria and Biofilm – *Lynn Pezzanite*

2:20 p.m. Wound Debridement Techniques – *R. Reid Hanson*

3:10 p.m. Wound Care Dressings – *Dean A. Hendrickson*

4:00-4:50 p.m. Skin Grafting Basics – *Dean A. Hendrickson*

Keeping Equine Practitioners in Equine Practice

Moderators: Amy L. Grice and Carol Clark
Sponsored by Purina, the creators of EquineVetNutrition.com.

What We Know

1:30 p.m. Equine Practice in 2021 – *Amy L. Grice*

2:00 p.m. Initial Findings of the AAEP Retention Task Force – *Rob Trimble*

What Happens?

2:30 p.m. Panel Discussion with Equine Practitioners NOT in Equine Practice
Panelists: Brittany Breidenbach, Mark Buchert, Tracy E. Norman, Jennifer Madera, Maggie Peitzmeier, and Thaddeus Williams

What Could Help? How I Do It - Innovative Models of Equine Practice

4:00 p.m. Finding Success and Satisfaction in Solo Practice – *Caitlin Daly*

4:20 p.m. Better Together: Utilizing an Emergency Co-operative to Prevent Burnout – *Amanda McCleery*

4:40-5:00 p.m. Alternative Schedules and Practice Roles: Rethinking Industry Norms Can Promote More Valuable and Sustainable Businesses – *Kelly A. Zeytoonian*

Medicine I: Therapeutics – Safety and Side Effects

Moderator: Peter Morresey
Sponsored by American Regent Animal Health, manufacturer of Adequan® i.m. (polysulfated glycosaminoglycan) and Betavet® (betamethasone sodium phosphate and betamethasone acetate injectable suspension).

1:30 p.m. Investigation of the Bi-Weekly Administration of Diclazuril on the Antibody Kinetics to *Sarcocystis neurona* in Healthy Horses – *Nicola Pusterla*

1:50 p.m. Prevalence of and Risk Factors Associated with Salmonella Shedding Among Equids Presenting to a Veterinary Teaching Hospital for Colic (2013-2018) – *Isabelle Kilcoyne*

2:10 p.m. Trends in Antimicrobial Susceptibility Patterns of Bacterial Isolates from Horses with Ulcerative Keratitis in Tennessee – *Braidee C. Foote*

2:30 p.m. Gentamicin-Induced Auditory Loss in Healthy Adult Horses – *Monica Aleman*

2:50 p.m. Effect of a Combination of Butorphanol and Detomidine on Endoscopic Assessment of Laryngeal Function of Thoroughbred Yearlings – *Hugo Almonte*

3:10 p.m. Subclinical Colitis Following NSAID Administration in Healthy Horses – *Rebecca Bishop*

3:30 p.m. Pharmacokinetics and Safety of an Oral Cannabidiol Product in Horses – *Alicia F. Yocom*

3:50 p.m. Effects of a Supplement Containing Cannabidiol on Sedation and Ataxia Scores and Health Parameters – *Michael St. Blanc*

4:10-5:00 p.m. Panel/Q&A

Table Topics

Sponsored by Dechra Veterinary Products.

Seating is limited so please arrive early.

1:30-3:00 p.m.

Geriatric Horses: PPID, Arthritis, Dentistry – *Robert Baratt*

How the Oral Examination Enters into the Pre-Purchase Exam – *Jack Easley and Brad Tanner*

- Non-Surgical Joint Therapies – *Katie Seabaugh and Richard Markell*
- The Subfertile Mare – *Patrick McCue and Kristina Lu*

3:30-5:00 p.m.

- Hindlimb Proximal Suspensory Disease: Management and Expectations – *Kent Allen and Lane Easter*

Marketing and Advertising: What Strategies = Profit – *Sherry A. Johnson and Mike Pownall*

Metabolic Disease – *Heidi Banse and Molly McCue*

KEYNOTE ADDRESS: Zap the Gap: Generational Differences Examined

Meagan Johnson

Practices often comprise veterinarians, techs and administrative staff from multiple generations, which influences individual expectations, actions and mindsets. To achieve patient health, practice success and professional fulfillment, it's essential to make these unique perspectives work together in collaboration instead of conflict.

During her keynote presentation, generational humorist Meagan Johnson will share tips and insights into building multi-generational effective relationships and making the most of each generation.

Johnson is a nationally recognized multi-generational expert and generational explorer who has educated through entertainment since 1998. Throughout her career as a business owner, professional speaker and author, Johnson has worked with a variety of organizations and associations to build a culture of multi-generational inclusivity and collaboration by exploring what drives a generation to succeed. She has worked with clients from Boeing, Microsoft and Intel to Cabela's, National Association of Realtors and the American Health Care Association.

Johnson is co-author of the best-selling book *Generations Inc.: From Boomers to Linksters—Managing the Friction Between Generations at Work.* She has been quoted by, among others, *Chicago Tribune, US News & World Report* and CNNMoney.com; and she has appeared on NPR, ABC Talk Live, CBSN, Newsy.com, Conde Nast's Profile.com and other media outlets and podcasts.

Sponsored by MERCK Animal Health

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MONDAY December 6

Morning

Frank J. Milne State-of-the-Art Lecture

7:30-10:15 a.m. **A Look at Lameness Through the Eyes of Functional Anatomy (and Biomechanics)**
Jean-Marie Denoix (see next page)
Moderator: Erin Contino
Produced by The Foundation for the Horse.
Sponsored by Platinum Performance, "Good Nutrition is Good Medicine."

The Business of Practice: Identifying Industry Trends and Their Effect on Equine Practice

Moderator: Aimee Eggleston Ahearn
Sponsored by Covetrus, "Advancing the World of Veterinary Medicine."

8:00 a.m. Business News Hour – *Caitlin Daly, Amy L. Grice, and Kelly A. Zeytoonian*

9:00-11:30 a.m. Collaborative Practice Models – *Mike Pownall*

Afternoon

In-Depth: Advances in Donkey and Mule Medicine

Moderator: Amy K. McLean

1:30 p.m. Understanding Endocrinology and Pharmacology in Donkeys and Mules – *Ramiro E. Toribio*

2:10 p.m. Applying the Current Knowledge of Clinical Pathology to Donkeys and Mules in Practice – *Erin Goodrich*

2:50 p.m. Advances in Donkey and Mule Reproduction Physiology and Techniques – *Igor F. Canisso*

3:30 p.m. Updates on Diagnostic Approach and Treatment of Some Donkey and Mule Diseases – *Fulvio Laus*

4:10-4:50 p.m. Improving the Understanding of Normal and Pain-Related Donkey and Mule Behavior – *Amy K. McLean*

How-to Session: Medical Reasons for Poor Performance

Moderator: Thomas J. Divers
Sponsored by Boehringer Ingelheim Animal Health.

1:30 p.m. How to Decide Which Heart Murmurs Are Relevant in Performance Horses – *Katharyn Jean Mitchell*

1:50 p.m. How to Diagnose Mild and Moderate Equine Asthma as a Cause of Poor Performance in Sport Horses – *Jean-Pierre Lavoie*

2:10 p.m. How to Diagnose and Manage Gastric Ulcers as a Medical Reason for Poor Performance – *Frank M. Andrews*

2:30 p.m. How to Diagnose Equine Degenerative Myeloencephalopathy in Sport Horses – *Amy L. Johnson*

2:50 p.m. Diagnosis and Management of Myofibrillar Myopathy in Warmblood Performance Horses – *Stephanie J. Valberg*

3:10 p.m. How to Use Serum Chemistries in the Evaluation of a Poor Performance Thoroughbred and Standardbred Racehorse – *Thomas J. Divers*

3:30 p.m. How to Assess the Suitability of Rider Size—Height, Morphology, and Weight—for Optimal Horse Welfare and Performance: A Review – *Sue Dyson*

3:50 p.m. How to Recognize Signs of Abnormal Equine Behavior During Tacking-Up and Mounting and to Understand Their Potential Clinical Significance – *Sue Dyson*

4:10-5:00 p.m. Panel/Q&A

Clinical Perspectives on Managing Equine Uterine Health

Moderator: Jeremy Whitman
Sponsored by Dechra Veterinary Products.

1:30 p.m. Review of Hysteroscopy in the Mare: A Video Perspective – *Patrick McCue*

1:50 p.m. How to Perform Microbial Culture of an Equine Uterine Sample in Clinical Practice – *Christina Divine*

2:10 p.m. How to Prepare Platelet-Rich Plasma for Use in Reproductive Practice with Mares – *Lorenzo G.T.M. Segabinazzi*

2:30 p.m. How to Use N-Acetylcysteine to Enhance Diagnosis of Bacterial Endometritis in Barren Mares – *Karen A. Von Dollen*

2:50 p.m. Fetal Ultrasonography of the First Phalange: A New Tool to Assess Fetal Growth and Bone Development – *Catherine D. Renaudin*

3:10 p.m. Equine Post-Mortem Oocyte Recovery: A Retrospective Analysis – *Jennifer Hatzel*

3:30-4:15 p.m. Panel/Q&A

The Business of Practice: Improving Your Practice, Financial, and Emotional Wellbeing

Moderator: Debbie Spike-Pierce
Sponsored by Covetrus, "Advancing the World of Veterinary Medicine."

1:30 p.m. Practice Valuation Methodologies and Strategies for Improvement – *Terry O'Neil*

2:30 p.m. Personal Financial Planning – *Terry O'Neil*

3:30 p.m. Understanding and Overcoming Impostor Syndrome – *Amy L. Grice*

3:50 p.m. Personal Finance for Vet Students and Recent (or Not-So-Recent) Grads – *Mindy C. Smith*

4:10 p.m. New Paradigms Needed in Equine Practice – *Amy L. Grice*

4:30-5:10 p.m. How to Protect Against Pre-Purchase Exam Malpractice Complaints – *Nina Mouledous*

Table Topics

Sponsored by Dechra Veterinary Products.
Seating is limited so please arrive early.

1:30-3:00 p.m.

FEI/USEF Updates – *Kent Allen and Stephen Schumacher*

Interpretation of the Chemistry Panel – *Elsbeth O'Fallon and Nathan Slovis*

MRI Diagnosis of Bone Contusion – Now What? – *Myra Barrett and Natasha Werpy*

Questions about Equine Odontoclastic Tooth Resorption with Hypercementosis (EOTRH) – *Leah Limone and Ed Earley*

3:30-5:00 p.m.

Equine Welfare – *Lauren Kleine and Alina Vale*

How COVID Helped My Practice Be Better – *Erin Denney-Jones and Monty McInturff*

Horse Is Still Lame Despite Intense Therapy: How to Manage the Client – *Sarah Gold and Melissa King*

Open Flaps or Endoscope: What Are Hurdles to Treating Sinus Disease? – *Ryland Edwards and Canaan Whitfield-Cargile*

FRANK J. MILNE STATE-OF-THE-ART LECTURE:

A Look at Lameness Through the Eyes of Functional Anatomy (and Biomechanics)

Jean-Marie Denoix, DVM, Ph.D., Cert.ISELP, LAIA-ECVDI, DACVSMR, DECVSMR

Gait abnormalities of lame horses are live expressions of the biomechanical stresses placed on painful anatomical structures. During his lecture, acclaimed equine locomotion expert Dr. Jean-Marie Denoix will elucidate this intimate link as the central component of interpreting significance of imaging findings, making the final diagnosis, and establishing an effective rehabilitation program.

His presentation will incorporate video recordings that follow the clinical examination of horses at the walk, trot, canter, and ridden or driven. Clinical observations will be analyzed in light of functional anatomy and biomechanics to establish the link between symptoms and their cause.

Dr. Denoix is a professor of veterinary anatomy and equine lamenesses at the National Veterinary School of Maisons-Alfort in France. In 1999, he founded the renowned Center of Imaging and Research on Equine Locomotor Affections in Normandy to provide expertise in the diagnosis and rehabilitation of locomotor system problems in sport and racehorses. He currently oversees rehabilitation programs at the CIRALE.

Dr. Denoix founded ISELP in 2006, the same year he received the Schering Plough Equine Research Award from the World Equine Veterinary Association for outstanding applied research in equine diagnostic imaging.

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TUESDAY December 7

Morning

An Ethical Decision-Making Model for Equine Practice: Implementation and Application

Moderator: Duane Chappell
Sponsored by Merck Animal Health and Zoetis.

6:30 a.m. Ethical Decision Making: A Veterinary Model and Case Scenarios – *Ernie Martinez*

6:50-8:00 a.m. Panel Discussion: Case Scenarios from Group Practice, Solo/Small Practice, Legal, and At Large
Panelists: TBD

Emerging and Re-Emerging Infectious Diseases

Moderator: Nicola Pusterla
Sponsored by Merck Animal Health.

8:00 a.m. Equine Hepatitis Viruses – *Joy Tomlinson*

8:25 a.m. Equine Coronavirus – *Nicola Pusterla*

8:50 a.m. Novel Rickettsial Species Causing Equine Neorickettsiosis – *Luis G. Arroyo*

9:15 a.m. Nocardioform Placentitis: A Continuing Question – *Pouya Dini*

9:40 a.m. *Streptococcus zooepidemicus:* Commensal or Pathogen? – *Andrew S. Waller*

10:05 a.m. Equine Herpesvirus-1 and Equine Herpesvirus-1 Myeloencephalopathy – *Gisela Soboll Hussey*

10:30 a.m. Trouble with Gamma-Herpesviruses – *Lutz S. Goehring*

10:55-11:20 a.m. Equine Rhinitis Viruses: The Upcoming Respiratory Pathogens – *Tanya M. Rossi*

Sports Medicine

Moderator: Josh Donnell
Sponsored by Zoetis. "For Animals. For Health. For You."

8:00 a.m. Comparison of Equine Synovial Sepsis Rate Following Intrasynovial Injection in Ambulatory vs Hospital Settings – *Lynn Pezzanite*

8:20 a.m. Effects of Racing on Systemic Cytokine mRNA Expression in 2-Year-Old Thoroughbreds – *Macarena G. Sanz*

8:40 a.m. Exercise Affects Proximal Sesamoid Bone Pathology in Thoroughbred Racehorses – *Sarah K. Shaffer*

9:00 a.m. Chiropractic Treatment of Lameness and Concurrent Axial Skeleton Pain and Dysfunction in Horses – *Samantha Parkinson*

9:20 a.m. Pharmacokinetics, Pharmacodynamic Efficacy, and Safety of Acetaminophen in Adult Horses with Naturally Occurring Chronic Lameness – *Melissa A. Mercer*

9:40 a.m. Characterizing the Cytokine Environment in Acute Tendon Injury to Enhance Stem Cell Therapy – *Drew W. Koch*

10:00 a.m. Histologic and Biomechanical Evaluation of Biopsy Samples of the Equine Digital Cushion from Forelimbs – *James Damone*

10:20 a.m. How to Incorporate a Modified Hoof Cast into Equine Veterinary Practice – *Stephen E. O'Grady*

10:40 a.m. Effect of Arena Surface Composition on Shear Ground Reaction Forces – *Christina M. Rohlf*

11:00 a.m. Current Joint Therapy Usage in Equine Practice: Changes in the Last 10 Years – *Gustavo Zanotto*

11:20-11:40 a.m. Evaluation of Autologous Protein Solution Injection for Treatment of Tendonitis in an Equine Model – *Angela M. Gaesser*

BIZ The Business of Practice: Leverage the Talent of Your Team

Moderator: Mike Tomlinson
Sponsored by Covetrus, "Advancing the World of Veterinary Medicine."

8:00 a.m. Leveraging the Talent of Your Team – *Amanda L. Donnelly*

"Do I have a systems problem or a people problem, or both?" If you have ever asked yourself this question, discover the answer as Dr. Donnelly shares how to ensure your practice has systems that improve efficiency and productivity. Moreover, she will teach practice leaders how to communicate better to improve job performance and retain the best team members. Acquire action steps to take to improve onboarding, employee engagement, and development of middle managers so team members can contribute fully to the success of the practice.

11:00-11:40 a.m. Integrating Telemedicine/TeleHealth into Practice: Roadmaps for Success – *Eleanor Green and Richard Markell*

Table Topics

Sponsored by Dechra Veterinary Products.
Seating is limited so please arrive early.

8:00-9:30 a.m.

Imaging of the Skull – *Beth Biscoe and Valerie Moorman*

Ophthalmology – *Nikki Scherrer and Ben Buchanan*

Sports Medicine Diseases with Surgical Options – *Amy Rabanal and Ashlee E. Watts*

Meet the Milne Lecturer – *Jean-Marie Denoix and Kent Allen*

10:00-11:30 a.m.

Diagnostic Analgesia Approaches for the Extremely Difficult Horse – *Larry Bramlage, Sue Dyson, and Sheri Miller*

Lameness Cases Where Imaging and Blocking Don't Make Sense – *Kurt Selberg and Beau Whitaker*

How to Get a Horse Out of a Jam: Rescue Approaches – *Ashley Boyle and John Madigan*

Regional Outbreaks of Gastrointestinal Disease – *Fairfield Bain and Thomas J. Divers*

Afternoon

In-Depth: Frontiers in Athletic Rehabilitation: What Is Translatable to the Horse?

Moderator: Sherry A. Johnson
Sponsored by Platinum Performance, "Good Nutrition is Good Medicine."

1:30 p.m. Effective Rehab Strategies for the Actively Competing Elite Athlete – *Sherry A. Johnson and Stephania L. Bell*

- Physiologic workload: strategies to mimic gameday
- Predicting athletic performance: "pre-purchase" scans for human and equine athletes
- Rehabbing with purpose: tackling the sticky spots in the offseason

3:00 p.m. Strategies to Optimize Recovery in the Post-Operative Athlete – *Brian K. Noehren and Lauren V. Schnabel*

- Role of pre-habilitation: will recovery be quicker?
- Positive responders, non-responders and everything in between: when outcome doesn't match reported success rates
- Global, yet targeted rehab: when it matters most
- Early mobilization: is sooner better?

4:30-5:00 p.m. Panel Discussion with the Speakers

How-to Session: Advancing Dentistry for Field Uses

Moderator: Brad Tanner
Sponsored by Cargill, manufacturer of ProElite® - There can only be one best™.

1:30 p.m. How to Perform a Thorough Oral Examination – *Leah Limone*

1:50 p.m. How to Obtain Diagnostic Dental Radiographs – *Leah Limone*

2:10 p.m. How to Recognize and Evaluate Periodontal Disease – *Cleet Griffin*

2:30 p.m. Equipment and Treatment of Periodontal Disease – *Brad Tanner*

2:50 p.m. How to Recognize and Manage Age-Related Dental Problems in Geriatric Patients – *Cleet Griffin*

3:10 p.m. How to Refer: What to Obtain, Gather, and Share for a Consultation or Referral – *Travis J. Henry*

3:30 p.m. How to Perform Minimally Invasive Sinoscopy – *Alvaro G. Bonilla*

3:50 p.m. How to Identify and Extract Blind Wolf Teeth – *Ashton Broman*

4:10-5:00 p.m. Panel/Q&A

Medicine II: Rescue, Repair, and Reflection

Moderator: Heidi Banse

1:30 p.m. Intravenous and Intramuscular Butorphanol Pharmacokinetics in Donkeys – *Joe S. Smith*

1:50 p.m. Pharmacokinetic Modeling and Distribution of Doxycycline in Healthy Female Donkeys After Multiple Intragastric Dosing – *Joe S. Smith*

2:10 p.m. How to Equip and Deploy a Regional, Integrated Veterinary Disaster Response Trailer – *Claudia Sonder*

2:30 p.m. Medical Care of Sheltered Equines During Three Large-Scale Northern California Wildland Fires – *Claudia Sonder*

2:50 p.m. How to Respond to Equine Trailer Crashes on the Roadside – *Rebecca Husted*

3:10 p.m. How to Develop an Equine Post-Mortem Examination Review Program – *Alina Vale*

3:30 p.m. Effect of Transcutaneous Carbon Dioxide Therapy on Wound Healing and Skin Graft Acceptance in Horses – *Angela M. Gaesser*

3:50-4:30 p.m. Panel/Q&A

Denotes a core concept for new graduates. *Denotes a Table Topic being re-offered live post-convention via Zoom.*

Understanding Generational Differences in Equine Practice

Moderator: Jamie Pribyl
Sponsored by NVA: for the love of animals and the people who love them.

1:30 p.m. Relevant Leadership: Leading & Communicating Effectively in the Multi-Generational Workplace – *Jay McChord*

2:45 p.m. Break

3:00-4:30 p.m. Panel: Veterinary Medicine Across the Generations *Moderators: Jay McChord and Jennifer Settlage*

Table Topics

Sponsored by Dechra Veterinary Products.
Seating is limited so please arrive early.

1:30-3:00 p.m.

- Diagnosing the Neurologic Horse in the Field – *Amy L. Johnson and Peter Morresey*
- Foot-Related Lameness – *Raul Bras and Greg Staller*
- How to Run a Successful Internship – *Will French and Karen Jackman*
- Management of the Neonate in the Field – *William F. Gilsenan and Laura Javsicas*

3:30-5:00 p.m.

- Imaging of the Stifle – *Kate Wulster and Sarah Sampson*
- Pain Management – *Lori Bidwell and Rachel Hector*
- Virtual/Remote Care/Technology and Innovation – *Richard Markell and Eleanor Green*
- When to Recommend ET and ICSI – *Ryan Ferris and Hunter Ortis*

AAEP/AAEVT Joint Roundtable Discussion

Sponsored by Dechra Veterinary Products.

3:30-5:00 p.m. Ideas on How to Improve Our Partnership for the Betterment of Our Equine Industry and Service to the Horse – *Kathleen Anderson, Ben Buchanan, Anne Baskett, Deb Reeder, Elyse Rowley, and Sheri Miller*

Explore how successful veterinary teams have created respectful working relationships, how veterinary technicians and assistants can be fully utilized, the challenge of finding and retaining excellent staff, and the importance of open communication. Discussion will be encouraged as to how we (AAEP and AAEVT) can better support our members; find solutions to the challenges our individual professions face; and work together to better serve our practices, ourselves, our clients, and the horse.

USDA Accreditation Training

Tuesday, Dec. 7

The USDA's National Veterinary Accreditation Program on Dec. 7 will offer 8 hours of sessions applicable to the mandatory training requirements for accreditation renewal. When available, a schedule of these sessions with descriptions will be accessible through the "Sessions" link at convention.aaep.org.

WEDNESDAY December 8

Morning

In-Depth: Respiratory Diseases in Horses

Moderator: Renaud Léguillette
Sponsored by CareCredit.

8:00 a.m. What Do We Know About the Pathophysiology of Equine Asthma? – *Laurent Couëtil*

9:00 a.m. Exercise-Induced Pulmonary Hemorrhage – An Occupational Hazard of High-Speed Exercise – *Warwick Bayly*

10:00 a.m. Treatment and Management of Equine Asthma (Mild, Moderate, and Severe) – *Renaud Léguillette*

11:00-11:30 a.m. Panel Discussion with the Speakers

Imaging

Moderator: Meghann Lustgarten
Sponsored by Hallmarq – your trusted imaging partner for improved animal health.

8:00 a.m. How to Perform an Equine Esophagram – *Elizabeth V. Acutt*

8:20 a.m. Deep Digital Flexor Tendon Lesions in the Pastern Are Associated with the Presence of Distal Tendinopathy – *Elizabeth V. Acutt*

8:40 a.m. Comparison of Bone Scintigraphy and Standing ^{18}F-NaF Positron Emission Tomography for Imaging of the Fetlock in Thoroughbred Racehorses – *Mathieu Spriet*

9:00 a.m. Longitudinal Monitoring of Fetlock Injuries in Thoroughbred Racehorses Using Standing ^{18}F-NaF Positron Emission Tomography – *Mathieu Spriet*

9:20 a.m. External Transcutaneous Ultrasound Technique in the Equine Cricoarytenoideus Dorsalis Muscle: Assessment of Muscle Size and Echogenicity with Resting Endoscopy – *Masato Satoh*

9:40 a.m. Comparison of Transrectal and Transabdominal Transducers in Identification of Pathology in Horses Presenting with Colic – *Hanna Haardt*

10:00-10:45 a.m. Panel/Q&A

Responsible Use of Antibiotics in Equine Practice: Strategies in Human and Veterinary Medicine

Moderators: Mats Troedsson and Lucas Pantaleon
Sponsored by Platinum Performance, "Good Nutrition is Good Medicine."

8:00 a.m. Human Health and AMR: Where Are We? – *Melinda Neuhauser*

8:20 a.m. Antibiotic Resistance in Farms: The Role of *R. equi.* – *Nathan Slovis*

8:40 a.m. Antibiotic Resistance in Small Animals and Interjection with Humans – *Megin Nichols*

9:00 a.m. Antibiotic Stewardship Program at a Veterinary Hospital – *Emily Feyes*

9:20 a.m. Antibiotic Use in Swine Medicine – *Heather Fowler*

9:40 a.m. Break

9:55-11:00 a.m. Panel Discussion with the Speakers

Consent to Use Photos

Registration and attendance at, or participation in, AAEP meetings and related activities constitutes an agreement by the registrant to AAEP's use and distribution of the registrant or attendee's image or voice in photographs, videotapes, electronic reproductions and audio tapes of such events and activities.

Bring the kids to Nashville

On-site childcare services available

Don't let unsettled childcare stand between you and your convention participation. KiddieCorp will again provide a quality, low child-to-staff children's program for ages six months to 12 years at the Music City Center. Snacks and beverages will be provided but meals must be supplied by parents. The children's program will be available Sunday, Dec. 5 through Wednesday, Dec. 8. To register your child(ren) or for more information, including the daily schedule and cost, visit convention.aaep.org/childcare.

TRAINING SESSIONS

Emergency management and dry labs

Veterinarians' Role in Emergency Management

Saturday, Dec. 4, Music City Center
1:30-5:00 p.m.
Moderator: John Madigan
Sponsored by The Foundation for the Horse.

Acquire the training and know-how to participate with local, regional, state, and national disaster management efforts. Topics will include the Incident Command System; training requirements; emergency planning structure and process; role of veterinarians in the planning process, evacuation, rescue, medical support, and sheltering; commonly encountered injuries and illnesses; and psychological impacts of being a first responder along with methods to prevent and deal with these issues.

This session is open to all attendees at no additional cost and with no advance registration necessary.

Presenters: Wesley Bissett, Wally Liberman, John Madigan, and Claudia Sonder

Clinical Skills Dry Labs

Sunday, Dec. 5, Music City Center
Session 1: 10:00 a.m.-noon
Session 2: 1:00-3:00 p.m.
Session 3: 3:30-5:30 p.m.
Cost: $250 per session (AAEP members only)
Attendance cap: 12 per lab session
Registration is on a first-come basis at **convention.aaep.org** or by phone at (859) 233-0147.

Enhance patient care by learning a new clinical technique or refreshing your existing skill set. All labs will be offered during each of the three sessions. Register for up to three of the following labs:

Lab A: Tendon Sparing Navicular Bursa Injection

Lab B: Tips on Collection, Processing and Interpretation of Endometrial Culture and Cytology

Lab C: Ultrasound-Guided Spinal Joint Injections

Lab D: Practical Skills in Podiatry

A detailed description of each dry lab is available at convention.aaep.org/dry-labs.

Broaden Your Horizons

Connect with employers during Convention Career Fair

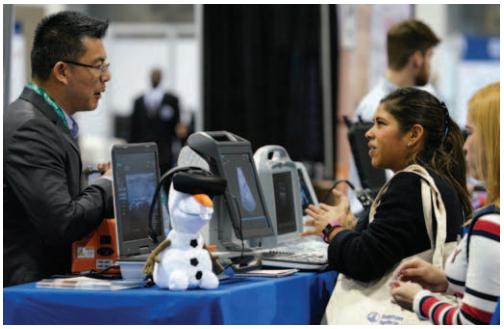
Are you in between jobs or looking for a new opportunity? Let AAEP help get your résumé in front of practices looking to hire at convention.

Meet with employers and recruiters to discuss your skill set and qualifications for their job openings. Here's how. Beginning Oct. 15:

1. Create or log in to your AAEP Career Center account at jobs.aaep.org.
2. Upload your résumé if you haven't already done so.
3. Indicate on your account page that you'll be attending the Career Fair at the convention, which will flag your résumé for participating employers to review and contact you (confidentially if you prefer).

You'll also be able to view a list of participating employers and create email job alerts to be notified of new Career Fair listings.

If you have questions about the Career Fair, contact Megan Gray, member concierge, at mgray@aaep.org.



AAEP Trade Show

Sunday, Dec. 5 - Tuesday, Dec. 7
Dec. 5: 10:00 a.m.-6:00 p.m.
Dec. 6: 10:00 a.m.-6:00 p.m.
Dec. 7: 10:00 a.m.-4:00 p.m.

Finding the right solutions providers is essential to practice success. Discover the latest technologies, services and products to improve your practice inside the trade show and pick up some free swag too! A complete list of exhibitors is available on the AAEP Convention App or at convention.aaep.org.

While in the trade show, grab a lunch included with your registration and stop by **AAEP Connect**, where you can chat with association and foundation staff, shop at the General Store, host a meeting, recharge your devices and get your shoes shined. Enjoy the following complimentary services within AAEP Connect:

Meeting Pods

Sponsored by EQUUS *and* EquiManagement*: Your sources for horse health and veterinary business information.*

Need to host a meeting during the convention? Four meeting pods are available for use during trade show hours. Reserve your meeting time at the *EQUUS/EquiManagement* booth. A charging station for your phone, tablet or laptop is available near the meeting pods.

Shoeshine Service

Sponsored by Dechra Veterinary Products.
Sunday, Dec. 5-Monday, Dec. 6, 11:00 a.m.-4:00 p.m.
Tuesday, Dec. 7, 11:00 a.m.-2:00 p.m.

Restore your shoes or boots to their original luster with a complimentary shoeshine from the professionals with Wells Shoeshine Service.

Portrait Hub

Monday, Dec. 6-Tuesday, Dec. 7, 11:00 a.m.-1:00 p.m.

Make your first impression count with a complimentary professional portrait for use on your practice website and social media channels.

Trade Show Reception

Sunday, Dec. 5, 5:00-6:00 p.m.

Enjoy complimentary wine while shopping for your next practice investment or simply exploring the offerings from more than 300 exhibitors.

Stable Education Product Demonstrations

Monday, Dec. 6-Tuesday, Dec. 7, 11:00 a.m.-1:00 p.m.

Grab lunch and find a seat in the Stable Education Area in the food court where exhibitors will conduct 15- or 30-minute product demonstrations, research presentations and new equipment introductions. The line-up of presentations will be available on the convention app, at convention.aaep.org and in the convention program on-site.

The material presented has not undergone review by the AAEP Educational Programs Committee and does not reflect the opinions or views of, or an endorsement by, the AAEP. No CE credit is given for these sessions.

Coffee Café

Satisfy your sweet tooth during lunch each day of the trade show at the Coffee Café in the AAEP Connect area. Indulge in complimentary sweets, treats and little eats while supplies last.

Trade Show B-I-N-G-O!

Using the bingo card in your convention bag, travel through the trade show and collect stickers on every exhibitor name. Submit your completed card at the AAEP booth for a $10 AAEP General Store gift certificate and to be entered in daily drawings for prizes, including Fitbits, VISA gift cards and more.

Welcome Reception
Sponsored by Rood & Riddle Equine Hospital and Nutrena®.
Saturday, Dec. 4, 5:30-7:00 p.m.

The traditional social kickoff takes on added meaning this year as you renew friendships face-to-face with colleagues, many likely not seen in person since before the pandemic began. Enjoy camaraderie, drinks and hors d'oeuvres.

Avenues Internship/Externship Career Night
Sponsored by Merck Animal Health.
Sunday, Dec. 5, 5:30-7:00 p.m.

Avenues practices: Find your next intern or extern among hundreds of capable students looking to further their training and launch their careers.

New Practitioners' Reception
Sponsored by IDEXX, the worldwide leader in veterinary diagnostics.
Sunday, Dec. 5, 6:30-8:00 p.m.

Expand your professional network among colleagues in their first 5 years of practice during this casual gathering offering complimentary food and beverage. During the reception, obtain a professional headshot photo at no charge to update your practice website and social media presences.

Student Faculty Advisors' Breakfast
Monday, Dec. 6, 6:30-7:30 a.m.

Faculty advisors from participating veterinary schools are invited to a casual breakfast and discussion of issues relevant to AAEP student programming.

Alumni Receptions
Monday, Dec. 6, 6:00-8:00 p.m.

Catch up with former classmates and meet recent graduates from your alma mater! A complete list of schools hosting a reception will be published in the convention program and on the convention app. For more information, call the AAEP office or check with your school's alumni office.

Christian Veterinary Mission Evening Seminar
Monday, Dec. 6, 6:30-7:30 p.m.

Enjoy an evening of fellowship, and hear how missions and veterinary medicine work together to make a difference across the globe! Open to all and registration is not required.

Storytelling Nashville Style

Benefiting The Foundation for The Horse

Sunday, Dec. 5, 8:00-10:30 p.m.
$75 *(includes a complimentary beverage & gift to The Foundation)*
Ticket required

Join us for an unforgettable night in which legendary storytelling is performed by some of the best singer/songwriters in Nashville. The lineup includes Grammy-winning artist Rory Feek and a couple of his hit-writing friends, Wynn Varble and Brice Long. These talented storytellers have written some of Nashville's biggest hits. Come check them out as they perform their music live with some of our ultra-talented veterinarian storytellers.

Join in the fun and celebrate raising funds for The Foundation for the Horse!

International Events

Sponsored by Antech, SOUND®, Your Worldwide Equine Diagnostic and Imaging Partner. Visit Booth 423 for more information.

These special events are exclusively for AAEP's international members outside of North America.

International Members' Breakfast
Monday, Dec. 6, 6:30-8:00 a.m.

Enjoy a light breakfast and discussion of pertinent issues affecting the profession on a global level.

International Members' Reception
Monday, Dec. 6, 6:30-8:00 p.m.

Meet and network with your fellow members from over 60 countries. Refreshments provided.

Christian Veterinary Mission Fellowship Breakfast
Tuesday, Dec. 7, 7:00-7:50 a.m.

Enjoy free breakfast, worship and fellowship with the CVM and other veterinary professionals. Open to all and registration is not required.

The President's Luncheon
Tuesday, Dec. 7, 11:30 a.m.-1:30 p.m. $60

Join AAEP officers, board members and honorees for lunch as we salute the outstanding contributions of leadership and volunteer service to the AAEP during our awards presentation. Outgoing board members will be recognized and new board members introduced.

After Party

Sponsored by Zoetis, "For Animals. For Health. For You."
Tuesday, Dec. 7, 6:30-10:30 p.m.
Wildhorse Saloon – Downtown Nashville
Free for all registered attendees and exhibitors.
Ticket required. RSVP when completing your convention registration.

Make it a night to remember in the Music City at the world-famous Wildhorse Saloon with music, dancing, food and more. Unwind from a day of learning with your AAEP family during an unforgettable celebration in the heart of downtown Nashville. Although the Wildhorse Saloon is within walking distance, shuttles also will be provided from the Music City Center.

Council and Committee Meetings

Council and committee meetings are open to all AAEP members unless specified otherwise. These meetings will conclude with a brief "closed" business session for council/committee members only. Meeting days and times are subject to change.

Saturday, Dec. 4

8:00-10:00 a.m.	Member Engagement Committee Performance Horse Committee Welfare & Public Policy Advisory Council
10:00 a.m.-Noon	Foundation Advisory Council Professional Conduct & Ethics Committee*
1:00-2:30 p.m.	Educational Programs Committee
1:00-3:00 p.m.	Infectious Disease Committee Racing Committee

Sunday, Dec. 5

4:00-5:30 p.m.	President's Advisory Council*

**Open only to members of the council or committee*

Health & Safety Guidelines

The AAEP and the Music City Center are committed to protecting the health and safety of our convention attendees. The AAEP will follow the most current guidance from the Centers for Disease Control and Prevention at the time of the event regarding the wearing of masks. The Music City Center has earned accreditation as a Global BioRisk Advisory Council (GBAC) STAR™ Facility for their stringent cleaning, disinfecting and infectious disease prevention processes. Learn more at convention.aaep.org.

General Membership Meeting

Monday, Dec. 6, 5:15-6:00 p.m.

Discover the AAEP's progress on issues important to the association, profession and industry during the past year during this 45-minute annual business meeting.

PARTNER SUNRISE SESSIONS

Rise and Shine!

Join AAEP Educational Partners for a complimentary breakfast (while supplies last) and exploration of a variety of equine healthcare and practice topics on Dec. 5-6 in the Music City Center.

Sunday, Dec. 5

6:30-7:30 a.m.

Innovation in Equine Asthma: Roundtable Discussion of the Use of Aservo® Equihaler® – *Sarah Reuss, Moderator.*
Hosted by Boehringer Ingelheim.

Infectious Disease Updates and Technology for Track and Trace – *Kevin Corley and Nicola Pusterla.*
Hosted by Merck Animal Health.

Healing with Horse Power: An Expert Panel on Regenerative Medicine – *Angela M. Gaesser, Laurie Goodrich, William King, and Tim Ober.*
Hosted by Zoetis.

Where Emotions and Economics Collide: Bridging the Gap Between Cost and Care – *Amy L. Grice.*
Hosted by CareCredit.

Monday, Dec. 6

6:30-7:30 a.m.

Equine Wellness Monitor: Improved Nutrition Through 3D Technology – *Abby Keegan.*
Hosted by Cargill.

New Research to Inform Feeding Recommendations for Senior Horses – *Mary Beth Gordon.*
Hosted by Purina.

Bisphosphonates in Veterinary Medicine: A New Horizon for Use. A Comparative Discussion of Veterinary vs. Human Usage – *Larry J. Sulva and Ashlee E. Watts.*
Hosted by Dechra Veterinary Products.

Redefining DJD Diagnosis, Refining Treatment, and Mastering Client Communication – *Speaker TBD.*
Hosted by American Regent Animal Health.

The material presented is done so at the discretion of the Educational Partner; does not reflect the opinions or views of, or an endorsement by, the AAEP; and has not undergone review by the Educational Programs Committee. No CE credit is given for these sessions unless RACE approval has been previously obtained by the presenting company.

Choose your preferred registration option

The 2021 Convention offers two registration options: in-person and virtual.Please read the following to determine which option is right for you!

In-Person Registration includes four days of educational sessions offering more than 150 CE hours from which to choose; access to the three-day Trade Show with more than 300 exhibitors plus lunch each day; the *Proceedings* book; and free social events like the Welcome Reception and The After Party. The in-person event takes place Dec. 4-8. All in-person attendees also receive on-demand access to video recordings of all Convention sessions and can participate in the live post-Convention Table Topics to be held virtually Dec. 13-17.

Virtual Registration includes on-demand access to 24 educational sessions plus live post-Convention Table Topics to be held virtually Dec. 13-17. On-demand viewing will be available beginning Dec. 13, with all sessions available for viewing by Dec. 31. The *Proceedings* book will be mailed to all virtual registrants.

Both in-person and virtual registration can be completed at convention.aaep.org.

Note: Sessions are available on-demand indefinitely for both virtual and in-person convention registrants. CE hours from on-demand sessions can be earned through March 31, 2022.

Hotel Accommodations

For your convenience, AAEP has secured room blocks at the seven hotels listed on page 20. The daily rate listed under each hotel name is for single/double occupancy and excludes 14.25% hotel tax and any applicable parking fees.

The deadline to reserve a room at the AAEP rate, cancel a reservation or make changes is Nov. 10. Please book your hotel room online at convention.aaep.org. **You must be registered for the convention to book a hotel room at the AAEP rate.**

Catch live music at Nashville's renowned honky-tonks on Lower Broadway, just a short walk from convention hotels.

Register for in-person by Sept. 15 and save $200

Register Online
Register online at convention.aaep.org. Annual dues must be current to register at the member rate. Hotel reservations can also be made through the site. Your convention registration confirmation will be automatically emailed.

Register by Mail or Fax
Photocopy the registration form and send with your payment by Nov. 10. Your canceled check will serve as your receipt. By including your credit card number on the form, you may fax us your registration at (859) 233-1968. You may make extra photocopies to register additional people. Confirmation will be emailed when your registration is processed.

Register On-Site
Register at the Music City Center beginning Dec. 3 at 3:00 p.m. Attendees registering at the student or resident/intern rate must present verification of enrollment in a veterinary school or a letter from an internship practice. New member registrants must present their DVM license or diploma.

Cancellation Policy
To ensure complete flexibility for our attendees during the COVID-19 pandemic, the AAEP will provide a full refund should you decide to cancel your registration. All registration cancellations should be submitted in writing to Kristin Walker at kwalker@aaep.org by Dec. 4.

Special Needs
If you require special accommodations to fully participate, attach a statement of needs to your registration form.

We Promise
We're so proud of the quality program that we promise to refund your registration fee if, for any reason, you are not satisfied with your convention education experience.

Contact Us
For more information, email Kristin Walker at kwalker@aaep.org; or call (800) 443-0177 (U.S. and Canada) or (859) 233-0147.

Disclosure

I understand that my participation in the event involves a certain degree of risk of loss, harm or injury to my person or property, including, but not limited to, harm from contracting COVID-19 or other viruses, acts of God, theft, fire or accident. I also understand that participation in this event is entirely voluntary and that the AAEP requires attendees to abide by any applicable rules of conduct or local or state laws that may be announced at any time during the event, which may include wearing personal protective gear and engaging in social distancing. While AAEP is the sponsor of this event and takes commercially reasonable steps to require the event facility to maintain the venue in a safe and healthy condition, I understand and acknowledge that AAEP has no direct control over and is not responsible for the acts or omissions of the facility or others involved in producing this event. I have carefully considered the risk involved and waive and release AAEP and all its officers, directors, employees, staff, volunteers, faculty and affiliates from any and all claims, damages, injuries, or expenses that I may incur from my participation in this event.

Thanks to Convention Organizers

This meeting is brought to you by the combined efforts of the program chair, Educational Programs Committee and Scientific Review & Editorial Committee.



From left:

Emma Read, DVM, MVSc, DACVS – Program Chair

Charles Scoggin, DVM, MS, DACT – EPC & SREC Chair

Erin Contino, DVM, MS, DACVSMR – EPC & SREC Vice Chair

The AAEP also thanks the following members of the EPC and/or SREC for their efforts organizing the 67th Annual Convention:

Liz Arbittier, Leea Arnold, Heidi Banse, Myra Barrett, Beth Biscoe, Raul Bras, Jim Bryant, Ben Buchanan, Anna Chapman, Ty Corbiell, Ashley Craig, Josh Donnell, Jack Easley, Leslie Easterwood, Ryland Edwards, III, Aimee Eggleston Ahearn, Robyn Ellerbrock, Ryan Ferris, Rob Franklin, Bill Gilsenan, Casey Gruber, Scott Hay, Nick Huggons, Laura Javsicas, Amy Johnson, Cody Johnson, Sherry Johnson, Barbara Jones, Kelley Jones, Lisa Katz, Melissa King, Craig Lesser, Meghann Lustgarten, Tim Lynch, Valerie Moorman, Peter Morresey, Meg Mullin, Taylor Myers, Britany Nehring-Lappin, Karen Nyrop, Ashley Olds-Sanchez, John Peloso, Mike Pownall, Alfredo Romero, Sarah Sampson, Nicole Scherrer, Carrie Schlachter, Lauren Schnabel, Maria Schnobrich, Katie Seabaugh, Jeremy Shaba, Debbie Spike-Pierce, Mike Tomlinson, Amanda Trimble, Claudia True, Jeremy Whitman, Cara Wright, Kate Wulster, and Luke Bass (board liaison).

AAEP 67TH ANNUAL CONVENTION
Advance Registration Form

After Nov. 10, please register online or on-site at the convention.

Full name: _____ _____ _____
FIRST MIDDLE LAST

Credential (DVM,VMD, etc.): _____ Preferred first name on badge: _____

Address: _____ City: _____

State: _____ Postal Code or Zip: _____ Country: _____

Phone: _____ Cell Phone (optional): _____ Fax: _____

Vet License # and State (U.S. registrants only): _____

Do you want to receive a copy of the *Proceedings* book on-site? ❒ Yes ❒ No
If you choose to not receive a Proceedings *copy, you will still have access to the publication digitally.*

Email: _____ ❒ Please remove me from all exhibitor mailing lists

Dietary requirements: ❒ Vegetarian ❒ Vegan ❒ Gluten Free ❒ Vegetarian & Gluten Free
❒ Vegan & Gluten Free ❒ Other, I will make other arrangements ❒ I do not have any meal requirements

Emergency contact name (required): _____ Phone: _____

Full name of guest (limit 2 per member): _____

Preferred first name on guest badge: _____

Address/City/State/Zip Code (guest): _____

Phone (guest): _____ Email (guest): _____

❒ **First-time convention attendee**

	Thru Sept. 15	Thru Dec. 1	After Dec. 1	Total
A. ❒ AAEP Member	$575	$675	$775	_____
B. ❒ AAEP Honor Roll Member	300	300	400	_____
C. ❒ Guest Attending Sessions*	575	675	775	_____
D. ❒ Guest Pass**	30	30	50	_____
E. ❒ AAEP New Member Applicant	850	930	1,030	_____
F. ❒ Non-Member	995	995	1,095	_____
G. ❒ Current Resident or Intern	350	350	450	_____
H. ❒ Storytelling Nashville Style (per person) Qty ____ Dec. 5	75	75	75	_____
I. ❒ President's Luncheon (per person) Qty ____ Dec. 7	60	60	60	_____
J. ❒ After Party (Dec. 7; ticket required)				Free
K. ❒ Dry Lab Experiences	**(Register online or by phone; see page 12)**			
L. ❒ Virtual Convention Option	**(Register online; see page 17)**			

* *Can be purchased only by AAEP members. Limit 2 per member.*
** *Can be purchased only by registered attendees. No access to sessions. Limit 2 per attendee.*

Total: _____

❒ I have read and agree to the disclosure statement on page 18

Payment Method: ❒ Visa ❒ MasterCard ❒ American Express ❒ Discover Card ❒ Check enclosed _____

Card #: _____ Expiration: _____ CVV Code: _____

Signature: _____ Date: _____

Return your registration and payment (if applicable) to AAEP in the enclosed envelope; or via fax with credit card information to (859) 233-1968. Last day to register by mail or fax is Wednesday, Nov. 10.

OFFICIAL HOUSING MAP: DOWNTOWN NASHVILLE

1. **Omni Nashville – Headquarters Hotel**
   $248/night
   250 Rep. John Lewis Way South (5th Avenue South)
   Adjacent

2. **The Westin Nashville**
   $269/night
   807 Clark Place
   Adjacent

3. **JW Marriott**
   $256/night
   201 8th Avenue South
   Adjacent

4. **Hilton Nashville Downtown**
   $235/night
   121 4th Avenue South
   1 block

5. **Hyatt Place Nashville Downtown**
   $209/night
   301 3rd Avenue South
   2 blocks

6. **Hilton Garden Inn Nashville Downtown/ Convention Center**
   $209/night
   305 Korean Veterans Boulevard
   2 blocks

7. **Renaissance Nashville Hotel**
   $225/night
   611 Commerce Street
   3 blocks

*** Distances noted are in relation to Music City Center**

MERCK Animal Health

FEATURED SPEAKERS & TOPICS

KEYNOTE:
Dr. Charlotte Lacroix
Understanding Personal Net Worth Is More than Finances

Dr. Bill Gilsenan: *Field Assessment of the Foal*

Dr. Amy Grice: *Communication*

Dr. Nicola Pusterla: *EPM, Coronavirus*

Dr. Jennifer Quammen: *Technicians Role in Connected Care and Telemedicine*

Chris Rizzo, LVT, VTS-EVN: *Wound Management*

Dr. Kurt Selberg: *Imaging*

Dr. Nathan Slovis: *Hematology*

Dr. Claudia Sonder: *Managing the Evacuated Horse in a Fire*

Dr. Kelly Zeytoonian: *Innovative Practice Models—Utilizing Staff*

We're Back, and We've Missed You!

The AAEVT welcomes ALL veterinary technicians, assistants, students, and support staff to join our Association at the 17th Annual AAEVT Convention.

Featuring special sessions for receptionists and office managers.

SATURDAY, DEC. 4

Conference registration 1:00-4:00 p.m.
Music City Center

3:00 - 5:00 p.m.	Roundtables & Workshops
5:30 - 7:00 p.m.	AAEP Welcome Reception

SUNDAY, DEC. 5

8:00 - 10:00 a.m.	Registration & Breakfast
10:30 a.m. - Noon	Keynote: Dr. Charlotte Lacroix
Noon - 1:30 p.m.	AAEVT Membership Meeting & Lunch
1:30 - 5:30 p.m.	Lecture & Scientific Sessions
5:30 - 7:30 p.m.	AAEVT Social, Scholarship Raffle & Silent Auction

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Noon - 1:30 p.m.	Lunch break
1:30 - 5:30 p.m.	Lecture Sessions

Exhibit Hall hours: 10:00 a.m. - 6:00 p.m.

TUESDAY, DEC. 7

8:00 a.m. - Noon	Lecture Sessions
Noon - 1:30 p.m.	Lunch break
1:30 - 4:30 p.m.	Lecture Sessions & Case Studies
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Highlights of recent clinically relevant papers

High-serum GGT activity in racehorses

This study by Sabine Mann and co-workers in the USA aimed to evaluate the role of oxidative stress, cholestasis, liver injury and infection with equine hepacivirus (EqHV) or equine parvovirus-hepatitis (EqPV-H) infection in racehorses with increased serum gamma-glutamyl transferase (GGT) activity.

The work consisted of a pilot study with eight horses with elevated serum GGT activity (≥50 U/L) and eight controls with normal GGT activity, followed by a larger study with 27 case-control pairs from three different yards. Serum liver chemistries, selenium measurements, viral PCR, and metabolomics were performed.

With both studies combined, the overall prevalence of EqHV was 9% and the overall prevalence of EqPV-H was 36%. There was no difference in prevalence or copy numbers between cases and controls for either virus. Cases had decreased serum selenium concentrations, higher serum glutamate dehydrogenase (GLDH) and alkaline phosphatase (ALP) activities and higher serum bile acid concentrations compared to controls. Metabolomics findings were not consistent between the two studies, with different metabolites emerging from each analysis. The authors concluded that the mechanism underlying high GGT activity in this population is likely complex and multifactorial, involving hepatic injury and possible cholestasis as well as oxidative stress. EqHV or EqPV-H infections are unlikely to be the primary cause for the high GGT syndrome seen in Thoroughbred racehorses.

Osteoarthritis prevention using MSCs

In this study Lélia Bertoni and co-workers in France evaluated allogeneic bone-marrow-derived and umbilical cord blood-derived mesenchymal stem cells (MSCs) to prevent the development of osteoarthritis (OA) in an equine model.

Osteoarthritis (OA) is a significant cause of pain in both humans and horses. In both species, regenerative therapy with allogeneic MSCs appears to be a promising treatment but, to date, no in vivo studies have attempted to compare the effects of different cell sources on the same individuals. This study evaluated the ability of a single blinded intra-articular injection of allogeneic bone-marrow (BM) derived MSCs and umbilical cord blood (UCB) derived MSC to limit the development of OA-associated pathological changes compared to placebo in a post-traumatic OA model applied to all four fetlock joints of eight horses. The effect of the tissue source (BM vs. UCB) was also assessed on the same individuals.

Observations were carried out using clinical, radiographic, ultrasonographic, and magnetic resonance imaging methods as well as biochemical analysis of synovial fluid and post-mortem microscopic and macroscopic evaluations of the joints until Week 12. A significant reduction in the progression of OA-associated changes measured with imaging techniques, especially radiography, was observed after injection of bone-marrow derived mesenchymal stem cells (BM-MSCs) compared to contralateral placebo injections. These results indicate that allogeneic BM-MSCs are a promising treatment for OA in horses and reinforce the importance of continuing research to validate these results and find innovative strategies that will optimise the therapeutic potential of these cells. However, they should be considered with caution given the low number of units per group.

Equine coronavirus outbreak in Japan

In this study Yoshinori Kambayashi and co-workers in Japan investigated an outbreak of equine coronavirus (ECoV) infection among riding horses in Tokyo, Japan.

An outbreak of ECoV infection occurred among 41 horses at a riding stable in Tokyo, Japan in 2020. This stable housed 16 Thoroughbreds and 25 horses of other breeds, including Andalusians, ponies and miniature horses. Fifteen horses (37%) showed mild clinical signs such as fever, lethargy, anorexia and diarrhoea, and they recovered within 3 days of onset. A virus neutralisation test showed that all 41 horses were infected with ECoV, signifying that 26 horses (63%) were subclinical.

The results suggest that subclinical horses played an important role as spreaders. A genome sequence analysis revealed that the lengths from genes p4.7 to p12.7 or NS2 in ECoV differed from those of ECoVs detected previously, suggesting that this outbreak was caused by a virus different from those that caused previous outbreaks among draught horses in Japan. Among 30 horses that tested positive by real-time RT-PCR, ECoV shedding periods of non-Thoroughbreds were significantly longer than those of Thoroughbreds. The difference in shedding periods may indicate that some breeds excrete ECoV longer than other breeds and can contribute to the spread of ECoV.

Use of *S. equi* ELISA in vaccinated horses

The dual antigen iELISA uses two Streptococcus equi ssp. equi *surface protein antigens composed of N-terminal portions of SEQ2190 (Antigen A) and SeM (Antigen C). It is currently used to identify animals exposed to* S. equi *which have developed an immune response to the target antigens. This prospective case-control study by Ashley Boyle, and co-workers in the USA and UK investigated the usefulness of the ELISA in horses vaccinated with a live attenuated intranasal vaccine against* S. equi.

The study consisted of 26 horses vaccinated annually with Pinnacle® IN and 26 non-vaccinated horses. Blood samples were obtained at annual strangles vaccination, 5 weeks post-vaccination and 10 weeks post-vaccination in horses that received a booster. Seropositivity was defined as an OD450 nm value ≥0.5 for one or both antigens.

At the 5-week time point, 76% of vaccinated horses were seropositive compared to 4% of non-vaccinated horses. Vaccinated horses were 14 times more likely to be seropositive or suspect than non-vaccinated horses. The OD450 value was significantly larger for Antigen C (SeM) than Antigen A (SEQ2190) for vaccinated horses.

With a high rate of seroconversion to both antigens due to vaccination, the dual antigen ELISA is not recommended for the diagnosis of previous *S. equi* exposure in vaccinated horses.

Use of adhesive for anastomosis

This pilot study by Augustin Lenoir and co-workers in France compared the use of a UV-polymerizable methacrylate adhesive (UV-PMA) versus an inverting pattern as the second layer of a two-layer hand-sewn jejunal anastomosis in horses.

Resection and anastomosis of small intestine during colic can lead to adhesions and recurrent colic. Several methods are available to reduce the rate of adhesions in the post-operative period, such as the use of serosal barriers. Surgical glues form a smooth surface, are fast to apply, and could reduce surgery time when performing anastomosis. A recently developed UV-PMA is designed to anchor into the biological tissues' top surface offering sealant and a smooth cover over the anastomosis site. This adhesive was used ex vivo on 15 samples of equine jejunum as the second layer of a two-layer anastomosis (1L-UV-PMA group) and compared to a two-layer anastomosis (simple continuous pattern covered with a Cushing pattern; 2L-CT group), in terms of feasibility, bursting strength pressure (BSP), luminal diameter reduction (LDR), and time of construction. Data were analysed using a paired t-test or a chi-square test.

The results showed no statistical difference in BSP, LDR, or any mode of failure between the two anastomosis types. However, the glue anastomosis formed a tunnel-like anastomosis and shredded under pressure, before apparition of leakage, preventing its usage in clinical cases with this methodology. The authors concluded that modification of the technique is warranted before testing in clinical cases.

Topical ophthalmic atropine in horses

This study by Lena Ström and co-workers in Sweden, France and the UK investigated the administration of topical ophthalmic atropine in horses, including the pharmacokinetics and effect on intestinal motility.

Topical ophthalmic atropine sulfate is an important part of the treatment protocol in equine uveitis. Frequent administration of topical atropine may cause decreased intestinal motility and colic in horses due to systemic exposure. Little is known on atropine pharmacokinetics in horses and this knowledge gap could impede the use of atropine because of the presumed risk of unwanted effects. Additional information could therefore increase safety in atropine treatment.

Atropine sulfate (1 mg) was administered in two experiments: In part I, atropine sulfate was administered intravenously and topically (manually as eye drops and through a subpalpebral lavage system) to six horses to document atropine disposition. Blood-samples were collected regularly and plasma was analysed for atropine using UHPLC-MS/MS. Atropine plasma concentration was below lower limit of quantification (0.05 μg/L) within 5 h, after both topical and i.v. administration. Atropine data were analysed using population compartmental modelling and pharmacokinetic parameters estimated. The typical value was 1.7 L/kg for the steady-state volume of distribution. Total plasma clearance was 1.9 L/h/kg. The bioavailability after administration of an ophthalmic preparation as an eye drop or topical infusion were 69% and 68%, respectively. The terminal half-life was short (0.8 h). In part II, topical ophthalmic atropine sulfate and control treatment was administered to four horses in two dosing regimens to assess the effect on gastrointestinal motility. Borborygmi-frequency monitored by auscultation was used for estimation of gut motility. A statistically significant decrease in intestinal motility was observed after administration of 1 mg topical ophthalmic atropine sulfate every 3 h compared to control, but not after administration every 6 h. Clinical signs of colic were not observed under any of the treatment protocols.

Taking the plasma exposure after topical administration into consideration, data and simulations indicate that eye drops administered at 1 and 3 h intervals will lead to atropine accumulation in plasma over 24 h. A 6 h interval allows total washout of atropine between two topical administrations. If constant corneal and conjunctival atropine exposure is required, a topical constant rate infusion at 5 μg/kg/24 h offers a safe alternative.

S. WRIGHT
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Case Report

Multiple extra-pulmonary disorders associated with *Rhodococcus equi* infection in a 2-month-old foal

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Keywords: horse; *Rhodococcus*; uveitis; abscess; immune-mediated haemolytic anaemia

Summary

A 2-month-old Thoroughbred filly was referred to Hagyard Equine Medical Institute for further evaluation of acute pyrexia and a suspected intra-abdominal abscess based on abdominal ultrasound performed in the field. Upon initial presentation, ophthalmic examination findings were consistent with marked bilateral uveitis including blepharospasm, diffuse corneal oedema, hyphaemia and fibrin deposition (**Fig 1**). Fluorescein staining was negative. Polysynovitis involving the hocks, stifles, carpi and all four fetlocks was noted, with no associated lameness. Abdominal ultrasound examination findings were consistent with the presence of a large abdominal mass (8 cm × 12 cm). Thoracic ultrasonography revealed multiple non-specific multifocal superficial pleural irregularities cranioventrally on both sides, but no areas of consolidation were visualised. A transtracheal wash confirmed the presence of a multi-sensitive strain of *Rhodococcus equi*.

The foal was hospitalised, and medical treatment initiated based on initial examination findings including antimicrobials, nonsteroidal anti-inflammatory drugs, topical ophthalmic treatment, gastroprotectants and intravenous isotonic polyionic fluids. Anaemia and thrombocytopenia were noted during hospitalisation. Results of a Coombs test were consistent with an immune-mediated haemolytic process.

The filly was discharged on Day 13 but was sent back to the hospital several days later for respiratory distress and fever. Recurrent pyrexia, abdominal discomfort and severe respiratory distress unresponsive to intensive medical support motivated euthanasia followed by necropsy after 30 days of treatment.

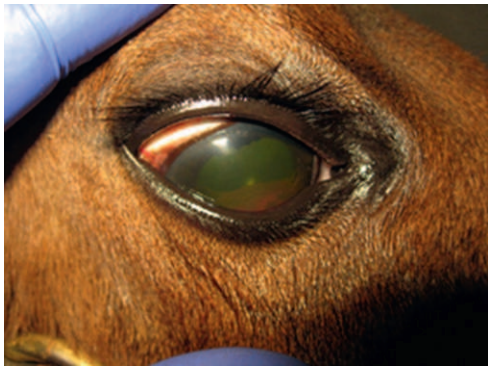

Fig 1: The right eye demonstrating signs of uveitis. Fibrin deposition and hyphaemia are visible ventrally.

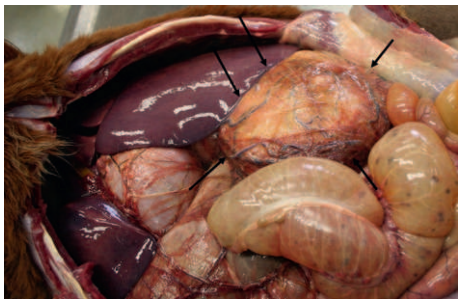

Fig 2: The abdominal cavity examined during necropsy. Abdominal abscess is delimited with black arrows.

Gross examination revealed diffusely dark red, heavy firm lungs with no observed pyogranulomas. Within the mesentery between the base of the caecum and large colon was a tan, multilobulated, semi-firm mass (26 cm × 16 cm × 7.5 cm) with pockets of caseous material (**Fig 2**). The mesenteric pyogranuloma weighed 2.4 kg. Histologically, a marked bronchointerstitial pneumonia with lesions compatible with acute respiratory distress and *Rhodococcus* pneumonia were observed. Pyogranulomas were not observed histologically. *Rhodococcus equi* was isolated from the mesenteric abscess and rare colonies cultured from the lung. The isolates were consistently susceptible to gentamicin, amikacin and imipenem and resistant to all other tested antimicrobials

Overall, six extra-pulmonary disorders were simultaneously diagnosed despite the lack of pulmonary pyogranulomas.

Key points

- Clinical disease due to *R. equi* infection most frequently manifests in horses as a bronchopneumonia with pulmonary pyogranulomas.
- This case with multiple extra-pulmonary disorders highlights the importance of a thorough and complete diagnostic work-up when *R. equi* is suspected as both prognosis and management of the case may be significantly affected.
- Immune-mediated mechanisms should be closely monitored as one of the possible consequences of *R. equi* infection.

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Case Report

Renal dysplasia, ectopic ureter, septic ureterectasia and cryptorchidism in an 11-month-old cob colt presenting with ascending pyoureter and pyocystis

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Keywords: horse; congenital urinary anomalies; renal dysfunction; hydroureter; pyoureter

Summary

An 11-month-old entire male cob colt was presented for unilateral cryptorchid castration and intermittent purulent urethral discharge. Normal urination had been observed in addition to the purulent discharge, and there had been no further health concerns noted. On presentation the colt was bright in demeanour with a normal appetite. Both urea and creatinine concentrations were within normal reference ranges. Cystoscopy, trans-cutaneous and trans-rectal abdominal ultrasonography and contrast-enhanced computed tomography confirmed unilateral cryptorchidism, ipsilateral renal dysplasia and pyoureter with dilatation and ectopia.

Cystoscopic examination identified mild mucosal erythema, and culture of the purulent material yielded a profuse, pure growth of *Streptococcus equi subspecies zooepidemicus*. The right ureteral opening had a normal appearance, and urine collected by catheterising the ureter was normal. The left ureteral opening could not be visualised; a bulge in the mucosa consistent with an intramural mass effect was noted at the level of the trigone ipsilaterally. Trans-cutaneous ultrasound examination at the anatomic region of the left kidney showed a tubular fluid-filled structure of mixed echogenicity. The normal discernible features of a left kidney could not be visualised. Computed tomographic (CT) examination of the abdomen under general anaesthesia was used to further identify the structures. This examination consisted of a noncontrast, followed by contrast-enhanced and a delayed post-diuretic (furosemide) CT examination to enable ureteral identification.

A large tortuous structure extending from the left retroperitoneal area tracking caudally to the region of the urinary bladder was identified. This structure was confluent with the bladder wall and coursed caudally to enter the urethra beyond the urethral sphincter, confirming ureterectasia and ectopia. Post-contrast images confirmed filling of the right ureter and urinary bladder with contrast material; however, only mild mural contrast enhancement of the tubular structure, consistent with persistent contrast within the mural vascular supply, was noted (**Fig 1**). There was no contrast present within the lumen at any time point, suggesting that the left kidney was either nonfunctional or the renal pelvis was discontinuous with the ureter.

The colt was subjected to euthanasia, and examination post-mortem confirmed a small, irregularly shaped left kidney with an enlarged renal pelvis that was continuous with a markedly distended ureter containing purulent material. An ectopic communication with the urethra was also confirmed.

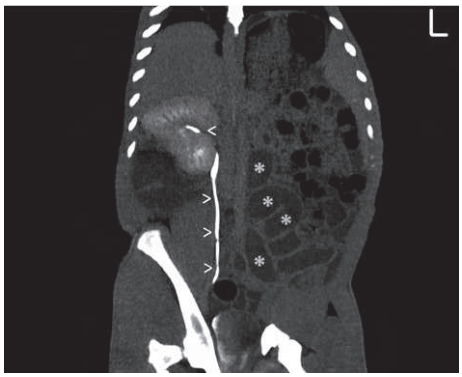

Fig 1: Dorsal plane thick slice reconstruction: white arrowheads indicate the normal contrast-filled right ureter with the distended tortuous left ureter shown with grey asterisks.

The intra-abdominal left testis was identified adherent to the caudal pole of the left kidney. Findings of histological examination of the left kidney were indicative of renal dysplasia.

While several reports exist of more than one concurrent congenital urogenital abnormality in an individual, to the authors' knowledge, concurrent renal dysplasia, pyoureter with dilatation and ectopia, and cryptorchidism have not been reported previously.

Key points

- A syndrome of cryptorchidism associated with renal and ureteral malformations has been reported in human patients, and a similar syndrome may exist within the equine population. Hence, multiple concurrent urogenital abnormalities should be considered in patients presenting for evaluation of a known urogenital abnormality such as cryptorchidism.
- Unilateral urinary tract malformation may not be associated with clinical signs and may be underdiagnosed.
- Contrast-enhanced computed tomography with delayed, post-diuretic ureteral enhancement may enable confirmation of renal dysplasia as well as ureteral ectopia.

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Case Report

Peritoneal fluid accumulation in the femoral canal as a result of a post-traumatic femoral hydrocele in a mature Warmblood stallion

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Keywords: horse; hernia; hydrocele; inguinal; femoral canal

Summary

A 14-year-old, 600 kg Warmblood stallion was evaluated for a swelling of the proximal medial aspect of the left thigh. The horse showed signs of discomfort on palpation of the swelling but was sound at the walk. The swelling continued to increase in size and reformed after surgical drainage. Ultrasonographic evaluation revealed a well-demarcated and encapsulated cavity containing anechoic fluid with fibrinous loculations surrounding the periphery of the cavity. Seventy-two days after the swelling developed, the horse was anaesthetised and positioned in dorsal recumbency for surgical exploration, debridement and reconstruction.

Once positioned in dorsal recumbency, the fluid-filled sac on the medial aspect of the left thigh reduced in size and a progressive swelling was noted in the left scrotum. Ultrasonography confirmed fluid accumulation between the parietal and visceral tunic (vaginal cavity) of the left testicle.

An inverted 'T' shaped incision was made over the fluid-filled sac for surgical access, and a thick capsule lining the fluid-filled cavity was identified and resected. As the incision was extended dorsally, it became evident that the fluid-filled sac communicated directly with the inguinal canal. An approximately 10 cm long tear was identified in the aponeurosis of the external abdominal oblique muscle, extending caudally from the superficial and deep inguinal rings (**Fig 1**). This tear allowed direct communication between the left scrotum and the fluid-filled sac. The spermatic cord was not located within the margins of the superficial inguinal ring or inguinal canal but located within the rent in the external rectus sheath as both deep and superficial inguinal rings were torn. Due to concern of increased risk of herniation of abdominal viscera secondary to the left inguinal canal trauma, an orchiectomy was performed.

The superficial inguinal ring and the tear in the rectus sheath were closed, the wound debrided, dead space obliterated and incisions closed. A drain was placed to facilitate post-operative drainage and a sterile bandage applied. The horse was discharged from the hospital 19 days after surgery, sutures were removed 25 days post-operatively and two-year follow-up confirmed the horse made a full recovery.

This case highlights an unusual trauma to the superficial and deep inguinal rings, the inguinal canal, the aponeurosis of the external abdominal oblique and its inguinal ligament and the related femoral ring anatomy resulting in accumulation of peritoneal fluid along the medial aspect of the left thigh, within and subsequently extending beyond the limits of the femoral canal.

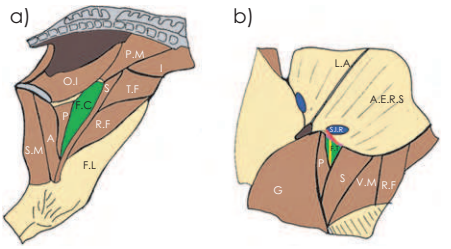

Fig 1: Anatomical depiction of the location of the tear through the superficial inguinal ring and external rectus sheath (red line). a) demonstrates the proximal and distal extent of the femoral canal on the medial aspect of the left thigh. b) is a caudoventral view of the inguinal region, dorsal is to the right, and the left hindlimb is abducted. The purple line indicates the vascular lacuna, and the yellow line denotes the passage of the neurovascular bundle and lymph nodes. A, adductor; A.E.R.S, aponeurosis of external rectus sheath; F.C, femoral canal; F.L, facia latae; F.T, femoral triangle; G, gracilis; I, iliacus; L.A, linea alba; O.I, obturator internus; P, pectineus; P.M, psoas major; R.F, rectus femoris; S, sartorius; S.I.R, superficial inguinal ring; S.M, semimembranosus; T.F, tensor faciae latae; V.M, vastus medialis.

Key points

- The vascular lacuna (femoral ring) forms a portion of the dorsal border of the femoral triangle and the apex of the femoral triangle gives rise to the femoral canal. In the intact state, the vascular lacuna is closed on the abdominal side by peritoneum and transverse fascia.
- Fluid accumulation along the medial aspect of stifle may be a result of fluid accumulation within the femoral canal because of inguinal trauma resulting in disruption to the femoral ring and triangle.
- Femoral hydroceles form thin-walled fluid-filled masses that communicate with the peritoneal cavity through the femoral ring.

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Case Report

A case of verminous mastitis in a mare

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Keywords: horse; mastitis; *Cephalobus*; nematode; thrombocytopenia

Summary

This report describes bilateral mammary gland infection with a previously unidentified *Cephalobus* species of environmental nematode. Only one previous case of verminous mastitis due to a *Cephalobus* species has been reported, pre-dating the widespread use of molecular diagnostics. A 12-year-old Boerperd mare was initially presented with a primary complaint of mild, bilateral, spontaneous epistaxis of 2 days' duration with no other symptoms. Endoscopy of the ventral nasal meati revealed mucosal petechiation. Seeping haemorrhage was observed to be coming from the nasal mucosa approximately 10 cm into the nasal passages bilaterally. No lesions were directly associated with the haemorrhaging area. Haematology demonstrated severe thrombocytopenia (2×10^9/L [$200–600 \times 10^9$/L]) and mild to moderate neutrophilia (2×10^9/L [$3.54–7.08 \times 10^9$/L]). Prothrombin time and activated partial thromboplastin time were mildly increased (20.1 s [13.4–19 s]; 90.7 [46.4–87.4 s]). As investigation for infectious diseases or other underlying pathologies revealed no abnormalities, a presumptive diagnosis of immune-mediated thrombocytopenia was reached. Immunosuppressive therapy was initiated with dexamethasone and subsequently azathioprine was added. On day 5, the mammary gland was observed to have swollen since presentation. It was neither hot nor painful, and clear fluid could be expressed from both sides. The following day, the mammary gland was warm and the mare showed signs of discomfort upon palpation. Milk-like fluid could be expressed from both sides. Fluid was submitted for cytology, which demonstrated the presence of multiple nematodes with concurrent neutrophilic inflammation (**Fig 1**). High numbers of nematodes of different sizes were present. Organisms ranged from around 50–250 μm in length. Various life stages including eggs were observed. Following receipt of this information, the mare was treated with a product containing ivermectin and praziquantel and the fluid samples were submitted for further nematode identification. Cold hosing of the mammary gland and intravenous flunixin therapy were also introduced. Thirteen days after admission, advice was received that the nematodes isolated from the mare's mammary gland were microscopically most consistent with a *Halicephalobus* species, despite some morphological inconsistencies. Given the severe, usually terminal pathology *H. gingivalis* can cause in human beings, the owners were advised that the public health implications of the horse's infection could not be definitively confirmed but were a concern. For this reason, humane euthanasia was advised and subsequently performed. Following pre-processing, nematode DNA extraction was performed, followed by completion of PCR and sequencing reactions. After further processing, the sample (GenBank accession number MK913516) was determined by BLAST to be closest (78% similarity) to an archived GenBank sequence from *Cephalobus cubaensis* strain PS-1197 (accession no. DQ903102.1). Sequencing data suggested that the nematode was a previously uncharacterised *Cephalobus* species. The contribution of the immunosuppressive drugs to the development of mastitis is unclear.

Fig 1:* Cephalobus *sp. female from a milk sample of a mare with arrows pointing on head (A), larvated egg in uterus (B) and tail (C) (×400 magnification).

Key points

- Invasive environmental nematode infection should be considered as a cause of mastitis in the mare.
- Cytology can provide useful information in the investigation of equine mastitis.
- Characterisation of free-living nematodes by microscopy is challenging and genomic sequencing enhances the probability of accurate identification.

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Case Report

Mammary botryomycosis and hemimastectomy in a post-partum Welsh Pony mare

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Keywords: horse; udder; mastitis; reproduction; surgery

Summary

A 9-year-old Welsh Pony mare presented 17 days post-partum for severe mastitis refractory to antimicrobial treatment. Mammary gland botryomycosis was suspected based on the clinical and ultrasonographic signs (abscesses and drainage tracks (**Fig 1**)). *Staphylococcus aureus* was isolated from the left mammary gland secretion. Hemimastectomy was performed after failure of medical treatment.

The mare was able to successfully nurse several foals following surgery suggesting that milk production from the remaining gland was sufficient to meet the foal nutritional requirements.

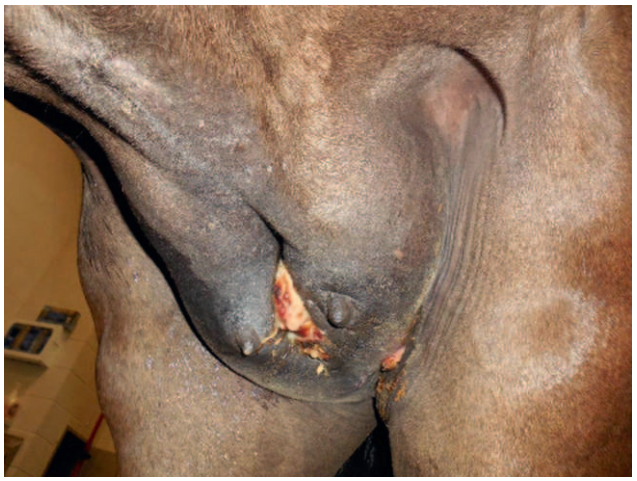

Fig 1: Appearance of the mammary gland, with left side enlarged showing ulcerations and purulent discharge.

Key points

- Mammary gland botryomycosis is a rare disease in equids but should be considered as a differential in cases of mastitis resistant to antimicrobial treatments.
- Ultrasonography and bacteriology are helpful in diagnosis of botryomycosis.
- Hemimastectomy is a good treatment option and does not jeopardise the chance for the mare to raise foals.

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Case Report

Suspected primary mycotic rhinitis and paranasal sinusitis in seven horses (2013–2019)

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Keywords: horse; mycosis; sinusitis; rhinitis

Summary

Sinonasal mycotic infections are uncommon diseases of the horse, and infective organisms are considered to be opportunistic. Medical records of horses diagnosed with primary sinonasal mycosis between January 2013 and January 2019 at a veterinary teaching hospital were reviewed.

Seven horses fulfilled the inclusion criteria over the study period. One horse was diagnosed with a primary mycotic rhinitis and six horses with primary mycotic paranasal sinusitis.

Clinical signs included unilateral mucopurulent nasal discharge (n = 6 horses), unilateral epistaxis (n = 4), facial deformity (n = 3), enlarged ipsilateral submandibular lymph node (n = 2) and lower eyelid swelling (n = 1). Clinical signs had been present for a few days to 5 months prior to presentation with no response to previous treatments.

Mycotic plaques were observed in the nasal portion of the ethmoidal labyrinth and ipsilateral nasal passage during rhinoscopy in one horse and in the paranasal sinuses during sinoscopy in six horses. The affected compartments included conchofrontal sinus (n = 6), caudal maxillary sinus (n = 5), rostral maxillary sinus (n = 2), conchal ventral sinus (n = 2) and sphenopalatine sinus (n = 1). Typical appearance showed areas covered by white-green material consistent with mycotic plaques, exudate and necrotic mucosa (**Fig 1**). Fungal culture was positive in five horses with predominance of *Aspergillus spp*. (n = 3).

All observed lesions were mechanically debrided under rhinoscopic guidance, sinoscopic guidance through a trephine hole or directly via a bone flap. A mean ± s.d. of 4 ± 2.9 debridement sessions was necessary to remove as much necrotic material. Medical treatment included topical application directly over the affected area with clotrimazole (**Fig 2**), enilconazole, nystatin or amphotericin B (mean of 10.1 ± 13.4 applications during hospitalisation) and additional inhalation of nystatin or amphotericin B (mean of 7.5 ± 2.7 days of nebulisation during hospitalisation). The mean ± s.d. duration of hospitalisation was 12.9 ± 9.2 days.

Six horses were available for long-term follow-up. The mean ± s.d. number of follow-up examinations was 2.8 ± 2.6 consultations. Based on follow-up endoscopic evaluations, it took up to 5 months for complete regression of the observable mycotic plaques.

In conclusion, mycotic rhinitis and sinusitis can be effectively treated with repeated surgical debridement and topical antifungal therapeutics, associated with a good prognosis.

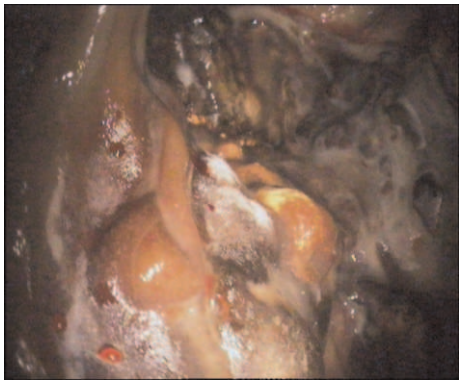

Fig 1: Necrotic material consistent with mycotic plaques observed during sinoscopy.

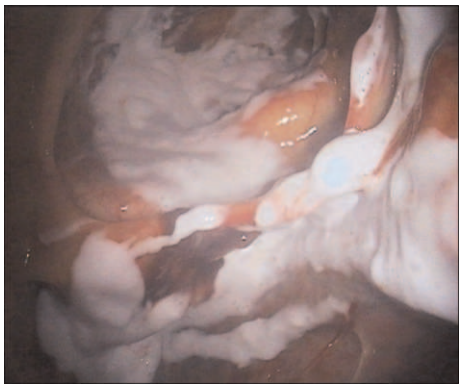

Fig 2: Mycotic sinusitis of the caudal maxillary sinus treated with topical application of clotrimazole under sinoscopic control.

Key points

- Diagnosing primary fungal infection in the upper portion of the respiratory tract is challenging because the clinician needs to exclude all other potential causes.
- Clinical signs are not specific, but sinonasal mycotic infection needs to be considered in cases of unilateral epistaxis.
- A combination of surgical debridement of the lesions and topical administration of antifungal agents is necessary to ensure a successful outcome.

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Clinical Commentary

Fungal infection of the upper respiratory tract in horses

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Fungal rhinitis is uncommon in horses, and its prevalence varies geographically (Stewart and Cuming 2015). The fungal invasion can present as an opportunistic infection as well as a primary infection such as the description in the case report by Pujol *et al*. (2021) in this issue of Equine Veterinary Education. The authors reported the clinical signs, diagnostic features, therapies and outcomes of seven horses with mycotic rhinitis and paranasal sinusitis to extend the knowledge in the management of this condition.

Overall, equine veterinary medicine is lacking of extensive and large studies in sinonasal mycosis to further understand the pathophysiology, early recognition and treatment of this disease in horses. This in addition the scarcity of cases with this condition increases the challenge for the equine practitioner to become comfortable diagnosing and treating these cases.

There is no pathognomonic clinical presentation of fungal infection of the upper airway in horses. Clinical signs include different types of nasal discharge, respiratory noise, coughing, facial deformities, lymphnode enlargement, dyspnoea, dysphagia, and presence of a protuberant mass at the nostrils, and these signs can vary depending on its chronicity, its nature and location within the respiratory tract (Ludwig *et al.* 2005; Stewart *et al*. 2008; Stewart and Cuming 2015). In advanced and chronic cases, the horse can present with neurological signs or fatal epistaxis if the mycotic plaque invades nerves and brain or the arterial blood supply, respectively (Borges and Watanabe 2011; Hunter and Nation 2011; Dobesova *et al*. 2012).

In addition to the clinical examination, blood work, upper airway endoscopy, sinoscopy and skull radiographs are commonly performed as diagnostic tools (Tremaine and Dixon 2001; Pollock 2007). Advanced imaging such as computed tomography (CT) and magnetic resonance imaging (MRI) are utilised to identify and further characterise the extent of the lesions. This case report by Pujol *et al*. (2021) highlights the use of CT to identify mycotic infection of the sphenopalatine sinus, which is otherwise very difficult to assess with skull radiographs and sinoscopy, and to rule out predisposing causes of sinusitis. Ultimately, histopathology and culture from fresh samples obtained during rhinoscopy, sinuscopy or surgery are used to confirm the clinical diagnosis and if possible identify of the pathogen. However, the results of fungal culture can take too long to yield results to be clinically useful, hence delaying appropriate treatment.

Identifying the correct fungi is important since some resistant strains are emerging in humans and animals (Seyedmousavi *et al*. 2015, 2018). Results by Pujol *et al*. (2021) revealed five out of six positive fungal culture results, with *Aspergillus ssp*. being the most common isolate similar to previous reports. Based on a recent study from Florida, USA (More *et al*. 2019), histopathology is very important to obtain the correct diagnosis of mycotic rhinitis and sinusitis since fungal culture and PCR/DNA sequencing can fail to identify the correct organism. In addition, PCR from nasal/fungal specimens may simply represent an environmental contaminant and not the cause of an infection. Furthermore, this case series from Florida and a recent case report from Queensland, Australia, identified new fungal pathogens such as *F. flavus* being the cause of infection for granulomatous rhinitis in horses.

The growth in the number of unrecognised fungal pathogens adds to the challenge for pathologists and clinicians to identify the correct organism and to implement the correct treatment.

Pujol *et al*. (2021) is one of the few reports in which mycotic infection is the primary disease in all the cases. This emphasises the importance for the clinician to rule out all of the other potential causes for fungal infection in the upper airway.

As described by Pujol *et al*. (2021), in cases of paranasal mycosis sinuscopy is very useful for diagnostic purposes to characterise the lesions, to obtain a fresh sample for histopathology and culture under visualisation as well as for treatment to perform surgical debridement of the lesions and to apply topical medication under sinoscopic control. The number of debridement sessions during hospitalisation and possible additional debridement procedures performed during follow-up examinations highlights the importance when possible to create a communication between the nasal passages and sinuses. This will facilitate access to the paranasal sinuses during endoscopy to monitor progression of the lesions, allow for follow-up debridement and evade repeating the sinusotomy.

Surgical treatment is almost always combined with medical therapy to treat fungal infections of the upper airway. However, the number of therapeutic options for the treatment of fungal infections is still quite limited when compared with those available for bacterial infections. In addition, affordability and possible side effects like toxicity make the use of these drugs very limited. Topical application of the antifungal drug is commonly used because it results in higher therapeutic concentrations over the mycotic plaque and decreases the risk of toxicity. One of the authors has reported a successful technique using topical fluconazole sinonasal bathing under general anaesthetic for treatment of a chronic fungal rhinitis in a horse (Lean and Ahern 2018) (**Fig 1**). This technique has been used previously in small animals for treatment of canine nasal aspergillosis (Mathews *et al*. 1996; Bray *et al*. 1998; Sharman and Mansfield 2012).

This report by Pujol *et al*. (2021) includes the use of antifungal inhalation as a method of drug delivery directly to the site of infection even though efficacy and mode of action have not been investigated in horses.

In summary, this report expands the information available in the literature for equine practitioners for case management of fungal infection in the nasal cavity and paranasal sinuses. The treatment can be expensive, time-consuming and labour-intensive. Therefore, long-term follow-up and financial investment from the owner must be considered from time of the initial presentation.

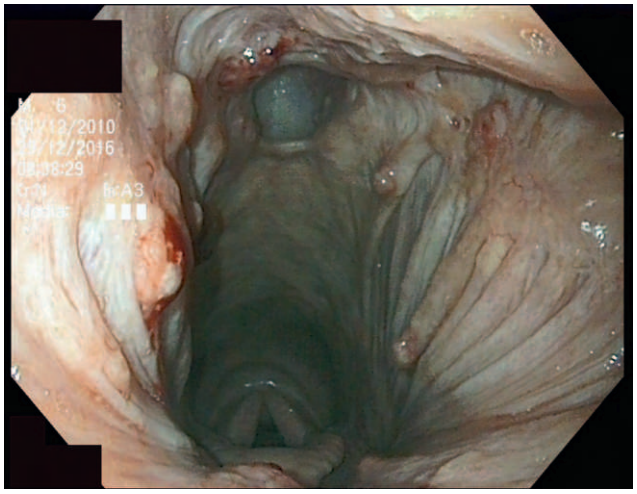

Fig 1: URT endoscopy showing fungal* Aspergillus ssp *infection in a horse treated with non-invasive soak under general anaesthesia.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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None.

Authorship

Both authors contributed to this clinical commentary.

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Case Report

Partial aneurysmectomy and autologous patch venoplasty in a horse diagnosed with pseudoaneurysm of the jugular vein

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Keywords: horse; vascular; aneurysm; thrombosis; thrombophlebitis

Summary

A 3-year-old female pony was first presented with thrombophlebitis of the left jugular vein (JV). Perivenous abscesses were surgically drained and curetted. The remaining cavities were flushed daily using a teat cannula. At one point, some blood was seen during flushing, so this was discontinued. Follow-up ultrasound examinations showed appropriate resolution, the drainage site healed by second intention and the mare was discharged. Two weeks after discharge, the mare presented an intermittent localised swelling of the left JV that progressively increased in size. The swelling was most clear during exercise and when lowering the head. At presentation, the mare showed a diffuse soft swelling over the cranial third of the JV. A 2 cm cutaneous depression could be felt in the middle of the swelling. When the vein was compressed caudally or the head was lowered, a local distention gradually appeared. The mare showed no signs of pain during palpation. Ultrasonography revealed a localised defect of the lateral wall of the JV at the level of the distention. Through the defect, the JV was connected to a thin-walled blood-filled cavity located between skin and vein (**Fig 1**). The size of the cavity increased markedly when the JV was compressed caudally and showed blood whirling. Based on the history and ultrasonographic appearance, the lesion was classified as an iatrogenic-induced pseudoaneurysm of the left JV. Treatment consisted of a partial aneurysmectomy preserving the healthy medial wall of the jugular vein. An autologous saphenous vein patch technique was used to reconstruct the vein (**Fig 2**) with the largest possible lumen to minimise thrombus formation. Anticoagulants, antimicrobial and anti-inflammatory drugs were administered pre- and post-operatively. In the post-operative period, significant narrowing of the reconstructed vein was observed during ultrasonographic follow-up due to swelling of the surrounding tissue, which gradually resolved. At 2 and 8 months post-operatively, no external deformation of the jugular vein was visible and ultrasonography revealed patent blood flow with only a slight difference in lumen diameter. The patch venoplasty proved a viable surgical technique for jugular vein reconstruction resulting in a sufficient lumen, no thrombus formation and a good cosmetic and functional outcome.

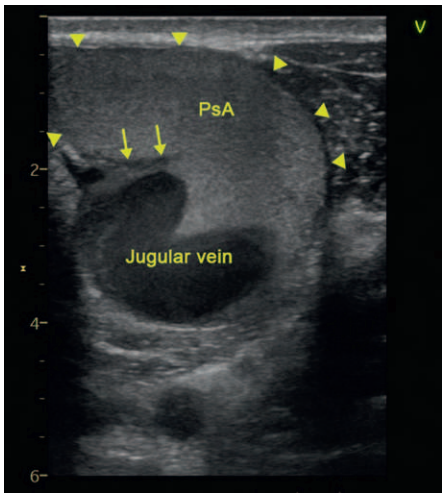

Fig 1: Transverse ultrasonographic image of the pseudoaneurysm (PsA) and its thin wall (arrowheads) which is located between jugular vein and skin. Right on the screen is dorsal. Part of the interrupted jugular vein wall is visible (arrows). The total displayed depth is 6 cm.

Fig 2: Picture taken during surgery after patch venoplasty was performed with an autologous saphenous vein patch (the horse's head is to the left).

Key points

- Pseudoaneurysms, especially venous, are rare and their aetiology is often of traumatic origin.
- Ultrasonography is an essential tool in the diagnosis of peripheral pseudoaneurysms.
- In larger and more chronic pseudoaneurysms, reconstructive vascular surgery is a viable treatment option. When the vessel can be partially preserved, a patch technique can be used to reconstruct the vein.

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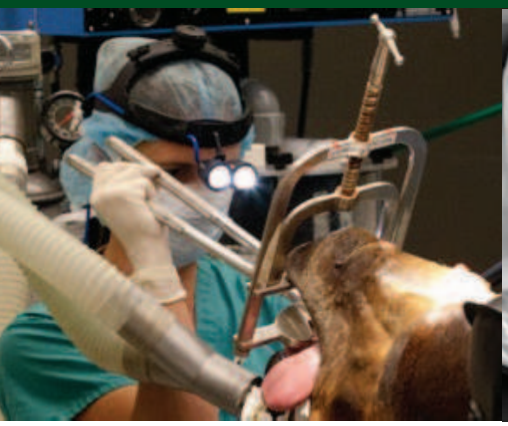
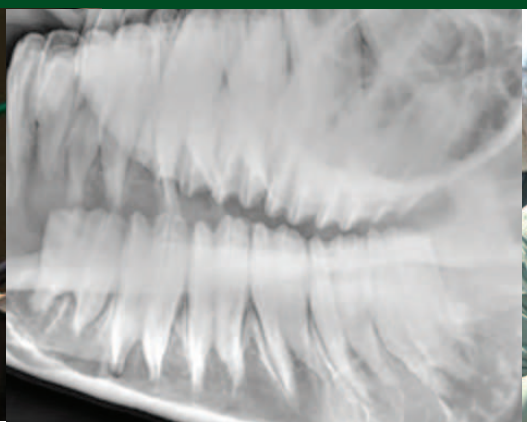


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Clinical Commentary

Venous aneurysm of the jugular vein in horses

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Keywords: horse; vascular surgery; aneurysm; jugular vein; vascular

Venous anomalies of the jugular vein are uncommon in the horse. Jugular venous aneurysms (congenital or pseudoaneurysm) in horses usually present as a compressible asymptomatic cervical mass enlarging on manual congestion of the jugular vein. They can be classified into primary (congenital) and acquired lesions. Primary venous aneurysms are true venous aneurysms because in these lesions the venous wall is intact, whereas false or pseudoaneurysm has a disruption of the inner layers of the venous wall. Two types of jugular vein aneurysm can be identified, fusiform or saccular, the former being the most common in people. Doppler ultrasound imaging confirms the diagnosis. Surgical treatment, aneurysmectomy with venorraphy or venoplasty is indicated in case of progressive aneurysmal expansion. This clinical commentary describes a 4-month-old foal presented with a primary aneurysm of the right jugular vein in the midcervial region. Treatment consisted of partial aneurysmectomy and venorraphy. Four years later, the horse had a patent jugular vein with a normal diameter and was trained without clinical signs of venous distension.

Vascular surgery in horses is uncommonly performed, but includes embolectomy, stenting, angioplasty and bypassing. In human medicine, special training programmes are available for future vascular surgeons (Al-Jundi *et al.* 2018), whereas veterinarians are generally self-trained in this discipline. Achieving competence in the full range of vascular procedures within veterinary medicine remains a challenge due to the low exposure, especially for venous surgery. Surgery of the jugular vein has been described for thrombophlebitis and false or pseudoaneurysma (Rijkenhuizen and van Swieten 1998; Wiemer *et al.* 2005; De Clercq *et al.* 2021). Venous anomalies of the jugular vein are uncommon in the horse and only occasionally described (Santos *et al.* 2016; De Clercq *et al.* 2021). Pseudoaneurysm formation is rarely encountered within the low-pressure venous system and can have iatrogenic as well as non-iatrogenic causes, which include traumatic injury (Al-Shaikhi *et al.* 2003; Ward *et al.* 2009; Swaika *et al.* 2013; Lee *et al.* 2014). They generally occur at the site of needling/puncture and may be thought of simplistically as haematomas communicating with the lumen. With time, they may develop a fibrotic sac but this is devoid of endothelium or vascular wall structure. Differential diagnosis includes a cavernous haemangioma (Cannon and Loh 1982). The aneurysm described by Santos *et al.* (2016) might have been a pseudoaneurysm with development of a sac with a fibrous clot.

Besides pseudoaneurysma with a disruption of the inner layers of the venous wall (Schäberle 2018), real or primary aneurysma can also occur in horses. Venous aneurysm is a term describing an isolated dilatation of a vein with an intact vessel wall. Two types of jugular vein aneurysm can be identified, fusiform or saccular, the former being the most common in humans (Gilbert *et al.* 1972; Andreev *et al.* 1998; Kloppenburg *et al.* 2015). Whether a dilatation of the vein is called an aneurysm in human medicine is still under debate (Jankovic *et al.* 2013; Rajput *et al.* 2013). Due to the low incidence in the horse, an abnormal increase in diameter would be considered appropriate to be defined as an ananeurysm, keeping in mind the difference from varicose veins which simply imply tortuosity combined with dilatation of the veins, and which occurs more often in horses (Reardon *et al.* 2015). Varicose veins are described in the vulva, secondary to occlusion of the jugular vein and occur occasionally elsewhere, such as the tarsus, knee joint and penis (personal communication). The occurrence of varicose veins is low as well, probably due to higher valvular density in the superficial veins in the limbs (Harfoush *et al.* 2015).

Venous aneurysms in humans can involve any veins in the body, including cervical, thoracic, visceral, and upper and lower extremity veins. They can be classified into primary (congenital) and acquired lesions (Al-Shaikhi *et al.* 2003; Aiyappan *et al.* 2013; Verma *et al.* 2013; Swaika *et al.* 2013; Mohanty *et al.* 2013; Lee *et al.* 2014; Kim *et al.* 2016; Neto *et al.* 2016). Primary venous aneurysms are true venous aneurysms because in these lesions the venous wall is intact (Al-Shaikhi *et al.* 2003; Aiyappan *et al.* 2013; Kim *et al.* 2016). Causative factors for acquired pseudoaneurysm include tumours, inflammation, degeneration, or trauma, or iatrogenic following an intravenous injection (Ward *et al.* 2009; De Clercq *et al.* 2021). That primary jugular venous aneurysm that can occur in horses will be demonstrated by the following case.

A Dutch Warmblood 4-month-old foal was referred with a mass in the right midcervical region, which had been increasing gradually in size with time but was only noticeable when the foal was eating from the ground. There was no history of clinical complaints, and the owner was unaware of any history of trauma, medical or surgical intervention in this area.

Physical examination revealed a slight distension in the jugular groove at rest, and when the head was lowered a soft, non-tender, non-pulsatile, compressible, well-defined sacculofusiform and fluctuant swelling at the midcervical region in the jugular groove (**Figs 1**, **2** and **3**) was evident. The skin overlying the mass showed no signs of inflammation, discoloration or thickening. With the head held in a normal position, the mass enlarged when manual compression of the jugular vein distal to the swelling was performed. No bruit was heard on auscultation over the swelling. The mass was examined sonographically, using a multiple frequency (9–12 MHz) linear array matrix transducer with manual congestion of the vein. The ultrasonic image of the vein revealed a 15 × 8 cm clear compressible mass, suggestive of

sacculofusiform venous aneurysm of the right external jugular vein, distending ventrally. No signs of thrombosis or thrombophlebitis were noticed nor thickening of the venous wall.

With colour Doppler imaging, there was laminar blood flow toward the heart suggesting that venous obstruction had not contributed to the swelling. Flow into the swelling ceased with digital compression of the jugular vein upstream from the mass. No swirling turbulent flow was present within the dilated cavity.

Based on the clinical presentation, the diagnosis was considered to be a congenital aneurysm of the jugular vein.

The treatment of choice in people for an external jugular vein aneurysm is surgical excision for cosmetic purposes and avoidance of potential complications, such as thromboembolism or rupture (Al-Shaikhi *et al.* 2003; Verma *et al.* 2013; Başbuğ *et al.* 2016; Kaur *et al.* 2016; Lucatelli *et al.* 2017). Because of the gradual increase in size in the foal, surgical management was advised.

Physical examination and blood analysis were without normal limits.

Prophylactic intravenous antibiotics (sodium benzyl penicillin, Benzylpenicillin Natrium[1] 22.000 IU/kg bwt i.v.) were administered 30 min before the procedure as well as butorphanol (Torbugesic[1] 0.05 mg/kg bwt, i.v.). Surgery was performed under general anaesthesia in left lateral recumbency following a standard protocol. Saline solution was infused intravenously throughout anaesthesia at 10 mL/kg/h.

The incision was extended over the jugular aneurysm, starting 3 cm cranially up to 3 cm caudally where the luminal intima was of normal calibre. The jugular vein was identified and circumferentially bluntly dissected over the whole aneurysmal part, preserving the branching veins. The branches were ligated (Vicryl[2] 2-0).

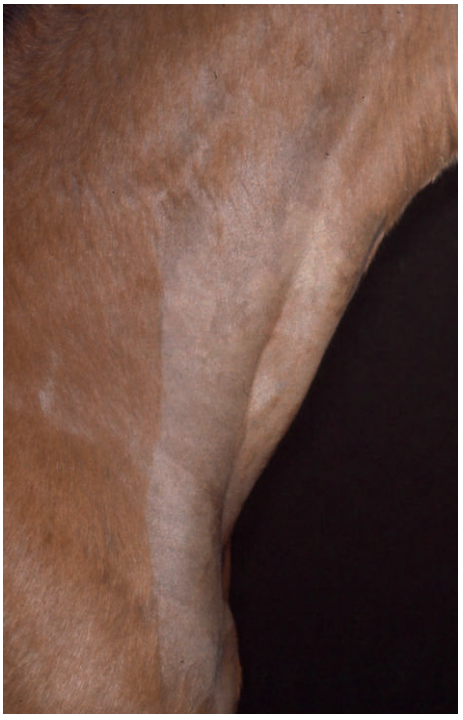

Fig 1: Image showing the right cervical region of the foal at rest: a slight distension in the jugular groove is noticed.

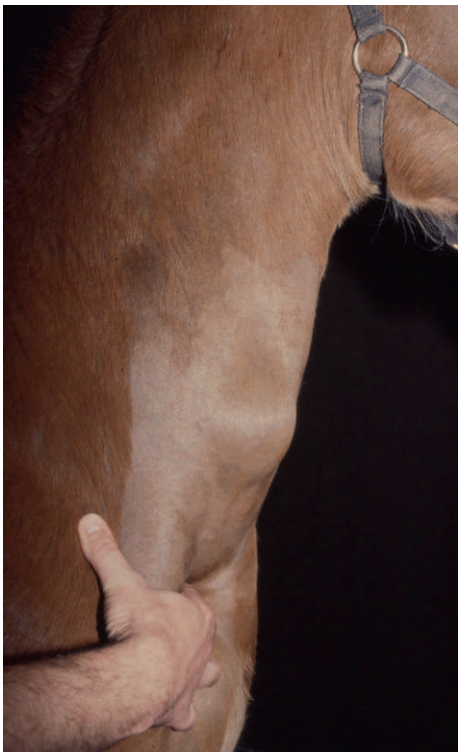

Fig 2: Image showing the right cervical region of the foal with the jugular vein manually congested: a soft, non-pulsatile, well-defined sacculofusiform and fluctuant swelling at the midcervical region in the jugular groove is visible.

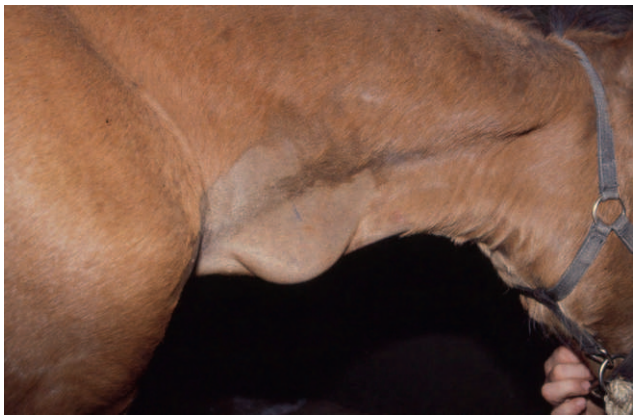

Fig 3: Image showing the right cervical region of the foal with the head down, revealing the swelling.

After systemic heparinisation (100 IU Heparin[3]/kg bwt i.v.), Penrose drains were looped around the patent ends of the jugular vein, and the vein was opened cranially to caudally by a longitudinal incision (**Figs 4** and **5**). Vessel wall thickness was normal. Tangential aneurysmectomy with lateral venorrhaphy was performed. To ensure that enough excessive venous wall was resected, a gummi tube with a diameter of 2.5 cm was inserted in the jugular vein as a guide and then the redundant venous wall was carefully removed by an elliptical incision (**Fig 6**). The vein was then reconstructed over the tube using a 5-0

polypropylene[2] longitudinal running perforating suture. Just before knotting the continuous suture, 20 mL of a heparin solution (250 IU heparin/mL physiologic saline) was injected into the proximal jugular vein. The vessel clamps were removed, and the suture line was then inspected for leakage (**Fig 7**). The subcutaneous tissue and skin were approximated with a continuous suture pattern using 2-0 USP poliglecaprone (Monocryl USP 2-0). Recovery was uneventful. Post-operatively, carbasalatum calcium (*5* mg/kg bwt per os once daily, Ascal[4]) and nonsteroidal anti-inflammatory drugs (Flunixin meglumine, Finadyne pasta[1], 1.1 mg/kg bwt once daily orally) were administered for 3 months and 3 days respectively. Histological examination of the wall was unfortunately not performed.

No perioperative anaesthetic or surgical complications occurred. Wound healing was by primary intention and no abnormal distension of the jugular vein was noticed (with and without manual congestion) and the foal was discharged 2 weeks post-operatively. Hand walking exercise was advised for 4 weeks with no feeding from the ground.

One year post-operatively, the yearling showed no distension of the vein when eating from the floor and the owner had no complaints. At the age of 4, the horse had a patent jugular vein with a normal diameter and was trained without clinical signs of venous distension.

Jugular venous aneurysm or jugular phlebectasia is the most commonly encountered venous malformation involving the neck veins in people. As a primary venous aneurysm is usually asymptomatic, the indications for surgery include the risk of thrombus formation due to stagnant venous blood in these lesions, risk of rupture, progressive expansion or disfiguring involving cosmetic considerations, as was the case in our patient (Calligaro *et al.* 1995; Andreev *et al.* 1998; Verma *et al.* 2013; Kim *et al.* 2016; Neto *et al.* 2016).

A saccular aneurysm can be treated by simple clipping, but if the aneurysm is fusiform several other surgical techniques have been described, including lateral venorrhaphy, plication with tangential mattress sutures, resection and replacement with an autologous venous graft or endovascular repair using self-expandable covered stents (Ritter *et al.* 1993; Belov *et al.* 1989; Johnstone *et al.* 2015; Zhang *et al.* 2020). An alternative treatment to preserve venous patency could be longitudinal constriction suture venoplasty with inlay technique using Dacron or polytetrafluoroethylene (Andreev *et al.* 1998; Jianhong *et al.* 2006).

In this case, an aneurysmectomy combined with venorrhaphy was performed, while in the case of De Clercq

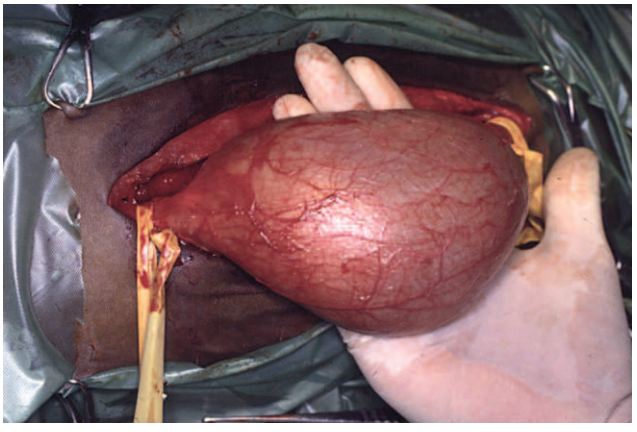

Fig 4: Intraoperative image showing the dissected jugular vein with Penrose drains looped around the patent ends of the jugular vein. The aneurysm is lifted with the hand. The head is on the right side of the image.

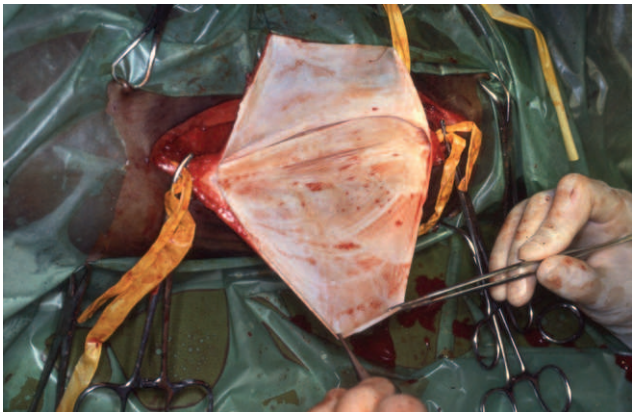

Fig 5: Intraoperative image showing the opened aneurysmal vein.

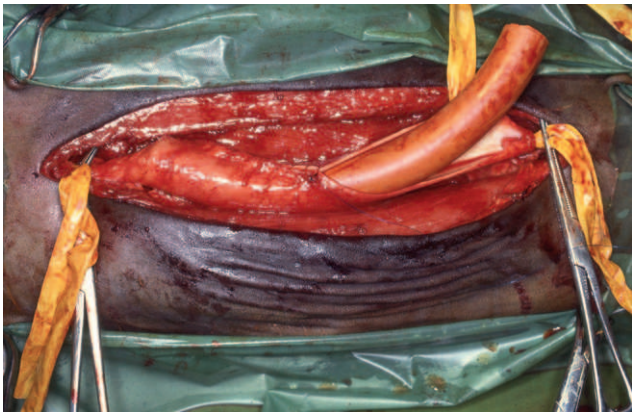

Fig 6: Intraoperative image showing the partly sutured jugular vein over the gummi tube, which was introduced in the jugular vein as a guide.

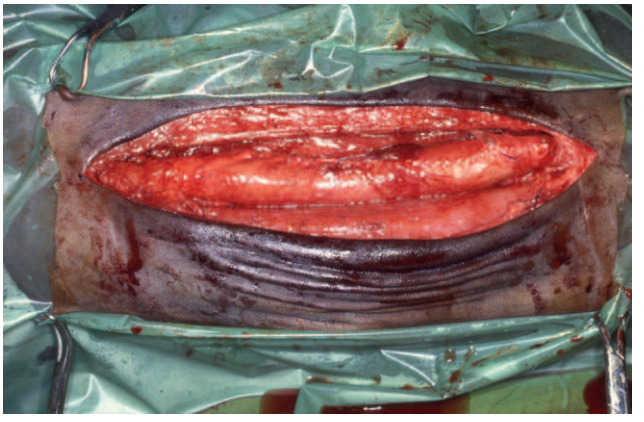

Fig 7: Intraoperative image of the suture line in the jugular vein.

et al. (2021), venoplasty was chosen. The difference was the fact that in our case, the diagnosis was a congenital venous aneurysm, whereas the other case was considered to be a pseudoaneurysm. In case of a suspected normal venous wall, the chance for stenosis after surgical management was considered to be small, and in order to prevent reducing the diameter of the vein too much, a guiding tube was used. In the case of a partial abnormal venous wall in a pseudoaneurysm (De Clercq *et al.* 2021), the risk of stenosis was considered huge and therefore a patch venoplasty was performed. In the article of De Clercq *et al.* (2021), the risk for thrombosis was mentioned in the case of a saphenous vein graft transplant due to its relative small size. Based on experiences with saphenous graft implants in the jugular vein in cases of thrombophlebitis, the ability of the graft to enlarge is enormous and even in one patient the diameter of the graft was twice the diameter of the jugular vein one year after implantation (personal communication).

In both cases, aneurysmectomy was performed, although simple plication of the excess vessel wall, rather than resection, by running a suture along the entire length (Lo and Tan 2007) might have been option, with the advantage of not opening the vein. Plication using staples along the longitudinal axes of the venous aneurysms with excision of the excessive aneurysmal tissue would also have been an option (Pierce *et al.* 2007, Tozzi *et al.* 2014). However, the use of the guiding tube for calibration of the venous diameter in the described case was quite useful. Furthermore, the presence of a metal material in horses would increase the infection risk and thick plication could hinder venepuncture of the jugular vein in future and the author considers excision of the excess aneurysm wall as a more controlled technique. Partial aneurysmectomy, with or without reduction venoplasty, seems to be a simple and viable option for the treatment of a (pseudo)aneurysma of the jugular vein in horses, taking care not to reduce the diameter of the vein too much.

In both cases, no recurrence of the aneurysm occurred. In people, techniques are described to avoid recurrence after aneurysmectomy, like wrapping the vein with a metal mesh (Grauhan *et al.* 2001) or reinforcement of the vein with a macroporous polyester external prosthesis (Berard *et al.* 2010). This could be kept in mind.

In conclusion, jugular venous aneurysms (congenital or pseudoaneurysm) in horses are rare, usually presenting as a compressible asymptomatic cervical mass enlarging on manual congestion of the jugular vein. Doppler ultrasound imaging confirms the diagnosis. Surgical treatment, aneurysmectomy with venorrhaphy or venoplasty is indicated in case of progressive aneurysmal expansion.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The horse was treated according to German ethics.

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Manufacturers' addresses

[1]Intervet International BV, Boxmeer, the Netherlands.
[2]Johnson & Johnson Medical B.V., Amersfoort, the Netherlands.
[3]Leo Pharmaceutical Products, Amsterdam, the Netherlands.
[4]Asta Medica Dagra Pharma BV, the Netherlands.

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Case Report

Occurrence of a vaginal septum in a foal diagnosed with pyometra

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Keywords: horse; pyometra; vaginal septum; endometritis; endoscopy

Summary

A 10-week-old Westphalian filly was referred for purulent vaginal discharge of 14 days' duration that had not responded to treatment with sulfamethoxazole/trimethoprim. The filly was in normal body condition, and vital signs were normal. Purulent vaginal discharge was the only abnormality identified on physical examination. Endoscopic examination of the filly's reproductive tract revealed a large quantity of caseous material and milky fluid throughout the vaginal and uterine lumens (**Fig 1**). The cervix was open, and the endometrial lining was inflamed. A vertical transluminal band of tissue (vaginal septum) was present just caudal to the cervix, dividing the vaginal lumen into left and right halves for a length of approximately 5–10 cm (**Fig 2**). Samples of exudate were obtained using sterile transendoscopic tubing, and endometrial biopsies were obtained. Cytological examination of the fluid revealed an exudate, characterised by a high number of degenerate neutrophils, frequently containing phagocytised cocci and diplococci. Histopathology confirmed endometritis, with marked infiltration by neutrophils, lymphocytes, plasma cells and macrophages. Microbiological culture yielded two Group B streptococcal species (*Streptococcus dysgalactiae* subspecies *equisimilis* and *Streptococcus equi* subspecies *zooepidemicus*). Both isolates were sensitive to penicillin and trimethoprim-sulfamethoxazole. Systemic treatment with potassium penicillin (22,000 IU/kg bwt i.v. q.i.d.) and gentamicin sulfate (6.6 mg/kg bwt i.v. s.i.d.) was initiated. Further treatments included extensive uterine lavage, undertaken using approximately 2 L of sterile warmed 0.9% sodium chloride solution under moderate pressure via a transendoscopic plastic tube, using the mobile terminus of the endoscope to enable up-and-down and side-to-side sweeping actions with the injected solution (on Days 1, 3, 5, 6, 11 and 13). This approach was intended to both dilute and physically disrupt the exudate in order to facilitate its removal. Intraluminal instillation of penicillin-containing saline (2×10^6 IU of potassium penicillin) was performed at the conclusion of each irrigation protocol. Flunixin meglumine (1.1 mg/kg bwt i.v.) was administered once following each procedure. Residual quantities of exudate were removed via endoscopically facilitated irrigation/suction on Day 13. Treatments with penicillin and gentamicin were discontinued on Days 7 and 13, respectively. The filly was discharged on Day 14 for treatment using sulfamethoxazole/trimethoprim (27 mg/kg bwt per os b.i.d.) for 4 weeks. Endoscopic examination of the uterus revealed normal findings 16 weeks later, and the problem had not recurred 19 months later.

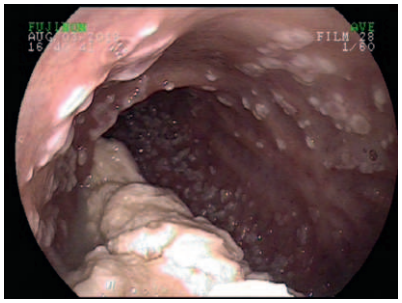

Fig 1: Endoscopic appearance of the lining of the uterus of a 10-week-old filly at time of hospital admission for a purulent vaginal discharge. Notice the large volume of purulent material that was present throughout both uterine horns.

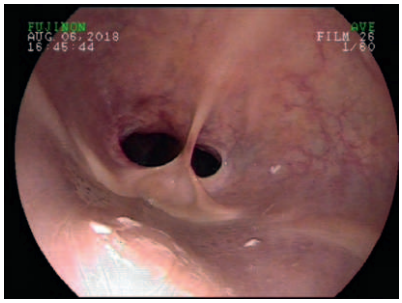

Fig 2: Endoscopic appearance of a longitudinal vaginal septum as it appeared on the third day of treatment following removal of purulent fluid and caseous material from the foal's reproductive tract.

Key points

- Development of pyometra in a prepubertal filly is rare.
- A possible predisposing role of a vaginal septum, another unusual finding in this case, was not clarified.
- Treatment that included evacuation of intraluminal exudate alongside systemic and local administration of antimicrobials to which the causative pathogens had been shown to be susceptible led to resolution of the pyometra.

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Clinical Commentary

Female caudal reproductive tract abnormalities

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Introduction

The report by McCarthy and coworkers (McCarthy *et al.* 2021) in this issue describes a case of vaginal septum with pyometra in a 10-week-old Westphalian filly foal. This is an interesting case report which evokes thought about the developmental abnormalities of the caudal female reproductive and urogenital tracts and their pathophysiology. Such anomalies are rare, reflected by the limited number of cases reported in the literature involving mares/fillies with uterine, cervical, vaginal and hymenal abnormalities.

Sexual differentiation and embryo development

To understand the pathogenesis, and crucially, the aetiology of these conditions, it helps to understand the steps involved in sex determination and differentiation during embryogenesis. Following fertilisation and for about the first 20% of gestation, prior to development of testes or ovaries, XX and XY zygotes are sexually indifferent (Windsor 2019). The reproductive tract is formed from the three primary germ layers of the early embryo: endoderm, mesoderm and ectoderm. The paired urogenital ridges form from the mesoderm and contain the mesonephros (the main excretory organ of the early embryo), the mesonephric (Wolffian) ducts (future vas deferens and epididymis in males), the paramesonephric (Müllerian) ducts (future oviduct, uterus and cranial vagina in females) as well as the undifferentiated, bipotential gonads (Christensen and Meyers-Wallen 2011).

Sexual differentiation of the embryo is reviewed by Christensen and Meyers-Wallen (2011). Briefly, the sexually indifferent phase is brought to an end when the above structures receive a signal which directs subsequent sexual development down the male pathway or leaves it to follow the default female pathway. Put simply, the presence of the *Sry* (sex-determining region Y) gene on the Y chromosome in genotypically male embryos directs sexual development down the male pathway. The *Sry* gene encodes SRY protein, which leads to activation and suppression of transcription of various other genes – supporting differentiation of the bipotential gonads into testes. In the developing testes, anti-Müllerian hormone (AMH) and dihydrotestosterone (DHT) secreted by Sertoli cells leads to degeneration of the paramesonephric ducts. Leydig cell-derived testosterone, along with dihydrotestosterone stimulate the formation of the male duct system from the mesonephric ducts, the closure of the urogenital sinus to form the urethra and prostate, the differentiation of the genital tubercle and the urogenital fold into the glans penis and the penile shaft respectively, and closure of the genital swellings (labioscrotal folds) to form the scrotum.

In the absence of the molecular effects of the *Sry* gene and testicular secretions, embryological development follows the default pathway to the female phenotype. The paired paramesonephric ducts become the oviducts, uterus and cranial vagina and the mesonephric ducts regress. Dissolution of the wall between the paramesonephric ducts caudal to the uterine horns is critical to allow formation of the uterine body, cervix and cranial vagina. This process varies tremendously between mammalian species, from the rabbit which has a 'duplex' uterus, the horse with a 'bicornuate' uterus and the human with a 'simplex' uterus. The caudal end of the combined paramesonephric ducts (utero-vaginal canal) meets the urogenital sinus from which a sinu-vaginal eminence or 'bulb' develops and ultimately forms the caudal vagina. This meets the distal end of the utero-vaginal canal as the sinu-vaginal eminence (mesodermic in origin) and ultimately forms the cranial vagina; together forming the solid vaginal plate which subsequently canalises becoming the tubular vagina. The vestibule forms from the urogenital sinus and the hymen are the membranous junction between the urogenital sinus and the canalised vaginal plate. The genital tubercle becomes the clitoris and the genital swellings remain open, to form the vulva, along with the urogenital folds.

Disorders of sexual development (DSD)

Departures from normal development in-utero may be caused by chromosomal abnormalities, present from conception, exposure to exogenous compounds (Titus-Ernstoff *et al.* 2010) or in many instances, are idiopathic in origin. Congenital disorders may be identified prepartum which may manifest in conditions such as hydrops; soon after birth (e.g. angular limb deformities, wry-nose, cleft palate); or in some cases, such as that presented by McCarthy *et al*. (2021), are present from birth, are only detected later in life.

Chromosomal abnormalities

Three of the more common chromosomal abnormalities leading to the development of an abnormal female reproductive tract are X monosomy, XY sex reversal and male pseudohermaphroditism (Bozsdky *et al*. 2003; Valligómez *et al*. 2011). Patients with X monosomy (63XO), known as 'Turner's syndrome' in humans, suffer from gonadal dysgenesis, which leads to the development of hypoplastic ovaries, uterus and cervix and individuals are reproductively sterile. Sex reversals are not strictly considered chromosomal abnormalities as a normal complement of chromosomes are present. In spite of this, the phenotypic presentation (gonadal tissue and genitalia) disagrees with the karyotype. In XY sex reversal, the patient has ovaries instead of testes, and instead of male genitalia, a variably-differentiated female tubular tract is present. Loss of the

Sry gene from the Y chromosome results in default to female sexual development, however, sometimes XY sex reversal occurs in *Sry* positive individuals, due to genetic mutations on the X or Y chromosome leading to an inability to convert testosterone to DHT or a failure to respond to DHT itself (Villagómez *et al.* 2011). In cases of male pseudohermaphroditism (64XY), a normal karyotype is once again present. Testes develop as normal (unlike in XY sex reversal), however, due to a mutation in the androgen receptor gene (carried on the X chromosome), the external genitalia is not directed down the male differentiation route and female external (or ambiguous) genitalia develop (Villagómez *et al.* 2020). Due to normal AMH production, however, the uterus is absent and the vagina is blind-ending. A diverse range of less common genetic and chromosomal abnormalities leading to sexual developmental anomalies are described in the human and veterinary literature, many of which are reported in horses (Lear and McGee 2012). Recently, a homozygous deletion on chromosome 29 has been characterised as a risk factor for equine DSD (Gosh *et al.* 2020).

Abnormalities by region

Uterus

Uterus didelphys or uterus bicollis (double cervix with or without a double uterus; Keller 1914; Macrae 1935; Blue 1985; Volkmann and Gilbert 1989; Hurtgen 2011a; Murcia-Robayo *et al.* 2018) have been reported in Clydesdale and Irish Cob mares with a variable vaginal component, ranging from no abnormality to a complete separation into two halves. Interestingly, the recent report by Murcia-Robayo *et al*. (2018) reported a case of uterus didelphys associated with mosaic X chromosome aneuploidy (63 XO/64 XX) suggesting a genetic component to abnormalities at this level. Aplasia of the uterine body or one uterine horn have been reported to variable degrees in American Paint Horses, Shire and a Shetland Pony breeds (Schlotthauer and Zollman 1956; Brown *et al.* 2007; Hurtgen 2011b). The author (J.R.C.) has experience of a single case of partial aplasia of the right uterine horn in an Arabian mare.

Cervix

Cervical abnormalities such as aplasia or hypoplasia are often found in combination with an underdeveloped or infantile uterus associated with X chromosome monosomy; however, cervical incompetence has been reported with unknown or absence of karyotypic abnormality (Allen 1981; Blanchard *et al.* 1982; Witte *et al.* 2012). The author (J.R.C.) has experience of an 8-month-old weanling presenting with urinary incontinence, which had pneumometra and endometritis; vaginoscopy revealed a perforate hymen and apparently incompetent cervix. In addition, the authors have two adult mares under their care with incompetent cervices (in the presence of normal levels of progesterone during dioestrus) which have proven fertile by embryo transfer.

Vagina

Vaginal septa are encountered rarely and usually present as a single vertical band of tissue in the midline of the caudal vagina (Parrilla Hernandez *et al.* 2013; Paccamonti and Crabtree 2019). The author (J.R.C.) has encountered a vaginal septum or 'curtain' of some 10 cm in length in a 2-year-old Thoroughbred filly with a small 'juvenile' vulva sitting above the level of the pelvic brim with pneumometra and endometritis. In this case, the cervix and uterus appeared to be normally formed. Rare reports in the literature exist of vaginal hypoplasia (Freeman and England 1997) and transverse vaginal septum (Payan-Carreira *et al.* 2007). The blind-ending vagina with a hypoplastic uterus beyond, is more commonly found with XY testicular disorders of sexual development (Vallagómez *et al*. 2011). Although sometimes similar on appearance, vaginal septae, almost exclusively encountered in maiden females, should not be confused with vaginal adhesions, typically seen in post-partum mares, which are usually a consequence of foaling trauma.

Hymen

Abnormalities of the hymen in the mare include imperforate (persistent) hymen and septate hymen. Cases with imperforate hymen are occasionally encountered in which the hymen is much thicker than the normal membranous form (**Fig 1**). These often present as tissue 'prolapsing' from the vulva due to accumulation of uterine and vaginal secretions in the vagina (hydrocolpos) and or uterus (hydro or mucometra) cranial to the vaginal obstruction. The authors treat these cases by simply cutting the hymenal tissue to allow the fluid to escape. Subsequent enlargement of the cut can be made by hand. The septate hymen (**Fig 2**) is also occasionally encountered but these are often broken down manually on the first manual vaginal examination. It is not clear from the literature how or when the hymen naturally ruptures in the growing filly. The authors note that the hymen is intact in a small proportion of maiden fillies and mares presented at stud for breeding and must be manually broken down (**Fig 3**). However, the majority of Thoroughbred fillies presented as 2-year-olds for routine presale breeding soundness evaluation possess hymenal tissue that has already ruptured. Further characterisation of the equine hymen between birth and the 2-year-old stage would be of significant interest. The hymen is often referred to as a remnant of no functional significance, however, it is possible that the hymen has evolved to protect the cranial reproductive tract from contamination especially when the genital organs are immature (Hobday *et al.* 1997).

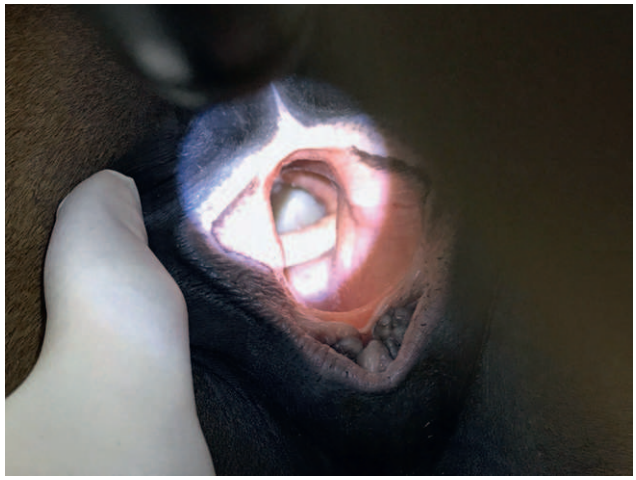

Fig 1: Imperforate hymen in a 2-year-old Thoroughbred filly with mucometra. Periodically a mass was seen protruding from the vulva. The hymen appears to be just cranial to the vestibulovaginal fold in this image

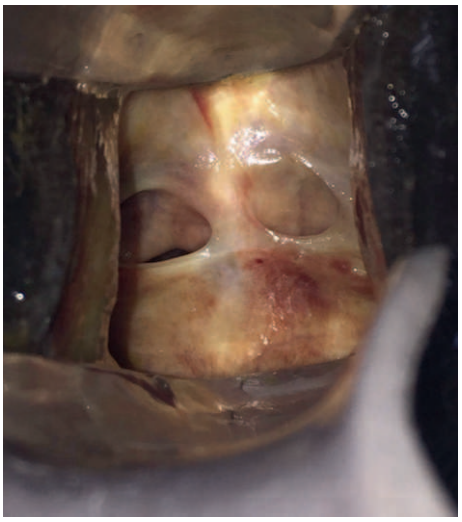

Fig 2: Septate hymen, diagnosed in an 11-month-old Thoroughbred filly via a speculum. The location of the cervix and transverse fold relative to the septate structure is critical in determining the diagnosis

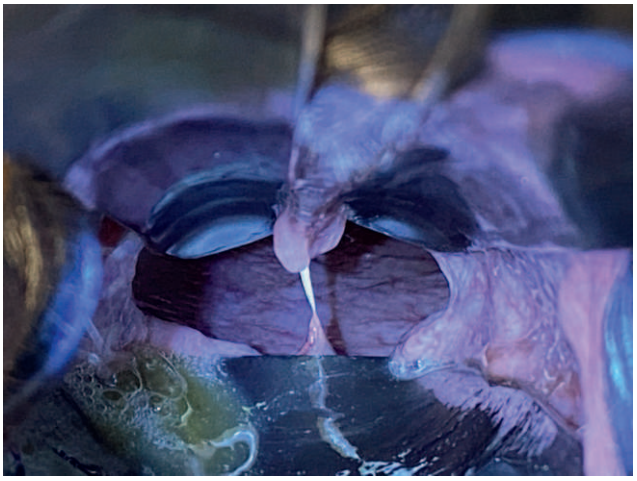

Fig 3: Septate hymen. Sometimes, the remnant cannot be easily reduced digitally and must be surgically transected. As the Polansky vaginal speculum was wound open in this case, the vestibular dilation alone caused the hymenal tissue to fray and tear

Caudal reproductive tract deformities involving the vagina and hymen are examples of where only theories exist as to their pathophysiology. During embryogenesis, where the utero-vaginal canal ends and the sinu-vaginal eminence begins is not clearly defined, indeed, conflicting theories regarding the specific origins of these structures still exist in the human literature (Kulkarni 2015). It has been recently suggested that the fused Müllerian ducts contribute only as the guiding structure for the developing vagina, rather than the cellular origin (Connell *et al.* 2013). However, given that vaginal septae exist, it suggests that tissues originating from the paramesonephric ducts extend at least as far as the caudal extremity of such remnants, representing a failure of the wall between the two ducts to dissolve. Whether or not this is an explanation for abnormalities as caudal as septate hymen is unknown. The underlying basic genetic mechanisms leading to formation of longitudinal vaginal septa remain to be determined (Connell *et al.* 2013). Transverse vaginal septa and imperforate hymens may in fact form by a different mechanism involving failure of complete canalisation of the vaginal plate. Hereditary imperforate hymen has been associated with alterations in the TBX3 gene in humans as part of ulnar mammary syndrome (Bamshad *et al.* 1997).

Reflecting on the report by McCarthy *et al*. (2021), there was no record of the gonadal status of the filly involved and karyotyping was not performed. Given that we have suggested that vaginal septal remnants may have formed as a failure of the wall between the two paramesonephric ducts to dissolve one should consider whether cervical and uterine abnormalities are also present. Endoscopic examinations performed by McCarthy *et al*. (2021) demonstrated a morphologically normal uterus with a body and two horns suggesting that a specific chromosomal abnormality is less likely. It is not clear from the images accompanying McCarthy *et al*. (2021) report, whether the cervix, described as 'wide-open', is shown as the constriction in the tubular vagina cranial to the septum or if the cervix lies beyond this region. We therefore assume it is the former and expect the cervix to be infantile given the age of the foal; however, re-examination after puberty would be required to determine whether the cervix develops and takes on a normal form or remains infantile.

There are several factors that may have predisposed the foal in McCarthy *et al*. (2021) case to uterine infection and pyometra formation: The ascending placentitis diagnosed 3 weeks prepartum may have resulted in bacterial contamination of the fetal fluids and exposure of the fetus to the Group C Streptococcal pathogens, which may have subsequently colonised the fetus' reproductive tract. Broad-spectrum antimicrobial therapy for the placentitis was provided using trimethoprim-sulfamethoxazole (TMS), which is known to penetrate fetal fluids (Rebello *et al.* 2006), but whether TMS can achieve minimum inhibitory concentration in a remote fetal uterine luminal infection is unknown. The bacteria later cultured from the filly's uterus was confirmed to be sensitive to TMS, however, TMS is known to have reduced efficacy against *Streptoccus equi* subsp. *zooepidemicus* in purulent environments (Ensink *et al.* 2003). Prolonged post-foaling recumbency could potentially have led to pooling of contaminated fluid in the reproductive tract and the subsequent dehydration of the filly may have aided inspissation of previously liquid purulent material. The presence of a transverse vaginal septum such as that described in rats by Lezmi *et al*. (2011) may lead to a partially occlusive barrier collecting fluid cranially adjacent to the cervix whilst also allowing potential ascending contamination, as is described in children with a micro-perforate hymen (Tardieu and Applebaum 2018). Kutzler (2001) and Cozens (2009) both reported cases of pyometra in mature mares, as a result of adhesions completely occluding the vaginal lumen, impairing normal uterine clearance mechanisms. Longitudinal bands or septa as described by McCarthy *et al*. (2021) are, however, unlikely to cause fluid retention and resultant ascending infection. It is reasonable to suggest that developmental abnormalities of the vagina and/or hymen that result in a perforate hymen, may render the juvenile uterus open to contamination and henceforth vulnerable to infection. Although assessment of perineal conformation is not routinely of specific interest in the prepubertal filly, the

absence of a hymen coupled with other conformational deficiencies of the perineum will lead to an increased risk of contamination of the cranial reproductive tract.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not required for this commentary.

Source of funding

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Authorship

Both authors jointly contributed to the conception and writing of the manuscript.

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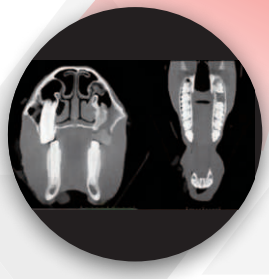

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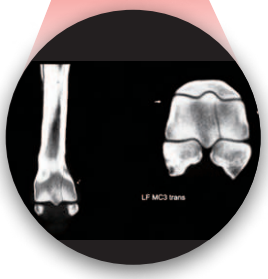

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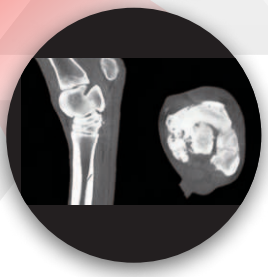

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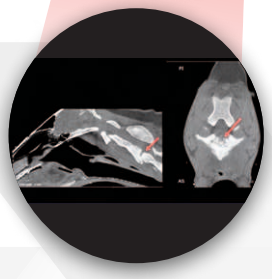
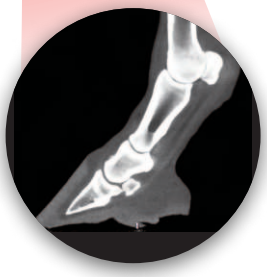


Neurological Disorder C2/C3



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Case Report

Presentation, stabilisation and contrast-enhanced computed tomographic (CT) diagnosis of a left gastrocaval portosystemic shunt in a pony foal

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Keywords: horse; portosystemic shunt; computed tomography; contrast; extra-hepatic; congenital

Summary

A 4-day-old pony foal was examined in the field for oral ulcerations, erythema and muzzle oedema secondary to abnormal behaviour including air biting and putative focal seizure activity ('chewing gum fits'), with inability to close the jaw. A cause for the neurological dysfunction had not been identified through palpation of the head and neck, endoscopy of the upper respiratory tract and radiographs of the head. At 2 weeks of age, the foal re-presented for recurrence of neurological dysfunction, obtunded-comatose mentation and collapse. Response to medical stabilisation was rapid, with improved demeanour and cardinal signs, however, marked neurological dysfunction persisted, including head pressing, central blindness, hypermetria in all four limbs and intermittent collapse. Based on the clinical findings, the evidence of neurological dysfunction, the haematological and clinical chemistry findings and the marked improvement with treatment, hepatic encephalopathy caused by a portosystemic shunt (PSS) was considered the most likely diagnosis. Contrast-enhanced computed tomography (CT) showed an anomalous vessel that extended between the left gastric vein and pre-hepatic caudal vena cava on the left side at the level of the cranial pole of the right kidney (**Fig 1**). Surgical intervention was not attempted due to financial constraints, and the foal was subjected to euthanasia. Post-mortem examination confirmed the presence of a vessel between the portal vein and the caudal vena cava at the level of the left gastric vein, indicative of a single, extra-hepatic left gastro-caval PSS.

Key points

- Portosystemic shunt (PSS) should be considered as a differential diagnosis in neonatal and older foals presenting with clinical signs of hepatic dysfunction and hepatic encephalopathy, prompting early medical intervention for stabilisation.
- Prompt correction of electrolyte, acid base, fluid and glucose derangements can result in a rapid clinical improvement, allowing for appropriate further diagnostics and medium-term management strategies to be implemented.
- Whilst ultrasound may facilitate diagnosis of an extra-hepatic PSS; contrast-enhanced computed tomography provides rapid detailed confirmation of the specific vascular anomaly to guide prognosis and potential surgery.

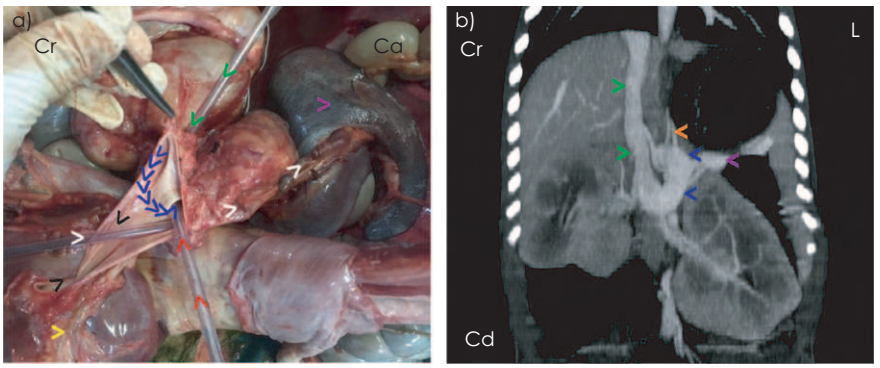

Fig 1: a–b: a)* Post-mortem *examination showing the path of the shunting vessel prior to dissection of the vessel (indicated by the blue arrowheads) where it communicates with the splenic vein (indicated by the white arrowheads), portal vein (indicated by the black arrowheads) and the caudal vena cava (indicated by the green arrowheads). The purple arrowhead denotes the spleen, the yellow arrowhead denotes the liver and the red arrowhead indicates the catheter that passes through the shunting vessel through to the caudal vena cava. b) Dorsal CT image showing the course of the shunting vessel (indicated by the blue arrowheads) from its origin in the left gastric vein (orange arrowhead) and the contribution from the splenic vein (purple arrowheads) before emptying into the caudal vena cava (green arrowheads).

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Clinical Commentary

Anaesthesia and analgesia considerations for foals with confirmed or suspected portosystemic shunt

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Keywords: horse; portosystemic shunt; foals; anaesthesia; hepatic dysfunction

The case report (Terpstra *et al.* 2021) describes the presentation, stabilisation and contrast-enhanced computed tomographic (CT) diagnosis of an extrahepatic portosystemic shunt in a pony foal with a brief discussion regarding the anaesthetic management. While neonatal animals have specific anaesthetic considerations, these may be further complicated by the presence of hepatic dysfunction due to suspected or confirmed portosystemic shunts.

It is known that hepatic compromise in the presence of a portosystemic shunt can cause encephalopathy, hypoproteinaemia, reduced hepatic perfusion, anaemia and a reduced ability to clear drugs (Adams *et al.* 2006). Therefore, the anaesthetic management of foals with portosystemic shunt can present a challenge. Hepatic dysfunction results in a decrease in the ability of the liver to metabolise and inactivate drugs and furthermore, a low plasma protein concentration means that the volume of distribution of drugs that bind to albumin is reduced, leading to a relative drug overdose (Bennett 2007). Poor liver development and abnormal circulation may result in altered uptake, metabolism and elimination of drugs with variable consequences (Bennett 2007).

In neonatal animals, the use of phenothiazines and alpha 2 adrenoreceptor agonists is not recommended due to their profound effects on the cardiovascular system (Bennett 2007). In healthy foals, benzodiazepines are a popular choice for pre-anaesthetic medication due to their minimal cardiorespiratory effects. However, in the presence of a portosystemic shunt and hepatic encephalopathy, there is increased sensitivity to benzodiazepines which is thought to be mediated via gamma-aminobutyric acid (GABA) receptors. Gamma-aminobutyric acid is an important inhibitory neurotransmitter in the central nervous system and interest in GABA and its receptor, arose from the observations that hepatic encephalopathy (HE) patients are very sensitive to barbiturates and benzodiazepines. The reason for the increased sensitivity has not been fully elucidated, but it is possible that patients with HE have increases in naturally occurring benzodiazepine-like receptor agonists which have an inherent ability to stimulate GABA receptors. Another theory to explain the sensitivity to benzodiazepines relates to the possibility that ammonia is associated with upregulation of peripheral-type benzodiazepine receptors located on the outer mitochondrial membrane of astrocytes. Flumazenil is a GABA antagonist which binds directly to the benzodiazepine receptor site and may also therefore have partial agonist and inverse agonist effects at high doses which may explain why the use of flumazenil in HE patients has been unpredictable and disappointing (Laccetti *et al.* 2000; Foster *et al.* 2010).

During medical stabilisation, sarmazenil (0.04 mg/kg bwt q. 4 h i.v.) improved the clinical signs of HE in one foal (Hug *et al.* 2012) and has been used in dogs with chronic HE. Sarmazenil is thought to work at regions of the GABA receptor not involved with the benzodiazepine binding site (ion channel) and may modulate presynaptic release of GABA which may explain its positive response (Meyer *et al.* 1998).

In young animals with hepatic compromise, opioids are commonly used for pre-anaesthetic medication as they provide good cardiovascular stability (Bennett 2007). However, since the liver is the primary site of biotransformation for most opioids, it is recommended that low doses of short-acting opioids are used in order to minimise drug accumulation and undesirable side effects (Bennett 2007). In our case, pre-anaesthetic medication consisted of butorphanol since the planned procedure was imaging only. However, morphine (0.1 mg/kg bwt i.v.) was used in one foal as pre-anaesthetic medication prior to surgical attenuation of a portosystemic shunt (Woodford *et al.* 2015). An intraoperative fentanyl infusion was used in another foal to provide analgesia during surgical treatment of a portosystemic shunt and ceased 30 min prior to recovery (Hug *et al*. 2012). In dogs, the disposition of fentanyl appears to be unaffected by liver disease (Bennett 2007).

Induction of general anaesthesia in foals with a portosystemic shunt has been performed using propofol (Hug *et al*. 2012; Woodford *et al.* 2015). Propofol is primarily a hypnotic agent with rapid onset of action, rapid redistribution and effects mediated via GABA receptors in the brain. Rapid intravenous injection of propofol can cause hypotension and apnoea, so it is recommended that the ability to monitor arterial blood pressure and a facility for ventilatory support are readily available (Kästner 2007). In the event of seizure activity, propofol has been used as an anticonvulsant owing to its ability to reduce cerebral metabolic requirements and allow a reduction in intracranial pressure (ICP) (Kästner 2007). In the current case report, ketamine was used as the induction agent which resulted in a smooth transition to recumbency and conditions which enabled prompt intubation of the trachea. However, ketamine is known to increase cerebral metabolism, cerebral blood flow and intracranial pressure (ICP) transiently which precludes its use in animals with known seizure activity (Kästner 2007). While the foal in the current case report had never shown seizure activity, the foal had shown signs of hepatic encephalopathy (HE) upon presentation to the hospital. The pathophysiology of HE is complex and likely involves several gut-derived neurotoxins, cerebral and systemic inflammation, cerebral vascular dysfunction and neuroendocrine abnormalities (Divers 2015).

The signs of HE had resolved in the current case, but it is likely that at the time of presentation, the inflammation and ammonia-induced free radical production in the brain in the presence of HE may also cause vasogenic oedema (Divers 2015) and may therefore have caused an elevation in ICP. It would therefore be advisable to avoid induction agents which precipitate an elevation in ICP in animals with seizure activity or evidence of HE. Total inhalational anaesthesia and the use of inhalational agent (mainly halothane) to induce general anaesthesia have been associated with the highest risk of death in foals (Johnston *et al.* 2002) which supports the use of injectable agents.

Isoflurane is considered the maintenance agent of choice in patients with liver disease due to the minimal hepatic metabolism and little effect on hepatic blood flow (Bennett 2007). In paediatric patients with liver disease, isoflurane and desflurane appear to have the least effect on hepatic and splanchnic blood flow and also demonstrate cardiovascular stability (Green and Ashley 2002). In the current case, inhaled isoflurane resulted in a consistent plane of general anaesthesia and adequate muscle relaxation for the imaging procedure. Isoflurane produces dose-dependent respiratory depression which may necessitate the use of controlled mechanical ventilation to avoid hypoventilation and reduce the work of breathing in a neonate. In the current case report, the foal breathed spontaneously throughout the anaesthetic duration of 25 min and maintained an end-tidal carbon dioxide tension ($ETCO_2$) between 6.6 and 8.0 kPa (50–60 mmHg).

Accurate and close monitoring is vital in every anaesthetised animal and is particularly important in neonates due to their increased vulnerability to the effects of anaesthetic and sedative agents. It is known that foals less than 4 weeks of age have an increased peri-anaesthetic mortality risk and while some of those foals are systemically ill, there is also a higher mortality rate in systemically healthy foals undergoing orthopaedic surgery (Johnston *et al.* 2002). In the current case, due to the limited access to the foal caused by the movement of the CT table and the position of the foal within the CT bore, pulse oximetry and capnography were used. Ideally direct arterial blood pressure monitoring and electrocardiography could also have been employed, particularly if the foal progressed to surgery or the imaging procedure was prolonged.

Intravenous fluid requirements are increased in neonates compared with adults due to an increase in total body water content and extracellular fluid volume (Holden 2007). Immature renal function means that fluid overload is not well tolerated, so measurement of packed cell volume (PCV) and total plasma protein (TPP) should be carried out in order to avoid haemodilution particularly in animals which may be hypoproteinaemic due to hepatic compromise. Intraoperative intravenous fluid therapy with a balanced isotonic crystalloid solution such as Hartmann's solution (Lactated Ringer's Solution) is recommended at a starting rate of 10 mL/kg/h (Robertson 2005). In the event of hypoproteinaemia (total plasma protein <50 g/L), a synthetic colloid or fresh frozen plasma infusion can be administered during general anaesthesia which provides intravascular volume support and helps maintain colloid osmotic pressure (Bennett 2007). Hypoglycaemia is an important consideration in the neonate, so blood glucose concentration should be monitored regularly so that fluids can be supplemented accordingly (Robertson 2005). In the current case, intravenous fluid therapy (Hartmann's solution) was administered at 10 mL/kg/h during the duration of general anaesthesia and blood glucose concentration was assessed prior to anaesthesia and once during the procedure.

General perioperative supportive care in all foals should include careful positioning, eye lubrication and attention to thermoregulation with the use of heated blankets when required (Robertson 2005). Post-operative fluid therapy is often warranted in neonates until they are able to re-start oral nutrition. Intravenous fluid therapy supplemented with glucose (4%) was required for 36 h post-operatively in one foal after shunt ligation prior to normal feeding behaviour returned (Woodford *et al.* 2015). Hug *et al.* (2012) described the use of a post-operative intravenous infusion of fresh frozen plasma in addition to intravenous crystalloid fluid therapy in a foal after shunt attenuation which was hypoproteinaemic after surgery.

Post-operative analgesia may incorporate the use of opioids and nonsteroidal anti-inflammatories (NSAIDs) alongside gastro-protectant therapy if necessary (Hug *et al.* 2012; Woodford *et al.* 2015). The anti-inflammatory effect of NSAIDs is usually the result of COX-2 inhibition, whereas the unwanted effects of these drugs are primarily due to COX-1 inhibition (Castagnetti and Mariella 2015). It is known that flunixin has a larger volume of distribution and lower clearance in neonatal foals compared with adult horses which affects the recommended dosing frequency (Semrad *et al.* 1993; Crisman *et al.* 1996). Phenylbutazone also has a larger volume of distribution and lower clearance in young foals compared with adult horses (Wilcke *et al.* 1993). Wilcke *et al.* (1998) studied the pharmacokinetics of ketoprofen in foals less than 24 h old and reported that clearance was lower and volume of distribution was larger than those determined for adult horses, indicating a longer dosing interval should be used. In contrast, Raidal *et al.* (2013) documented a faster clearance of meloxicam in foals after oral administration compared with the rates reported in adult horses. The findings of this study supported the oral administration of meloxicam suspension at 0.6 mg/kg bwt per os every 12 h in healthy foals less than 7 weeks of age (Raidal *et al.* 2013). However, care must be exercised when extrapolating the results of this study to the use in compromised foals with evidence of portosystemic shunt and hepatic dysfunction.

Gastro-protectant therapy may be warranted in hospitalised neonates; however, the potential adverse effects of gastric acid suppression in this population warrant consideration. Gastric acid serves an important barrier function against bacterial colonisation. Sepsis is a major cause of morbidity and mortality in neonatal foals, and translocation of bacteria across the gastrointestinal tract is believed to be an important source of infection (Javsicas and Sanchez 2008). In neonatal foals, sucralfate may be a viable alternative to omeprazole and has been shown to be superior to ranitidine in providing partial protection against the gastrointestinal manifestations of phenylbutazone toxicity in neonatal foals (Geor *et al.* 1989). In order to ensure that analgesia is appropriate, regular pain assessment is important during the post-operative period in all equine patients, particularly neonates.

In summary, while the incidence of portosystemic shunts in foals appears to be low, the presence of hepatic dysfunction

in the neonate should alert the clinician to the potential presence of an intra- or extrahepatic shunt. Knowledge of the pathology present and the physiological and pharmacokinetic implications enables appropriate choices to be made for the anaesthetic and analgesic management.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Case Report

Successful surgical management of a medial humeral epicondyle fracture in a Thoroughbred foal

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Keywords: horse; foal; fracture; medial humeral epicondyle; arthrotomy; elbow

Summary

A 2-week-old 75 kg Thoroughbred filly was presented for the investigation of an acute forelimb lameness characterised by a shortened cranial phase of the stride, a dropped elbow and reluctance to bear weight. Examination revealed a painful soft tissue swelling with marked instability and crepitus at the level of the left elbow joint. Radiographs revealed a medial epicondyle physeal fracture of the left humerus (Salter–Harris type II fracture) with displacement of the medial humeral epiphysis in a caudodistal direction (**Fig 1**). Under general anaesthesia, a medial arthrotomy over the elbow joint was made taking care to avoid iatrogenic damage to the ulnar nerve. The insertions of the deep and the superficial digital flexor muscles, in addition to the flexor carpi radialis and ulnaris muscles, were sharply transected from the caudodistal aspect of the medial humeral epicondyle to allow en-bloc removal of the fragment (**Fig 2**). Four weeks post-operatively, the foal was 3/5 lame and radiographs identified the presence of an irregular subchondral radiolucent area at the level of the distal medial condyle of the humerus, and the joint was therefore injected with corticosteroids in an attempt to reduce joint inflammation and lameness. The foal was then turned out into a small pen for a further 6 weeks. When the foal was re-evaluated 10 weeks after surgery, she was sound in all gaits and the previously identified radiolucent lesion had smoother margins with increased bone density. Follow-up examination at 2 years of age revealed the filly to be sound before and after forced flexion of the elbow joint with radiographs showing resolution of the subchondral bone defect on the medial humeral condyle. The owner was satisfied with the outcome and intended to present the filly at public auction. This case report describes a previously unreported surgical treatment for a fracture of the medial epicondylar physis in a foal.

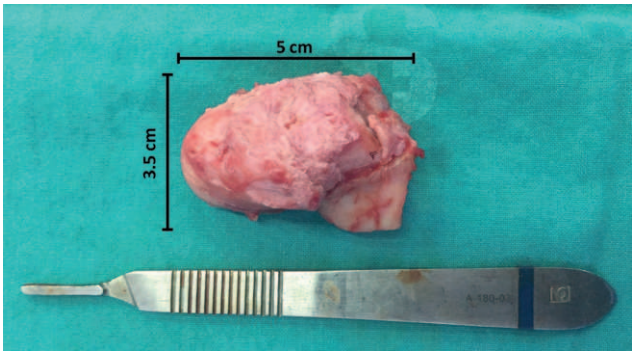

Fig 2: Medial humeral epicondylar epiphysis after surgical removal.

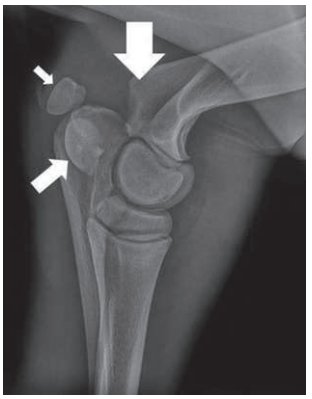

Fig 1: Preoperative mediolateral (flexed) radiographic image of the left elbow joint showing the medial humeral epicondylar epiphysis displaced in a caudodistal direction (midsize arrow), the distal metaphyseal area of the humerus where the aforementioned epiphysis should be attached (large arrow) and the proximal ulnar apophysis (small arrow).

Key points

- Medial humeral epicondylar fractures are rare in horses.
- Clinical signs include lameness at the walk characterised by a shortened cranial phase of the stride, a dropped elbow and reluctance to bear weight. A skyline (flexed proximocaudal-distocaudal) radiographic view is particularly useful to reach a definitive diagnosis of a medial humeral epicondylar fracture.
- The successful outcome of this case report demonstrates that such injuries may potentially be treated successfully by en-bloc removal of the medial epicondylar epiphysis. However, surgeons should be aware of possible undocumented complications or undesirable outcomes.

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Clinical Commentary

Humeral fractures in the foal

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Keywords: horse

Introduction

Fractures of the humerus occur uncommonly in foals and are usually a result of direct trauma, such as a kick or collision (Glass and Watkins 2019). Fractures tend to be closed due to the heavy musculature surrounding the humerus, although fractures involving the distal or proximal aspect of the bone can be open. While diaphyseal fractures are predominantly seen in adult horses, physeal fractures involving the proximal or distal physes are commonly described in foals (Glass and Watts 2017; Levine and Aitken 2017). Clinical signs include moderate-to-marked swelling, crepitation and moderate-to-severe lameness. Foals with complete diaphyseal fractures will often have a dropped elbow. This is due to fracture instability and overriding of the fracture fragments and/or radial nerve damage due to the course of the nerve along the caudal aspect of the humerus along the musculospiral groove. A diagnosis of a humeral fracture is made radiographically. A medial to lateral projection and craniomedial to caudolateral oblique projection are used to define fracture configuration. A proximocranial to distocaudal projection of the proximal humerus can be helpful in foals with proximal physeal fractures. Computed tomography, if available, can also be very useful for surgical planning.

Diaphyseal fractures

Although the treatment recommendation for diaphyseal fractures in foals is generally surgical, conservative treatment can be occasionally successful depending on fracture configuration. Long, oblique fractures may have overriding fragments that interdigitate providing some degree of stability. These fractures can be suitable for conservative management with stall confinement for 4–6 months with radiographic monitoring of fracture healing. In previous studies, 7/10 horses (Zamos and Parks 1992) and 4/17 horses (Carter *et al*. 1993) between the ages of 4 months and 3 years were sound for riding following conservative treatment of a humeral fracture. Although some humeral fractures can heal with conservative management in foals, support limb complications occur commonly and warrant serious consideration. Foals with limited weightbearing on one limb will have a tendency to develop a varus deformity in the support limb and a carpal flexural deformity in the fractured limb (Glass and Watts 2017).

Open reduction and internal fixation (ORIF) is indicated in unstable diaphyseal fractures, especially displaced fractures with a short oblique to spiral configuration. Several methods of internal fixation have been described including stacked pin fixation (Zamos and Parks 1992), Rush-pin fixation (Hunt *et al*. 1992), bone plate fixation (Rakestraw *et al*. 1991) and interlocking intermedullary nail (IIN) fixation (Glass and Watkins 2016a,b). Although there is only a single report of successful bone plating of a humeral fracture in the literature (Rakestraw *et al*. 1991), the author has successfully treated a small number of foals with double plating using locking compression plates (LCP). The IIN is a custom-designed implant system that has been used to treat a large number of foals with diaphyseal fractures. In one report, successful repair was achieved in 17/27 foals (Glass and Watkins 2016b). Combination of this system with a bone plate has also been described with 11/15 foals able to perform their intended use following treatment (Glass and Watkins 2016a). Following internal fixation, foals should be confined to a box stall for 2 months prior to controlled walking for 30 days and return to small paddock turnout at 3 months post-operatively.

Physeal fractures

Fractures of the distal and proximal physes of the humerus have been reported sporadically in the literature. Fractures affecting the proximal humerus can involve the proximal physis alone or can occur in conjunction with fracture of the greater tubercle (Embertson *et al*. 1986). Distal physeal fractures are more common (~65% of humeral physeal fractures) and can involve the humeral condyles and/or epicondyles (Embertson *et al*. 1986). These fractures can also occur in conjunction with fractures of the proximal radius and/or ulna (Embertson *et al*. 1986).

The existing literature suggests a poor prognosis for treatment of distal physeal fractures. Embertson *et al*. (1986) reported the outcome of physeal fractures in foals with 0/7 foals with a distal humeral physeal fracture surviving with conservative treatment or internal fixation. Two foals with a fracture of the medial epicondylar physis were treated conservatively, with one foal surviving and achieving soundness. One foal with a proximal physeal fracture treated conservatively did not survive. Carter *et al*. (1993) described the treatment of nine distal humeral physeal fractures and one proximal humeral physeal fracture in a foal. Of the distal physeal fractures, only one foal treated conservatively survived while three foals were subjected to euthanasia prior to treatment, three foals treated with internal fixation (dynamic compression plate or screws) did not survive, and one foal treated conservatively did not survive. Conservative treatment of the one foal with a proximal physeal fracture was successful. Auer *et al*. (1996) described the successful treatment of a 7-month-old Arab foal with a displaced Salter–Harris type IV fracture of lateral condyle of distal humerus, a

nondisplaced Salter–Harris type III fracture of the proximal radius and a nondisplaced fracture of ulna. The distal humerus was stabilised with two 5.5-mm cortex screws placed in lag fashion across the epicondyle and two 3.5mm cortex screws and one 5.5mm cortex screw placed in lag fashion in the distal epicondylar crest. The fracture in the proximal radius was repaired using a single 5.5-mm screw, while the ulnar fracture was repaired with a 3.5-mm 1/3 tubular plate. Despite severe lameness for 2 months, the horse was noted to be sound 4 years post-operatively. Recently, Ahern and Richardson (2010) described successful internal fixation of a Salter–Harris type II fracture of the distal humerus using cortex screws placed in lag fashion and an LCP applied to the distal caudolateral humerus. The fracture was approached via a transverse osteotomy of the ulna which facilitated exposure of the caudal humerus. The ulnar osteotomy was also repaired with an LCP. Six months post-operatively, the filly was walking and trotting normally with a subtle extensor deficit. Due to difficult surgical access to the distal humerus, ulnar osteotomies are also recommended in people and dogs (Wong and Baratz 2009). Although few successful reports of plate fixation of humeral fractures currently exist, the superior biomechanical properties of LCPs achieved through the creation of a fixed angle construct may increase the prognosis of humeral fractures in the horse.

Finally, in a recent case report by Mereu *et al.* (2021), a successful outcome of a foal with a physeal fracture of the medial epicondyle was described. In this report, a 2-week-old Thoroughbred filly with a displaced Salter–Harris type II fracture of the medial epicondyle was treated surgically via an arthrotomy and fragment removal. Two years post-operatively, only mild osteoarthritis of the elbow was present radiographically and the horse was sound with normal range of motion of the joint. Although fragment removal was successful in this case, this technique is obviously only appropriate for smaller fragments that do not play a major role in joint articulation.

Conclusion

In summary, although humeral fractures in the foal are generally associated with a poor prognosis for life and athleticism, newer surgical techniques and stronger implants may facilitate improved outcomes in these animals.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Original Article

An investigation of the shape of the hoof capsule in hindlimbs, its relationship with the orientation of the distal phalanx and comparison with forelimb hoof capsule conformation

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Summary

There is limited information documenting hind foot conformation. The objectives of the study were to describe the shape of the hoof capsule of hindlimbs from the lateral aspect in horses of variable breeds, and, within horses, to compare the conformation of the hoof capsule of forelimbs and hindlimbs and determine the orientation of the distal phalanx within the hoof capsule in hindlimbs. Lateral photographs of the fore and hind feet (n = 225) and lateromedial radiographs of the hind feet (n = 29) were obtained. Differences among breed and shoeing status groups were assessed using multivariable mixed-effects linear regression models. Angular parameters and ratios of linear measurements were compared between fore and hind feet; angular radiological variables and photographic parameters of the hind feet were compared. The mean dorsal hoof wall angle for hind feet (50.9°±3.7°) was smaller than forefeet (51.8°±3.9°) (P = 0.04). The mean heel angles for hind feet (36.4°±9.6°) were smaller than forefeet (40.1°±9.3°; P < 0.001). Dorsal hoof wall (P < 0.001) and heel (P = 0.002) angles were larger in unshod than shod feet. In the hind feet, the dorsal hoof wall was parallel to the dorsal aspect of the distal phalanx. The median angle of the distal phalanx to the horizontal (angle S) was 0.6° (interquartile range: −1.4, 2.3°). There was a positive relationship between angle S and the hoof wall angle (W); each 1° increase in angle S was associated with 0.6° increase in angle W (P < 0.001). Angle S was also positively associated with photographic heel angle; each degree increase in the angle S was associated with 1.8° increase in the heel angle (P < 0.001). It was concluded that the angle of the distal phalanx to the horizontal in hindlimbs is smaller than published values for forelimbs. The orientation of the distal phalanx in hindlimbs is correlated with external characteristics of the hoof capsule.

Introduction

There is a widely held view that conformation and lameness are related. It has been reported in Dutch Warmbloods that horses with asymmetrical forefeet have a shorter sporting career compared with their peers (Ducro *et al*. 2009a). Despite many studies investigating aspects of equine conformation (Magnusson and Thafvelin 1990; Holmström *et al*. 1990; Barrey *et al*. 2002; Anderson and McIlwraith 2004; Anderson *et al*. 2004; Love *et al*. 2006; Weller *et al*. 2006a, 2006b, 2006c; Ducro *et al*. 2009b; Jönsson *et al*. 2014), there is limited evidence-based literature relating specifically to the conformation of equine hind feet. The 'breakover' length, defined as the horizontal distance between the dorsodistal aspects of the hoof capsule and the distal phalanx, respectively, of hind feet was related to gluteal muscle soreness (Mansmann *et al*. 2010). In two recent studies which were based on lateromedial radiographic images of hind feet, the angle of the distal aspect of the distal phalanx to the horizontal was smaller in horses with hindlimb lameness than in nonlame horses (Clements *et al*. 2020; Pezzanite *et al*. 2019). In flat racing Thoroughbreds, a relationship was observed between the orientation of the distal phalanx and radiopharmaceutical uptake in the third metatarsal bones. If the plantar process of the distal phalanx of hind feet were lower than the toe of the distal phalanx, there was increased radiopharmaceutical uptake in the plantar condyles of the third metatarsal bones, reflecting stress-related bone injury (Walmsley *et al*. 2019).

Measurements of hoof conformation from digital photographs are accurate (White *et al*. 2008) and superior to those collected with hoof angle measuring devices (Moleman *et al*. 2005). It is generally accepted that in an ideally conformed horse, the dorsal hoof wall and heel should be parallel (Parks 2003). However, we have previously documented hoof capsule shapes in forelimbs and the heel angle (HA) was smaller than the dorsal hoof wall angle (DHWA) (Dyson *et al*. 2011a). There is a variable opinion as to whether the hindlimb DHWA is larger or smaller than in forefeet (Balch *et al*. 1991; Turner 1992; Jackson 1992). It was suggested that the DHWA is variable, but is approximately 50–54° in the forelimbs and about 3° larger in the hindlimbs (Balch *et al*. 1991). However, in a study of 25 horses of various breeds the DHWA determined radiologically was similar (approximately 50° and 49°, respectively) in forelimbs and hindlimbs (Cripps and Eustace 1999). In contrast, in a study of 81 ponies the DHWA of the hind feet was smaller than in the forefeet (Thieme *et al*. 2015).

We have previously demonstrated that the variations in shape and orientation of the distal phalanx are not consistently predicted by external characteristics of the hoof

capsule in forefeet (Dyson *et al*. 2011a, b). It has been suggested that there is an inverse relationship between the angle of the solar aspect of the distal phalanx to the horizontal and the force applied by the deep digital flexor tendon (DDFT) to the navicular bone in forelimbs (Eliashar *et al*. 2004). In horses with injuries of the podotrochlear apparatus or the DDFT, the angle of the dorsal aspect of the distal phalanx to the horizontal was slightly smaller than in horses with other forefoot-related injuries (Dyson *et al*. 2011b).

The objectives of this study were (1) to describe the shape of the hoof capsule of hindlimbs from the lateral aspect in horses of variable breeds; (2) within horses, to compare the conformation of the hoof capsule of forelimbs and hindlimbs; and (3) to determine the orientation of the distal phalanx within the hoof capsule in hindlimbs. It was hypothesised that (1) the DHWA would be larger than the HA in hindlimbs; and (2) the DHWA and the HA of hind feet would be smaller than forefeet.

Materials and methods

Horses

All four feet of a convenience sample of horses (n = 225) were photographed. The group consisted of 48 horses which underwent orthopaedic assessment (in hand, on the lunge and ridden) at the Animal Health Trust (AHT), and 177 nonlame horses, assessed in-hand only, comprising Thoroughbred racehorses and broodmares prior to sale, former Thoroughbred racehorses undergoing retraining as riding horses or being used for jockey training, sports horses at competition yards, further education college horses, general-purpose riding horses (including horses used for unaffiliated competition) and unbroken Welsh ponies. The breeds and shoeing status of all the horses were recorded. Feet were excluded if the coronary band was not clearly visible, and there was a history of previous laminitis, if hoof wall repair material obscured dorsal or palmar/plantar aspects of the hoof capsule and if the feet had not been trimmed for more than 6 weeks.

Photography

Lateral photographic images were obtained by one investigator (S.J.D.) using a digital camera (Canon EOS 77D[1]), after cleaning the feet when necessary. The camera was centred midway between the dorsal and palmar/plantar aspects of the coronary band at a standardised distance of 0.75 m. Horses stood on a horizontal level, concrete surface, bearing weight evenly on all four limbs. The repeatability of image acquisition was previously demonstrated; there were no differences in linear or angular measurements acquired from the same feet shod or unshod (Dyson *et al*. 2011a).

Radiography

Radiographic images of the hind feet were acquired in a subset of horses examined at the AHT (n = 29), as a part of the clinical assessment. Lateromedial computed radiographic images (Carestream[2]) of both hind feet were obtained. The toe of the hoof capsule was positioned in a v-shaped indentation on the top surface of a wooden block 17 cm high, with the sole of the foot vertical. Shoes were not removed. The x-ray beam was centred perpendicular to the hoof, midway between the dorsal and plantar aspects, approximately 1 cm distal to the coronary band. The imaging plate was held against the medial aspect of the hoof capsule, with a focus-imaging plate distance of 100 cm. Radiographs had to fulfil the following inclusion criteria: the plantar processes of the distal phalanx were superimposed and no more than 5 mm apart at any point, and there was a distinct trabecular pattern in the spongiosa of the navicular bone, with clearly demarcated plantar compact bone, and the sagittal ridge of the navicular bone was well-defined.

Image analysis

Photographs

The DHWA (the angle between the dorsal aspect of the hoof capsule and the horizontal), HA (the angle between palmar/plantar aspect of the hoof capsule and the horizontal), coronary band angle ([CBA] derived from a line drawn between the most proximal, dorsal aspect of the hoof capsule and the most proximal, palmar/plantar aspect of the hoof capsule and the horizontal), dorsal (DCBH) and palmar/plantar (PCBH) coronary band heights and weightbearing length (WBL) were measured from the digital images using image analysis software (ImageJ[3]; **Fig 1a**,**b**). If the dorsal hoof wall had an abrupt change in its alignment, or if the dorsal aspect of the hoof wall had a convex or concave shape, the measured angle was that of the majority of the length of the dorsal hoof wall. All measurements were performed by one analyst (K.K.). Repeatability for each measurement was determined by assessing each measurement 10 times on 10 randomly selected photographs. Final measurements were obtained and used for analysis when the coefficient of variance for all measurements was <2%. Dorsal: palmar/plantar coronary band height (D:PCBH) ratio and dorsal coronary band height: weightbearing length (DCBH:WBL) ratio were calculated. The use of ratios of the distance measurements permitted comparisons within and among horses of variable sizes.

Radiographs

Before obtaining the measurements, all the radiographs were rotated, so that the dorsodistal aspect of the hoof capsule was pointing to the left. The following were measured using ImageJ[3]: the angle of the dorsal hoof wall to the horizontal (Angle W), the angle between the dorsal aspect of the distal phalanx and the weightbearing surface (Angle DP), and the angle of the solar (distal) border of the distal phalanx to the horizontal (Angle S; **Fig 1c**). All measurements were performed by one analyst (K.K.). Repeatability for each measurement was determined by assessing each measurement 10 times on 10 randomly selected radiographs. Final measurements were obtained and used for analysis when the coefficient of variance was <2% for all measurements.

Data analysis

Data were imported from a Microsoft Excel (v.2010)[4] spreadsheet into Stata (IC v.15.0)[5], where all statistical analyses were conducted. Normality was assessed by visually inspecting data distribution histograms overlaid with normal and kernel density plots and the Shapiro–Wilk normality test. All data were accordingly summarised as either means

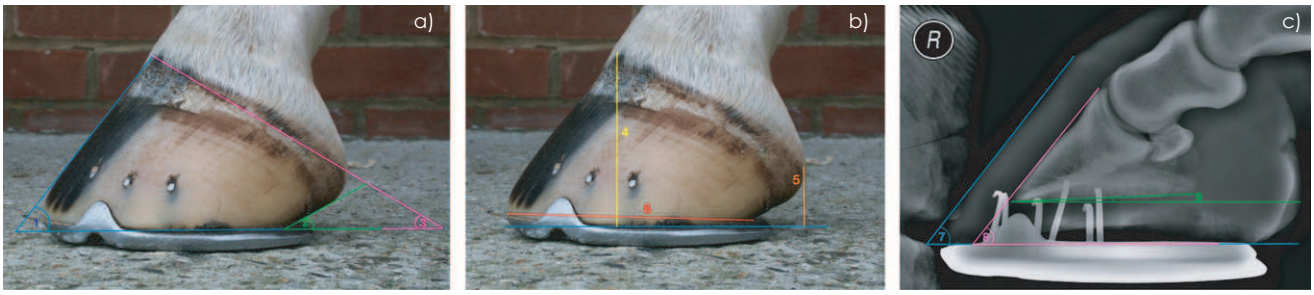

Fig 1: Photographs and radiograph of a hind foot showing how the a) angular photographic parameters: dorsal hoof wall angle (1), heel angle (2), coronary band angle (3), b) linear photographic parameters: dorsal coronary band height (4), palmar/plantar coronary band height (5), weightbearing length (6) and c) radiographic angular parameters: the angle of the dorsal hoof wall to the horizontal (the equivalent of the ground surface) (7—angle W), the dorsal aspect of the distal phalanx to the horizontal (8—angle DP) and the solar border of the distal phalanx to the horizontal (9—angle S) were obtained.

(±s.d., range) or medians (interquartile range [IQR], range). Significance was set at $P < 0.05$.

Breed differences in photographic limb angular parameters

One-way ANOVA was initially used to assess the presence of breed differences in mean DHWA, HA and CBA within each of the four limbs. The post hoc Tukey test was used to identify significant pairwise differences in angle means between breeds. The Kruskal–Wallis test was used to assess the presence of breed differences in D:PCBH and DCBH:WBL ratios within each of the four limbs. The Bonferroni correction was used to adjust for multiple comparisons (P-value significance 0.05/20 = 0.0025). Subsequently, multivariable mixed-effects linear regression modelling was used with each angle and ratio as an individual outcome, while adjusting for breed, limb location (fore or hind), limb side (right or left) and whether the foot was shod or unshod, with horse as a random effect to account for similarities between limbs belonging to the same horse. Variables were excluded from the final models using a stepwise backward elimination process and retained where the likelihood ratio statistic was $P < 0.05$.

Symmetry between right and left feet of forelimbs and hindlimbs

The paired sample *t* test was used to assess the symmetry of DHWA, HA and CBA between pairs of forelimbs and hindlimbs. The Wilcoxon signed-rank test was used to assess symmetry of D:PCBH and DCBH:WBL ratios between pairs of forelimbs and hindlimbs. The Bonferroni correction was adjusted for multiple comparisons (P-value significance 0.05/5 = 0.01).

Relationship between photographic angles and linear measurement ratios in forelimbs and hindlimbs

The paired sample *t* test initially assessed the difference between mean DHWA and HA to determine whether the angle of the hoof wall approximated that of the heel. To further investigate whether the hoof wall and heel may be parallel, multivariable mixed-effects linear regression modelling assessed the relationship between DHWA and HA, while adjusting for breed, limb location (fore or hind), limb side (right or left) and whether the foot was shod or unshod, with horse as a random effect. Variables were similarly excluded from the final models using a stepwise backward elimination process and retained where the likelihood ratio statistic was $P < 0.05$. Multivariable mixed-effects linear regression modelling was also used to assess relationships between angles (from both photographs and radiographs) and ratios, using the method already described while adjusting for the same set of explanatory variables.

Symmetry of the hind feet and relationship between radiographic parameters and the hoof capsule in the hindlimbs

The Wilcoxon signed-rank test and mixed-effects linear regression modelling assessed differences and associations between radiographic angles, and between the shape of the hoof capsule and the orientation of the distal phalanx, in the hindlimbs.

Mixed-effects linear regression model diagnostics

Scatter plots of continuous variables, with linear fitted values, corresponding 95% confidence intervals, and a lowess smoother predictor line were used to assess linearity and presence of outliers. Standardised residuals were additionally assessed for normality by plotting quantiles of the model residuals against quantiles of the normal distribution.

Results

Nine hundred photographs of feet were acquired, of which 890 images of 225 horses met the inclusion criteria. These included 220 right forefeet, 222 left forefeet, 223 right hind feet and 225 left hind feet. Bilateral lateromedial radiographs of the hind feet were obtained from 29 horses.

Descriptive data

The breed distribution is summarised in **Table 1**. The majority of horses were shod, either on all four feet (38.7%; n = 87) or on two forefeet (33.3%; n = 75), while 28.0% (n = 63) were unshod. The data collected from photographs and radiographs are shown in **Tables 2** and **3**, respectively. The mean DHWAs for all forefeet and all hind feet were 51.8° (±3.9°; range: 39.6, 63.1°) and 50.9° (±3.7°; range: 38.6, 62.4°), respectively. The mean HAs for all forefeet and all hind feet were 40.1° (±9.3°; range: 12.3, 64.1°) and 36.4° (±9.6°; range: 16.3, 61.1°), respectively. The median angle S for hind feet was 0.6° (IQR: −1.4, 2.3°; range: −3.7, 6.9°).

Fig 2: Photographs of the a) right forefoot, b) right hind foot and c) lateromedial radiograph of the right hind foot of an Irish sports horse. The photographic images are rotated horizontally to mimic the orientation of all images during measurement acquisition. The radiographic image is rotated so that the dorsodistal aspect of the hoof capsule is pointing to the left. In a), the dorsal hoof wall angle (DHWA) and heel angle (HA) are 50.0° and 41.5°, respectively. In b), the DHWA and HA are 51.8° and 34.5°, respectively. In c), the dorsal hoof wall angle (angle W) is 51.3°, the angle of the dorsal aspect of the distal phalanx to the horizontal (angle DP) is 51.4°, and the angle of the solar aspect of the distal phalanx to the horizontal (angle S) is 2.7°.

TABLE 1: Breed distribution of the 225 horses for which lateral photographs of all four feet were obtained

Breed	Number	Percentage
WBL/sports horse*	53	23.6
Thoroughbred†	108	48.0
Pony‡	33	14.7
Cob§	13	5.8
Other¶	18	8.0
Total	225	100.0

* WBL, Warmblood; sports horse: WBL cross, Irish sports horse, WBLxThoroughbred.
† Thoroughbred: Thoroughbred or Thoroughbred cross.
‡ Pony: Connemara Pony or Connemara cross, Fell Pony, New Forest Pony, Welsh Pony or Welsh cross, Pony, Shetland Pony.
§ Cob: Cob, Welsh Cob.
¶ Other: Irish Draught, Friesian, Arab cross, crossbred, Miniature Horse, Andalusian, Shire cross, Percheron cross.

Breed, limb and shoeing status differences in photographic angular parameters

Multivariable mixed-effects linear regression modelling identified significant differences in photographic angular parameters between breed, limb location (fore or hind) and shoeing status. The DHWA was 2.0° (95% CI: 0.9, 3.1°) larger in Ponies compared with Thoroughbreds ($P < 0.001$), was 0.4° (95% CI: −0.7, −0.02°) smaller in hind feet compared with forefeet ($P = 0.04$) and was 1.6° (95% CI: 1.03, 2.1°) larger in unshod compared with shod feet ($P < 0.001$). The HA values were smallest in Thoroughbreds. Ponies had the greatest difference, with 11.4° (95% CI: 9.0, 13.9°) larger HAs compared with Thoroughbreds ($P < 0.001$). Heel angles were also 4.3° (95% CI: −5.3, −3.4°) smaller in the hind compared with forefeet ($P < 0.001$) and 2.1° (95% CI: 0.8, 3.5°) larger in unshod compared with shod feet ($P = 0.002$). The CBA was 2.2° (95% CI: −3.1, −1.3°) smaller in Ponies and 3.0° (95% CI: −4.3, −1.7°) smaller in Cobs compared with Thoroughbreds ($P < 0.001$). Unshod feet had 1.6° (95% CI: −2.1, −1.1°) smaller CBAs compared with shod feet, and CBAs were 4.1° (95% CI: 3.7, 4.4°) larger in hind compared with forefeet ($P < 0.001$).

The ratios of photographic linear parameters varied among breeds. The D:PCBH ratio was 0.2 (95% CI: −0.4, −0.1), 0.4 (95% CI: −0.5, −0.3) and 0.4 (95% CI: −0.6, −0.2) times smaller for Warmbloods, Ponies and Cobs, respectively, compared with Thoroughbreds ($P < 0.000$). The D:PCBH ratio was also larger in hind compared with forefeet and smaller in

TABLE 2: The mean values ± standard deviation of the angular photographic parameters in degrees (°) (dorsal hoof wall angle, DHWA; heel angle, HA; coronary band angle, CBA) in the different breeds (see Table 1) of the left/right, fore/hind feet in 225 horses

Angular parameters (°)	WBL/SH†	TB‡	Pony	Cob	Other	All horses
Left forefoot						
DHWA (n = 222)	51.1 ± 3.7	50.1 ± 3.7	53.3 ± 4.0	52.8 ± 3.1	51.8 ± 4.3	51.1 ± 3.9
HA (n = 222)	41.1 ± 9.0	36.3 ± 9.1	47.4 ± 6.6	42.6 ± 6.9	41.8 ± 9.7	39.8 ± 9.5
CBA (n = 222)	23.2 ± 3.2	23.9 ± 2.7	21.6 ± 2.5	22.0 ± 4.0	23.0 ± 3.6	23.2 ± 3.0
Right forefoot						
DHWA (n = 220)	50.6 ± 3.7	49.8 ± 3.7	52.6 ± 3.7	50.5 ± 2.8	51.3 ± 4.7	50.6 ± 3.8
HA (n = 219)	41.3 ± 7.4	36.2 ± 8.1	49.1 ± 7.6	44.6 ± 6.6	45.1 ± 6.5	40.4 ± 9.0
CBA (n = 218)	23.1 ± 2.7	24.0 ± 3.0	21.4 ± 2.6	23.1 ± 3.0	22.3 ± 3.5	23.2 ± 3.0
Left hind foot						
DHWA (n = 225)	50.9 ± 3.2	50.1 ± 3.3	52.6 ± 4.1	51.5 ± 3.5	52.3 ± 4.6	50.9 ± 3.6
HA (n = 225)	37.2 ± 7.4	32.5 ± 8.2	44.8 ± 9.1	39.4 ± 7.3	39.1 ± 11.4	36.3 ± 9.4
CBA (n = 225)	27.5 ± 2.9	28.1 ± 3.0	24.6 ± 2.6	23.5 ± 3.5	25.6 ± 3.8	27.0 ± 3.4
Right hind foot						
DHWA (n = 223)	51.0 ± 3.5	49.9 ± 3.4	52.9 ± 4.1	51.5 ± 3.7	52.3 ± 3.9	50.9 ± 3.7
HA (n = 223)	37.1 ± 8.4	32.3 ± 8.0	46.4 ± 9.2	41.0 ± 8.0	38.5 ± 9.8	36.6 ± 9.7
CBA (n = 223)	27.2 ± 3.4	27.8 ± 2.9	23.9 ± 2.7	22.4 ± 3.4	25.5 ± 3.6	26.6 ± 3.5

TB‡, Thoroughbred; WBL/SH†, Warmblood or sports horses (see Table 1).

TABLE 3: Median values (interquartile range [IQR]) of angular radiographic parameters between left and right hind feet. There were no significant differences between left and right hind feet

Parameter(°)		All hind feet (n = 58) Median (IQR)	Left hind (n = 29) Median (IQR)	Right hind (n = 29) Median (IQR)	P-value*
Angle W	Dorsal hoof wall angle	50.1 (47.9, 52.5)	50.4 (47.9, 53.4)	50.1 (47.9, 52.2)	0.59
Angle DP	Distal phalanx angle	50.2 (48.5, 52.3)	50.4 (48.1, 52.9)	49.5 (48.7, 52.1)	0.91
Angle S	Solar angle	0.6 (−1.4, 2.3)	0.6 (−1.6, 1.9)	0.5 (−1.3, 2.7)	0.33

* Wilcoxon signed-rank test P-value for the difference in median values between left and right hind feet.

unshod compared with shod feet (P < 0.001). The DCBH:WBL ratio was larger in hind compared with forefeet and in unshod compared with shod feet (P < 0.001), with a small breed effect (P = 0.02).

Symmetry between right and left feet of forelimbs and hindlimbs

In the forelimbs, the only significant difference between angular measurements identified using the paired sample t test was for the DHWA (P = 0.02), but this did not retain significance after correcting for multiple testing. The mean DHWA of the left forefeet (51.1° [±3.9°; range: 41.6, 63.1°]) was 0.5° (±3.2°) larger than in the right forefeet (50.6° [±3.8°; range: 39.6, 60.8°]). There were no significant differences identified between left and right forefeet for the ratios of the linear parameters.

The mean CBA was 0.4° (±2.2°) larger in the left hind feet (27.0° [±3.4°; range: 17.7, 34.9°]) compared with the right hind feet (26.6° [±3.5°; range: 17.9-36.2°]; P = 0.004). No other left-right asymmetries were identified in the hind feet.

Relationship between photographic angles and linear measurement ratios in forelimbs and hindlimbs

The paired sample t test revealed consistent differences in mean angles of the hoof wall and heel in both the forefeet and the hind feet (P < 0.001 for all paired feet combinations). The mean DHWA was consistently larger than the mean HA in both the forefeet (mean differences in the left and right forefeet were 11.3° [±8.2°] and 10.1° [±8.0°], respectively) and the hind feet (mean differences in the left and right hind feet were 14.6° [±8.2°] and 14.4° [±8.0°], respectively). Multivariable mixed-effects linear regression modelling, adjusting for the significant effect of limb location, further revealed a positive relationship between DHWA and HA, with every one-degree increase in HA associated with a 0.2° (95% CI: 0.17, 0.21°) increase in DHWA (P < 0.001). These findings suggest that the hoof wall is unlikely to be parallel to the heel in either the forefeet or the hind feet.

Multivariable modelling identified significant associations between D:PCBH ratio and DHWA, HA and CBA, while adjusting for the significant effects of breed, limb location and shoeing status. A negative relationship was identified between D:PCBH ratio and DHWA, with every degree increase in DHWA associated with a 0.01 (95% CI: −0.02, −0.004) decrease in the D:PCBH ratio (P = 0.001). Similarly, for every degree increase in HA there was a predicted 0.01 (95% CI: −0.01, −0.005) decrease in D:PCBH ratio (P < 0.001). There was a positive relationship between D:PCBH ratio and CBA, with each degree increase in CBA associated with a 0.1 (95% CI: 0.1, 0.1) increase in D:PCBH ratio (P < 0.001).

Symmetry of the hind feet and relationship between radiographic parameters in the hindlimbs

The Wilcoxon signed-rank test did not identify significant differences in the radiographic parameters between the left and right hind feet. Linear regression modelling identified a positive relationship between angles S and W; each 1° increase in angle S was associated with a 0.6° (95% CI: 0.3, 0.8°) increase in angle W (P < 0.001).

Relationship between the shape of the hoof capsule and the orientation of the distal phalanx

The Wilcoxon signed-rank test did not identify a significant difference between DP angle and angle W in either the left or right hind feet. Linear regression modelling identified a positive relationship between radiographic angle S and photographic HA (Fig. 2). Each degree increase in the angle S was associated with a 1.8° (95% CI: 1.0, 2.6) increase in the HA (P < 0.001).

Discussion

The study was designed to characterise the conformation of the hoof capsule in the hind feet assessed from the lateral aspect and to compare this with the hoof capsule shape of the forefeet. In addition, the relationship between the distal phalanx orientation and the hoof capsule conformation of the hind feet was described. In accordance with our hypotheses, the DHWA in the hind feet was consistently larger than the HA. There was also a significant difference between DHWA and HA in the forefeet. The DHWA and HA of the hind feet were smaller than in the forefeet, also in accordance with our hypotheses.

Thoroughbreds had significantly smaller mean values of the DHWA and HA, but the mean CBA was larger than in the other breeds, which is consistent with a previous comparison of the forefeet hoof conformation between Thoroughbreds and Standardbreds (Thomason *et al*. 2008). Our results were similar to the mean forefoot DHWA of American Thoroughbred racehorses (Kane *et al*. 1998). In the current study, the DHWA was slightly smaller in hind feet compared with forefeet, in accordance with Thieme *et al.* (2015), but contrary to other observations (Balch *et al*. 1991). Overall, the HA and CBA were smaller in the hind feet than in the forefeet, although for ponies alone the CBA in the hind feet was larger than in the forefeet. This was contrary to previous observations in ponies (Thieme *et al.* 2015). Within all breed groups, the HA values were highly variable, which may reflect farriery techniques (Kummer *et al*. 2006, 2009), different management practices (stabling or turn out), terrain and environmental factors (Hampson *et al*. 2013), or variable exercise intensity or duration (Peel *et al*. 2006; Faramarzi

et al. 2009; Hampson *et al*. 2013) in the horses participating in the study. Shoes provide protection to the hoof capsule, and the shoeing interval will influence hoof capsule growth and thus measurements.

A significant influence of the hardness of the ground surface and the distances travelled on the angular and linear dimensions of the hoof capsule and the hoof wear was observed in the forelimbs of a group of Australian feral horses (Hampson *et al*. 2013). Soft substrate and moderate distances (5–10 km/day) reduced hoof wear; the horses travelling long distances (>10 km/day) on hard ground had larger mean DHWAs and HAs (Hampson *et al*. 2013). In the current study, unshod feet had larger DHWA, HA and DCBH:WBL ratios, and smaller CBA and D:PCBH ratios compared with shod feet, even when adjusted for breed differences.

There may be a relationship between size of the distal phalanx and hoof capsule angles (Kummer *et al*. 2006). In the forefeet of Warmbloods, there was a negative correlation between the DHWA and the length of the distal phalanx, measured from the dorsodistal aspect of the distal phalanx to the middle of the articular surface on a lateromedial radiograph.

In the current study, the hind feet had higher D:PCBH and DCBH:WBL ratios than the forefeet, which may suggest that the hind feet have relatively more hoof horn material to resist compressive weightbearing forces acting on the hoof capsule than the forefeet (Balch *et al*. 1991), or are subject to different biomechanical forces (Merkens *et al.* 1985). The peak amplitudes of the ground reaction force were higher in forelimbs than in hindlimbs (Merkens *et al*. 1985). However, hind hooves landed with a higher velocity than the fore hooves, and the maximal hoof friction, characterised by the caudal horizontal acceleration peak, was higher in the hind feet than in the forefeet during the impact phase of stance (Back *et al.* 1995). In contrast, more oscillations were observed in the forefeet than in the hind feet, because the amplitude of vertical velocity at impact and peak acceleration was greater in the forefeet than in the hind feet (Back *et al.* 1995). More information is needed to better understand hindlimb biomechanics and their relationships with hindlimb conformation and injury.

Contrary to earlier descriptions of the ideal hoof conformation (Parks 2003), the dorsal hoof wall was not parallel to the heel in either in the forelimbs, as previously documented (Cripps and Eustace 1999; Kummer *et al*. 2006; Dyson *et al*. 2011a,b; Labuschagne *et al*. 2017), or in the hindlimbs. The DHWA was approximately 1.3 times larger than the HA in the forefeet and 1.4 times larger than the HA in the hind feet.

In a previous study, the DHWA was slightly smaller in the hind feet than in the forefeet (Cripps and Eustace 1999), but aligned with the DP angle of the hind feet, as in the current study. In our study, there was a positive correlation between angle S and angle W. Furthermore, we determined a significant positive association between angle S and the HA in the hind feet. Moderate strength (Fowler *et al*. 1998) ($RS = 0.42$, $P < 0.0001$) of this correlation was described previously in the forefeet (Dyson *et al*. 2011b). Therefore, the assessment of the hoof capsule shape of hind feet may be useful to predict the orientation of the distal phalanx within the hoof capsule, assuming that the trimming interval does not exceed 6 weeks. A trimming interval of 8 weeks may influence the position of the distal phalanx within the hoof capsule (Kummer *et al*. 2006) and alter both alignment of the phalanges and the loading patterns on the associated tendons and ligaments.

The median angle S (0.6°) was only determined in a small subset of lame horses, but was smaller than the suggested reference range for forefeet (2–10°, Parks 2003; 5.7 ± 1.6° in a group of feral Australian horses [Hampson *et al*. 2013]). Our results were more consistent with the reference range of the median angle S (0.9°) in the hind feet of a group of nonlame sports and pleasure horses (Pezzanite *et al.* 2019) and the mean angle (1.6°) in a nonlame mixed group of UK horses (Clements *et al.* 2020). In contrast, the plantar processes of the distal phalanx in the hindlimbs were lower than the toe in 60% of Australian Thoroughbred racehorses (Walmsley *et al*. 2019). Horses in which the solar border of the distal phalanx was horizontal, or in which the plantar processes of the distal phalanx were lower than the toe, had superior racing performances compared with those in which angle S was greater than zero. However, horses in which the plantar processes of the distal phalanx were lower than the toe had a greater risk of subchondral bone injury of the third metatarsal bones compared with those in which angle S was zero or greater (Walmsley *et al*. 2019). Angle S was significantly smaller in sports, pleasure and racing horses with stifle pain compared with hock pain (Clements *et al.* 2020). In contrast, in sports and pleasure horses an angle S of ≤0° was more prevalent in horses with lameness originating from the distal tarsus and proximal metatarsus, compared with nonlame horses or horses with stifle pain (Pezzanite *et al.* 2019). Fifty-three per cent of the horses in the latter study were unshod at the time of assessment. Horses with hindlimb lameness that were shod had a smaller angle S compared with unshod lame horses (Clements *et al.* 2020). It is currently not known if being barefoot has any long-term influence on hind foot hoof capsule shape and orientation of the distal phalanx, although in the current study DHWA and HA were larger in unshod hind feet compared with shod feet. There remain limited data concerning the differences between biomechanics of the forelimbs and hindlimbs and the relationship between the conformation of hind feet and hindlimb injuries.

The study has some limitations. The radiographs of the hind feet were obtained with the foot in a vertical position, whereas when the photographs were acquired, the feet were fully load-bearing, which could potentially have created some differences between the measured angles. We did not investigate the mediolateral balance of the measured feet, because only lateral images were acquired. The horses included in the study were from many yards and had been trimmed and shod by a large number of farriers of variable experience and skill. Variable trimming techniques could have influenced the results. The nonlame horses were only assessed moving in straight lines, which does not equate with an absence of lameness under other circumstances. Only a subset of the study population underwent radiography because there was no clinical indication to perform radiographic assessment in the nonlame horses.

In conclusion, our study confirms that the DHWAs are larger than the HAs in both fore and hind feet, but the DHWAs and HAs in hind feet were smaller than in the forefeet. Median angle S is <1° in the hind feet. Evaluation of the hoof capsule conformation of the hind feet may be

useful to predict the orientation of the distal phalanx within the hoof capsule.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The study was approved by the Clinical Ethical Review Committee of the Animal Health Trust, AHT 36 2018. Explicit owner consent for inclusion in this study was not sought, but all owners consented to the use of all case information for scientific publication.

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Authorship

The study was conceived and designed by S. Dyson; the data were collected by K. Kalka; statistical analysis was performed by D. Pollard; data were interpreted by K. Kalka and S. Dyson, who also wrote the manuscript, with contributions from D. Pollard; all authors approved the final version.

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Original Article

The clinical features and short-term treatment outcomes of scirrhous cord: A retrospective study of 32 cases

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Keywords: horse; scirrhous cord; castration; complication; treatment; funiculitis

Summary

Scirrhous cord (SC) is an uncommon complication of castration, characterised by chronic infection of the spermatic cord remnant. It is reported that surgical excision of the infected tissue is the most effective means of treatment, but there are few published studies assessing the outcomes of horses treated for SC. The aims of this retrospective study were to describe the clinical features and short-term outcomes in horses treated for SC at two equine hospitals in the UK. The clinical records of horses diagnosed with SC over a 10-year period were reviewed. A diagnosis of SC was made if the gelding presented with typical clinical signs with confirmation at surgery. Thirty-two cases of SC were identified at the two equine hospitals. The mean age at presentation was 6 years (range 2–14 years, n = 22), and the median time from castration to presentation was 29.5 days (range 20–2500 days). Mean age at castration was 4.3 years (range 6 months to 10 years, n = 10). Clinical signs included scrotal swelling, discharging wounds, hindlimb lameness and pyrexia. Five horses demonstrated hyperfibrinogenaemia (n = 8). Microbial culture isolated various bacterial species. All 32 cases were treated with surgical excision of the infected tissue and discharged from the hospitals between 1 and 10 days post-operatively. A limitation of this study is that it was a retrospective study with no long-term follow-up available. It was concluded that the results of this study confirm that SC can present at variable time points following castration, even many years later, and that a variety of bacterial species may be involved. Surgical excision of infected tissue is a successful treatment with a good short-term prognosis for survival.

Introduction

Castration is one of the most common surgical procedures performed in equine practice. Despite the routine nature of this surgery, complications can occur and are reported to be a common cause of veterinary malpractice claims (Kilcoyne 2013). There are a number of different techniques of castration (Searle *et al*. 1999; Green 2001; Kilcoyne 2013; Owens *et al*. 2018; Schumacher 2019), and the choice of technique is more often based on surgeon preference and previous experience than published evidence. Potential complications are numerous and include scrotal oedema, haemorrhage, omental herniation, evisceration, incisional infection, funiculitis (inflammation of the spermatic cord), scirrhous cord (SC), inguinal and abdominal abscessation, peritonitis and penile trauma (van der Velden and Rutgers 1990; Moll *et al*. 1995; Schumacher 1996; Mason *et al*. 2005; Arnold and Chaffin 2012; Kilcoyne *et al*. 2013; Shearer *et al*. 2017; Beavers and Mitchell 2018; Rosanowski *et al*. 2018; Racine *et al*. 2018).

Scirrhous cord (SC) is a chronic form of funiculitis, where the surgical incisions attempt to heal with persistent infection of the spermatic cord stump (Kilcoyne 2013). According to Kilcoyne (2013), scirrhous cord is generally caused by a *Staphylococcus* spp. infection and usually develops following extension from a scrotal infection, contamination by emasculators or ligatures (Kilcoyne *et al*. 2013; Schumacher 2019). Septic funiculitis presents initially with oedema of the scrotum and/or prepuce, in addition to pyrexia and sometimes lameness (Schumacher *et al*. 2013). Marked enlargement and thickening of the spermatic cord is usually palpable in the inguinal region and may progress proximally through the inguinal ring where enlargement may be detected on rectal examination (Claffey *et al*. 2018).

Treatment of SC may resolve with antimicrobial therapy and re-establishment of drainage, but it is reported that surgical excision of the infected tissue is the most reliable means of treatment (Searle *et al*. 1999; Pollock 2012; Schumacher *et al*. 2013). Surgical excision is reportedly more difficult in chronic cases due to associated fibrosis. Despite being a well-recognised complication of castration, there are few published studies assessing the outcomes of horses treated for SC. The aims of this retrospective study were to describe the clinical features and outcomes in horses treated for SC at two equine hospitals in the UK.

Materials and methods

The clinical records of horses diagnosed with SC at two equine referral hospitals in the south-east of England between 2007 and 2017 were reviewed. Cases comprised of both external referrals and those castrated in the two hospital practices or by their respective ambulatory teams. No data were available with regard to the environment in which the castration was performed. A diagnosis of SC was made if the gelding presented with typical clinical signs (swelling of the scrotal/inguinal region with a palpably enlarged spermatic cord remnant uni- or bilaterally, with or without a draining tract, with or without pyrexia or lameness). Confirmation of SC was obtained at surgery (gross swelling of one or both spermatic cord remnants with granulation tissue and inspissated purulent material).

The data collected were assimilated into a Microsoft Excel® spreadsheet and included breed, age at castration,

age at diagnosis, castration technique used, previous treatments, clinical findings on presentation, diagnostic imaging findings, duration of surgery (defined as the time from induction to movement to the recovery box), and antimicrobial and anti-inflammatory drug use peri- and post-operatively. All data were anonymised in accordance with the University of Surrey's code of research ethics. Given the retrospective nature of the study over a relatively long time period, data were often limited with respect to the initial castration procedure.

Results

Thirty-two cases of SC were identified at the two equine hospitals (centre 1 n = 13; centre 2 n = 19). Breed was recorded in 24/32 (75%) horses and included eight Warmbloods/crosses, six cobs/crosses, four draught horses, two Thoroughbreds, two ponies, one Hackney and one Quarter Horse.

Age at presentation for treatment of SC ranged from 2 to 14 years, with a mean age of 6 years (n = 22). The exact age of 10 horses was not recorded. Age at castration was recorded in only 10/32 (31%) cases and ranged from 6 months to 10 years with a mean of 4.3 years. Of the horses where the age at castration was recorded, 9/10 presented for the treatment of SC within 4 months of castration. The overall median time between castration and SC presentation was 29.5 days (range 20–2500 days). The technique of castration was known in only seven horses with six using an open technique (four standing, one recumbent) and one a semi-closed technique (recumbent). The use of ligatures at initial castration was only recorded in one case; PDS[1] was used in an open castration performed standing. The specifics of each individual castration technique are beyond the scope of this paper.

Clinical signs included scrotal swelling in all horses. The presence or absence of a draining tract was recorded in 25 cases: nine had a draining tract and 16 did not (**Figs 1** and **2**). The swelling ranged from 5 to 20 cm in width, with a mean of 9.6 cm. The side involved was recorded in 22 cases, with 16 affected on the right side, four on the left side and two bilaterally affected. A discharging wound was noted in nine horses, with the nature of the discharge varying from serous, serosanguinous to purulent. Hindlimb lameness was recorded in three horses, which was bilateral in two horses and left unilateral in one horse. Pyrexia (rectal temperature ≥38.6°C) at the time of diagnosis was recorded in six horses. Haematological results were recorded in eight horses, of which five demonstrated hyperfibrinogenaemia (plasma fibrinogen >4.0 g/L).

Treatments instigated prior to SC diagnosis were recorded in 16 horses including 7/16 (44%) that received antimicrobial therapy and 6/16 (38%) that received antimicrobial therapy in combination with nonsteroidal anti-inflammatory drugs. Other treatments recorded in individual horses included topical application of copper sulphate crystals and lavage of the draining tract. Specific details were not available regarding antimicrobial and anti-inflammatory therapies used prior to referral for surgery.

Microbial culture and sensitivity results were recorded in eight cases obtained from samples taken during examination at the referral hospitals. Organisms isolated from these 8 samples included *Streptococcus equi* subspp. *zooepidemicus* (2), Beta-haemolytic *Streptococcus* spp. (2), *Streptococcus parauberis* (1), *Proteus* spp. (2), *E. coli* (1), *Acinetobacter* spp. (1), *Enterococcus* spp. (1), *Pasteurella* spp. (1), *Achromobacter* spp. (1) and a gram-negative coccus (1). *Staphylococcus* spp. were not identified in any horses.

Ultrasonographic examination results were recorded in 8 cases, characteristically showing an enlarged spermatic cord remnant (circular to oval structure) with a hyperechoic outline filled with heterechoic material (**Fig 1**). In one case, multiloculated hypoechoic structures were identified (subsequently confirmed as a multiloculated abscess) (**Fig 2**).

Following referral and diagnosis, all 32 horses were treated by surgical excision of the infected tissue under general anaesthesia. Horses were anaesthetised using a standard ketamine (2.2 mg/kg bwt i.v.) and diazepam (0.04 mg/kg bwt i.v.) co-induction, maintained on isoflurane in 100% oxygen and placed in dorsal recumbency before a routine aseptic skin preparation was performed. An elliptical incision was made around the infected tissue, and the enlarged spermatic cord was isolated using a combination of blunt and sharp dissection. The segment of thickened spermatic cord was removed using Serra emasculators (**Figs 1** and **2**). Transfixation ligatures were placed around the proximal segment of the spermatic cord in 18 cases, with polyglactin 910 (Vicryl[1]) most commonly used in 11/ 18 (61.1%) cases and PDS[1] in 1/18 (5.6%) cases; the suture material used was not recorded in the remaining six cases. The surgical site was partially closed in 11 cases and left open in six cases. A Penrose drain was placed in four cases. Sterile packing was used to fill 'dead space' in five cases following surgery, and this was removed after 1 day (n = 3); 2 days (n = 1) or 3 days (n = 1). Surgical time ranged from 15 to 115 min (mean 41 min).

Perioperative antimicrobial therapy was recorded in 18 cases and varied on an individual basis predominantly including procaine penicillin (25,000 IU/kg bwt i.m. q. 12 h) and gentamicin sulphate (6.6 mg/kg bwt i.v. q. 12 h). Procaine penicillin was used alone in seven cases, gentamicin sulphate alone in two cases and both drugs in combination in six cases. The mean duration for procaine penicillin use was 1.3 days (range 1–5 days, n = 13) and gentamicin sulphate 1.25 days (range 1–3 days, n = 8). Oxytetracycline (8 mg/kg bwt i.v. q. 24 h) was used in two cases for 1 day and ceftiofur (2.2 mg/kg bwt i.v. q. 12 h) in one case for 1 day.

Horses were discharged from the respective hospitals with oral antimicrobial treatment in 25 cases; trimethoprim-potentiated sulphonamides (30 mg/kg bwt per os q. 12 h) were used in 21 cases with mean duration of 4.5 days (range 1–8 days, n = 19), doxycycline (10 mg/kg bwt per os q. 12 h) was used in two cases for 7 days, and enrofloxacin (7.5 mg/kg bwt per os q. 24 h) was used in two cases for 5 and 10 days, respectively. Total duration of antimicrobial therapy ranged from 1 to 11 days (mean 5.5 days).

Post-operative antimicrobial choice was influenced by the results of culture and sensitivity where available. In this study, antimicrobial therapy was nonstandardised given its retrospective nature.

Analgesia was provided using three different drugs pre- and post-operatively phenylbutazone (n = 24), flunixin meglumine (n = 7) and morphine (n = 1). In some cases, horses received flunixin meglumine preoperatively and then changed to phenylbutazone post-operatively, but no

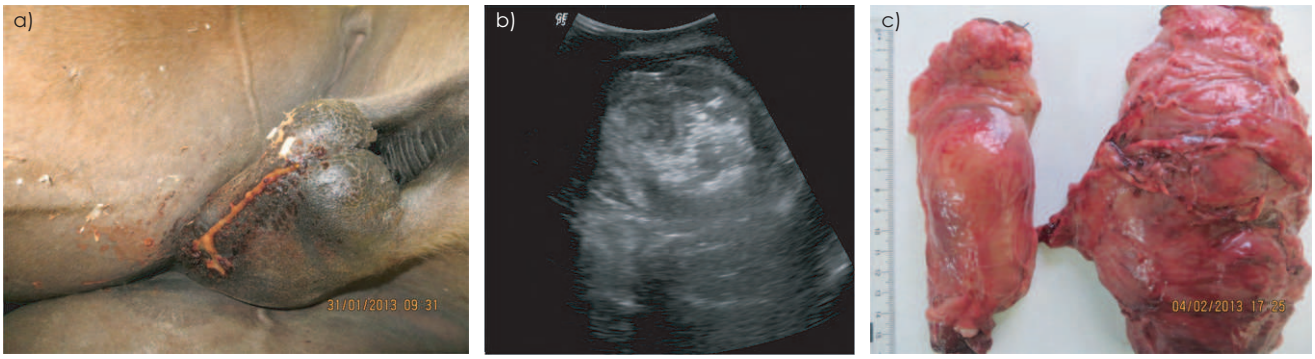

Fig 1: Bilateral scirrhous cord in a 3-year-old Thoroughbred gelding. a). Scrotal swelling, with a draining tract. Caudal is to the left. b). Transverse ultrasound image of the left spermatic cord stump showing swelling and heterogeneous echogenicity. c). The excised spermatic cord stumps (left stump on the right of photograph and right stump on left).

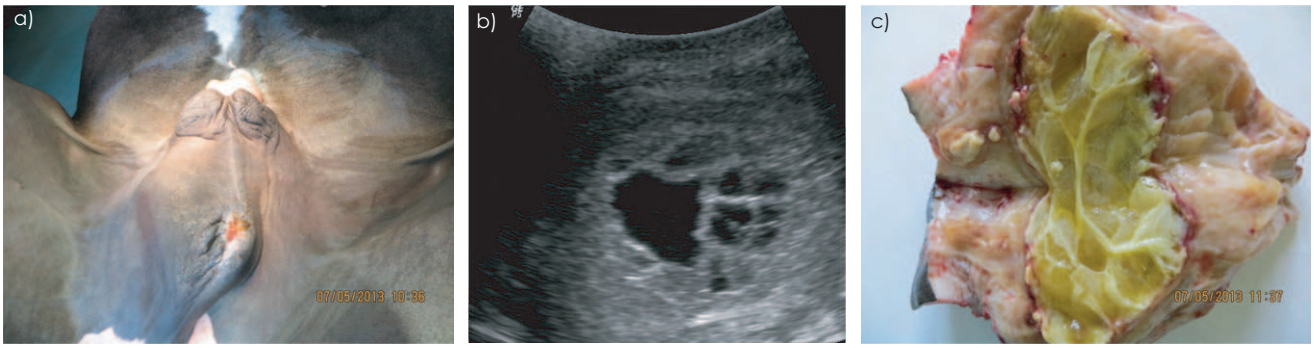

Fig 2: Scirrhous cord in a 2-year-old Warmblood cross gelding. a). Scrotal swelling with a draining tract. Horse in dorsal recumbency. b). Transverse ultrasound image of the scirrhous cord showing a multiloculated hypoechoic structure. c). Cut section of the excised scirrhous cord showing a multiloculated abscess.

justification for this change was given in the records. In the 24 cases that received phenylbutazone, the duration of treatment was recorded in 22 with a mean of 4.3 days (range 1–8 days, n = 22); flunixin meglumine treatment duration was recorded in five cases with a mean of 2 days (range 1–6 days). The single case that received morphine sulphate did so for a single dose.

All horses were discharged from the hospital between 1 and 10 days post-operatively with varying instructions regarding return to work. Instructions included box rest until the incision was fully healed, 3 days box rest followed by an increase in hand walking programme, immediate turnout and immediate return to low-level work. A number of other combinations of the aforementioned regimes were also documented.

Attempts were made to collect data from follow-up questionnaires and phone calls; however, these data were only partially available in seven cases given the potential 10-year time period since presentation. There was a lack of comparable data to draw any meaningful conclusions; however, the period of restricted exercise following discharge was recorded in three cases as 14, 21 and 21 days with time for full return to work totalling 14, 42 and 42 days, respectively. No cases of wound dehiscence were reported in the seven cases; however, purulent discharge was reported in three of those cases. Purulent discharge resolved by 3 days in one case without intervention, 21 days in a second case requiring daily lavage with dilute iodine solution and oral trimethoprim-potentiated sulphonamides (30 mg/kg bwt per os q. 12 h), and the third case resolved after 10 days with twice daily chlorhexidine lavage.

Histopathological examination of the resected spermatic cord remnant was recorded in five horses. This revealed central areas of tissue necrosis with intense neutrophilic infiltration, surrounded by a variable zone of mixed inflammation with macrophages (including epithelioid macrophages), lymphocytes, granulocytes and plasma cells, and a zone of granulation tissue with perivascular lymphoplasmacytic aggregates.

Discussion

Scirrhous cord is thought to be an uncommon complication of castration, and this is supported by the fact that there were only 32 cases diagnosed at two large equine hospitals in the UK over a 10-year period. In addition, only 23 cases of spermatic cord stump infection were reported in 17 years at a single large equine hospital in the USA (Claffey *et al*. 2018). The results obtained from this retrospective study support previous findings that surgical excision as a treatment for SC has a good short-term prognosis for survival (Claffey *et al*. 2018). All horses in this study, as well as in the study of Claffey *et al*. (2018), survived to hospital discharge. Unfortunately, we were only able to obtain partial follow-up data from seven of the horses included in this retrospective study; hence, we are unable to provide any meaningful long-term follow-up data.

In the study of Claffey *et al*. (2018), long-term follow-up was available for 16 horses at a mean time of 27.4 months post-surgery. Complete resolution of clinical signs and return to previous use was documented in 14 of 16 horses; one horse had persistent purulent drainage and a second horse was retired due to reduced performance.

There have been a number of publications reporting complication rates following castration. A study in 2013 from the USA recorded a complication rate of 10.2% in 324 equids castrated by either a closed or semi-closed technique, and identified a higher complication rate in those horses undergoing semi-closed castration (Kilcoyne *et al*. 2013). Infection was present in 7 (21%) of the 33 horses with complications. A more recent study from the UK reported a complication rate of 11.2% in 392 field castrations performed by 53 participating veterinary surgeons where post-operative follow-up data were available (Hodgson and Pinchbeck 2019). In this study, 44 of the 392 horses suffered a complication following castration with a total of 81 complications recorded; 14 of which were infection (Hodgson and Pinchbeck 2019). In another study of 121 horses undergoing open standing castration in the UK, 20.7% developed 'scrotal sepsis' (Mason *et al*. 2005), whereas a study of horses undergoing open standing castration in Hong Kong reported that 36.7% developed funiculitis (Rosanowski *et al*. 2018). It should be noted that the comparison of complication rates between different studies is challenging given varying definitions.

Interestingly, despite the belief that *Staphylococcus* spp. are commonly involved in SC (Pollock 2012; Schumacher 2019), *Staphylococcal* spp. were not identified in any of the eight cases where culture was performed, and in only one of nine cases reported by Claffey *et al*. (2018), suggesting that other bacteria may play a more significant role than previously identified. This finding supports those of a study from Hong Kong of 250 horses undergoing open standing castration where *Staphylococcus* spp. were only identified in one of eight cases with post-castration complications where bacterial cultures were performed (Rosanowski *et al*. 2018). However, the majority of horses in all of these studies received antimicrobials pre- and/or post-operatively, which may have altered the bacterial flora. Only a small number of cases in this study had recorded details of culture and sensitivity results; in the authors' opinion, this represents a failure to record the results rather than a failure to perform the microbial cultures. Microbial culture should be performed in every case to guide appropriate antimicrobial treatment. In addition, nine of the horses in this study were treated between 2007 and 2011 where antimicrobial stewardship was only in the early stages (Dyar *et al*. 2017). The two horses that received enrofloxacin were both treated in 2012.

The mean age at presentation was 6 years (range 2–14 years, n = 22), which was older than horses presented for surgical treatment of spermatic cord stump infection reported by Claffey *et al*. (2018) (mean age 4.1 years). Of the 10 horses where the age at castration was recorded, 9 presented for the treatment of SC within 4 months of castration. The overall median time between castration and SC presentation was 29.5 days (range 20–2500 days). This is comparable to the population of horses reported by Claffey *et al*. (2018) where the median interval between castration and presentation in 19 horses was 33 days; only four of 23 cases (17%) in that study presented more than 3 months after the original castration had been performed. In our experience, some cases of funiculitis will respond to prolonged antimicrobial therapy without surgery (unpublished results). Surgical treatment of spermatic cord stump infection at an earlier stage of acute inflammation may be complicated by an increased risk of haemorrhage, and it is notable that five of the 23 cases described by Claffey *et al*. (2018) required revision surgery due to haemorrhage (n = 2) or persistent infection (n = 3). The two cases requiring a second surgery due to haemorrhage were performed at 0 and 2 days. None of the horses in the current study required a revision surgery for persistent haemorrhage during the hospitalised period. However, the lack of long-term follow-up data does not allow comparison between the two studies in terms of persistent infection, although none of the horses in the current study were represented to the hospitals for further surgery after initial discharge.

Unfortunately, the age at which castration was performed was only recorded in the medical records in 10 of the 32 horses; in many cases, the current owners had purchased the affected horses as geldings and the exact date of castration was unknown. However, the mean age of castration in these 10 horses was 4.3 years (range 6 months to 10 years, median 2.5 years). This is higher than the median age of 1 year in 495 routine field castrations undertaken in the UK reported by Hodgson and Pinchbeck (2019). In the latter study, castration of older animals was associated with an increased risk of bleeding and post-operative stiffness of gait and/or swelling. A higher risk of post-operative complications in older horses, possibly due to the larger scrotal size and larger testicular vessel size, was also reported by May and Moll (2002); however, in another study of 324 horses, no association between age at castration and post-operative complications was found (Kilcoyne *et al*. 2013). Further long-term follow-up studies with larger numbers of horses are required before any definitive conclusions regarding age and techniques of castration and the risk of subsequent complications can be drawn.

In this study, the right spermatic cord was affected in 16 cases compared with only four on the left and two bilaterally. The reason for this apparent predilection of the right cord to develop SC is uncertain. To the authors' knowledge, this has not been previously reported. In the review of horses with spermatic cord stump infection by Claffey *et al*. (2018), the right spermatic cord was solely affected in 25% of cases (5/20), the left in 45% (9/20), and 30% (6/20) had bilateral involvement. Further investigation would be warranted to fully evaluate any significance of the apparent finding of a predilection to right-sided disease. Likewise, further studies with larger numbers of cases would be required to assess any breed predilection. No clear breed predilection was noted in this study, with the majority being Warmbloods/crosses (8), cobs/crosses (6) and draught horses (4) in 24 horses where breed was recorded; this may, at least partly, reflect the breeds most commonly examined at the two hospitals, although 17% draught horses are higher than expected. Associations between breed and castration complications have been suggested previously, with draught horses, Standardbreds and Warmbloods at greater risk of eventration (Mason *et al*. 2005; Getman 2013; Kilcoyne 2013), and French trotters at greater risk of haematoma formation (Robert 2017).

Diagnosis of SC is greatly aided by ultrasonography, which is now readily available in clinical practice. Ultrasound

examination may not be well tolerated in all horses, particularly if the area is painful on palpation; appropriate handling facilities and sedation may be utilised to facilitate safe examination. Visualisation of the spermatic cord is most easily achieved with the probe placed in a horizontal orientation (Chenier 2009). It is stated that a normal spermatic cord measures approximately 2.4 × 1.9 cm (Brinsko *et al*. 2010); however, to the authors' knowledge, there are no detailed studies quantifying the normal diameter.

Long-term follow-up would have greatly enhanced the results of this retrospective study; however, in many cases, these data were not available for a number of reasons including prolonged time from initial procedure, inability to contact owner and change of ownership. The seven cases where follow-up was available were incomplete, inhibiting our ability to draw any meaningful conclusions. However, Claffey *et al*. (2018) report long-term follow-up for 16 of their 23 cases with 14 returning to their previous level of work. Only one case was reported to have persistent purulent discharge for 37 months following surgical excision; this pony returned to low-level work. A further case did not return to the previous level of work despite resolution of clinical signs and was subsequently retired from racing after 7 months.

In conclusion, the results of this study confirm that SC can present at variable time points following castration, up to many years later. This highlights the importance of post-castration follow-up with clients and adequate discussion of potential complications. Castration of older horses might be a risk factor for the development of SC. Clinical signs include unilateral scrotal swelling with a palpably thickened core, with or without a discharging tract, pyrexia and lameness. A variety of bacterial species may be involved in these infections, with staphylococcal species being rarely isolated. Surgical excision of infected tissue is a successful treatment with good short-term prognosis for survival, with all 32 horses in this study and that by Claffey *et al*. (2018) surviving to hospital discharge. In order to fully assess the risk factors for SC and long-term outcomes, longitudinal, multicentred, prospective studies would be necessary.

Authors' declaration of interests

No conflicts of interests have been declared.

Ethical animal research

Not applicable.

Owner informed consent

Not required, however, consent was obtained in those cases followed up by questionnaire.

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Authorship

All authors contributed to the conception and design of the study. M. Duggan, T. Pengelly and T. Mair contributed to the analysis and interpretation of data. All authors contributed to drafting the article or revising it critically for important intellectual content, and all authors contributed to the final approval of the version to be published.

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Review Article

Revisiting the use of hydroxyethyl starch solutions in equine fluid therapy

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Keywords: horse; hydroxyethyl starch; colloid osmotic pressure; oncotic pressure; colloid

Summary

The last decade has led to major shifts in opinions on the use of hydroxyethyl starch (HES) solutions in fluid therapy, specifically in human patients with sepsis. The majority of evidence documenting adverse effects of HES solutions on coagulation and renal health come from studies in people. However, these findings have led to investigation into the safety of HES solutions in veterinary species. While there are now studies investigating the effects of HES solutions on coagulation and renal health in dogs, cats and horses, information regarding long-term follow-up, clinical significance of these changes and use of these solutions in critically ill animals is still lacking. The information presented here serves to review the physiology of oncotic pressure and the rationale behind colloid use, specifically HES solutions. Additionally, the foundation of arguments against the use of HES and the available literature regarding HES use in animals will be summarised.

Introduction

The use of synthetic colloids, specifically hydroxyethyl starch solutions, is a controversial topic in both human and veterinary critical care (Zarychanski *et al*. 2013; Cazzolli and Prittie 2015). While HES solutions offer a more economical and stable substitute for natural colloids, recent research in humans and small animals has identified safety concerns that may also apply to equine medicine (Perner *et al*. 2012; Hayes *et al*. 2016; Sigrist *et al*. 2017a,b; Diniz *et al.* 2018). Historically, the perceived benefit of colloids over crystalloids was that they increase oncotic pressure and provide more significant volume expansion and thus improved tissue perfusion through lower infusion volumes, thereby decreasing the risk of fluid overload in some groups of patients (Jones *et al.* 1997; Hoffmann *et al.* 2002; Myburgh *et al.* 2012; Glover *et al.* 2014; Joosten *et al.* 2018). In neonatal foals, an inverse relationship between oncotic pressure and plasma lactate levels has been identified, suggesting that maintaining adequate oncotic pressure directly affects plasma volume and appropriate tissue perfusion (Magdesian *et al.* 2004). However, there are other studies that do not recognise a direct association between oncotic pressure and improved patient outcomes (Sise *et al.* 1982; Golab *et al.* 2011). Higher oncotic pressure was also associated with a shorter duration of mechanical ventilation and significantly lower post-operative lactate concentrations in human infants undergoing cardiac bypass, although there was no significant difference in other outcomes between patients with high and low oncotic pressure (Golab *et al.* 2011).

It is not uncommon in equids to have significant gastrointestinal disease and associated hypoalbuminaemia, but the cost of equine plasma administration is frequently cost-prohibitive (Jones *et al.* 2001). Therefore, HES offers an attractive alternative. However, it has been identified in human medicine, and to a lesser degree in the veterinary literature, that there can be significant adverse effects of HES administration, the most significant being induction of coagulopathies and acute kidney injury (Schortgen *et al.* 2008; Blong *et al.* 2013; Epstein *et al.* 2014; Glover *et al.* 2014; Hayes *et al.* 2016). While only mild alterations in coagulation have been identified in horses and acute kidney injury after administration has not been documented, the lack of evidence merely highlights the lack of investigation and does not necessarily document the safety of these products in horses (Blong *et al.* 2013; Epstein *et al.* 2014). In addition to the identification of significant potential adverse effects resulting from HES administration, evolution in the understanding of fluid dynamics has also changed perceptions of the purported benefits of HES administration (Levick and Michel 2010; Woodcock and Woodcock 2012).

Review of fluid dynamics

Historically, fluid exchange between the vascular space and the interstitium was described by Starling's equation, wherein Filtration force= $(P_{cap} - P_{int}) - \sigma(\pi_{plasma} - \pi_{int})$ (Starling 1896; Levick and Michel 2010; Woodcock and Woodcock 2012).

Original Starling's equation
Filtration force = $(P_{cap} - P_{int}) - \sigma(\pi_{plasma} - \pi_{int})$
Revised Starling's equation
Filtration force = $(P_{cap} - P_{int}) - \sigma(\pi_{plasma} - \pi_{g})$

Key
P_{cap} = intravascular hydrostatic pressure
P_{int} = interstitial hydrostatic pressure
σ = Staverman's osmotic reflection coefficient
π_{plasma} = plasma oncotic pressure
π_{int} = interstitial oncotic pressure
π_{g} = glycocalyx oncotic pressure

Advances in research have led to a revision of Starling's equation which takes into account the effect of the endothelial glycocalyx on the pressure gradient between the vascular lumen and the interstitial space (Adamson *et al.* 2004; Jacob *et al.* 2006; Levick and Michel 2010;

Woodcock and Woodcock 2012). While an extensive review of the intricate interactions within Starlings equation and the endothelial glycocalyx is beyond the scope of this article, it is crucial that the reader understands the basis of the equation and the role that the endothelial glycocalyx plays in affecting fluid flux from the vascular to the interstitial space (Starling 1896; Levick and Michel 2010; Woodcock and Woodcock 2012).

The endothelial glycocalyx is a network of membrane-bound proteoglycans and glycoproteins attached to the luminal endothelium (Levick and Michel 2010; Woodcock and Woodcock 2012). The glycocalyx is considered a 'protected' region of the vasculature, and in humans, it has a fluid volume of approximately 700 mL (Woodcock and Woodcock 2012). In health, when the glycocalyx is intact, it is impermeable to starch molecules (such as Dextran) greater than 70 kDa in size, and semi-permeable to albumin and other proteins (Woodcock and Woodcock 2012). The revised Starling equation replaces the oncotic pressure of the interstitium with the oncotic pressure glycocalyx (π_g) (Levick and Michel 2010; Woodcock and Woodcock 2012). Through the use of rat vascular models, Adamson *et al*. determined that the interstitial oncotic pressure has far less effect on filtration than suggested by Starling's original equation. This difference was attributed largely to the presence of the glycocalyx since filtration from the vascular to interstitial space increased significantly when the glycocalyx was destroyed by heparinase (Adamson *et al.* 2004). This finding, among others, has led to the development of the 'no-absorption' rule which defies the previous assumption that fluid from the interstitium could be drawn back into the vascular space by increasing capillary oncotic pressure (Woodcock and Woodcock 2012).

The forces described by either version of Starling's equation can be altered significantly by various disease processes and provide the foundation on which utilising fluid therapy to maintain homoeostasis is achieved. Inflammation can lead to significant increases in capillary permeability which allows for leakage of fluid and solutes from the vasculature into the interstitium (Chappell *et al.* 2009; Woodcock and Woodcock 2012). Inflammatory mediators have been documented to increase shedding and degradation of the glycocalyx which can also lead to extravasation of fluid and oedema formation (Chappell *et al.* 2009; Woodcock and Woodcock 2012). Accumulation of interstitial fluid/oedema increases the distance across which nutrients and oxygen must diffuse to reach tissues. The loss of fluid from the vasculature decreases intravascular hydrostatic pressure and negatively impacts systemic perfusion (Fielding 2015).

Colloid osmotic pressure (COP, oncotic pressure) is determined by the major proteins in the plasma including albumin, fibrinogen and globulins. Albumin, due to its small size (69 kDa), negative charge and high concentration, exerts 60–80% of the oncotic pressure (Magdesian 2003). In equine medicine, infectious or inflammatory gastrointestinal diseases such as *Lawsonia intracellularis,* Salmonellosis, *Neorickettsia risticii,* Coronavirus and Clostridium spp., right dorsal colitis and diseases in which protein is lost to third spaces (e.g. the pleural and peritoneal cavities) often lead to significant hypoalbuminaemia and subsequent decrease in COP and resultant oedema formation. These conditions can lead to endotoxaemia and SIRS that then cause an increase in capillary permeability and/or shedding of the glycocalyx and a concomitant decrease in π_{plasma}, with the net result being a shift of fluid out of the capillaries and into the interstitium (Jones *et al.* 1997; Jones *et al.* 2001; Chappell *et al.* 2009; Woodcock and Woodcock 2012; Pantaleon 2015; Hepworth-Warren *et al.* 2017).

In a clinical setting, multiple parameters can be measured to help guide decisions regarding fluid therapy. Physical examination findings, including heart rate, mucous membrane colour and character, jugular fill, temperature of extremities, urine output and skin tent, provide crude indicators of hydration status. Laboratory parameters utilised to guide fluid therapy planning include packed cell volume, total protein, urine specific gravity, lactate, creatinine and electrolytes (Tennent-Brown 2015). Oncotic pressure can also be monitored to assess the need for colloid support. Equations have been established to estimate $\pi_{plasma,}$ based off of plasma protein that have a strong correlation with measured values for COP (Brown *et al.* 1994; Magdesian *et al.* 2004). While these values are relatively similar to measured values in healthy animals, variations in the albumin: globulin ratio in ill animals affect the calculation and make the values less accurate (Brown *et al.* 1994; Magdesian *et al.* 2004). Thus, direct measurement by a colloid osmometer is the most accurate method of assessing COP (Brown *et al.* 1994; Magdesian *et al.* 2004).

Colloids vs. crystalloids

Fluid therapy is a key component of clinical practice, and colloids and crystalloids are the two broad categories into which intravenous fluids are categorised. By definition, a crystalloid is a solution whose particles can easily pass through a semi-permeable membrane, whereas a colloid is a solution in which the particles are too large to pass through a semi-permeable membrane. Crystalloids readily cross the endothelium, and approximately 75% of the infused volume redistributes rapidly into the interstitial space within 60 min of administration (Magdesian 2015). In cases of acute blood loss or hypovolaemia, it has been recommended that 3 to 4 times the intravascular deficit be administered to allow for the rapid redistribution to the extravascular space (Magdesian 2003). Colloids remain for a longer period of time in the intravascular space, increase COP and expand the plasma volume by 70–200% of the infused volume (Solanke *et al.* 1971; Roberts and Bratton 1998; Magdesian 2003; Pantaleon 2015). The purported benefits of colloid use over crystalloids in fluid therapy include the smaller required volumes to achieve volume expansion, longer duration of action in the vascular space and the positive effect these solutions have on intravascular oncotic pressure (Guidet *et al.* 2012). Colloids administered alone increase COP and historically were thought to draw fluid from the interstitium into the vascular space, although the latter has now been disproved with adoption of the 'no-absorption rule' (Woodcock and Woodcock 2012). In humans, 1 L of hetastarch increased COP by 36% whereas the same volume of albumin only increased COP by 11% and administration of 1 L of saline decreased COP by 12%. While these numbers are substantial in humans, one must consider the volume of colloids required to significantly affect COP in an animal nearly ten times the size of a human patient (Treib *et al.* 1999). In patients with SIRS or endotoxaemia, increased

capillary permeability may lead to redistribution of colloid molecules into the interstitium and thus can exacerbate oedema formation (Margraf *et al*. 2018). This increased permeability and tendency towards extravasation of fluid has more recently been attributed to changes in the integrity of the glycocalyx associated with inflammation (Chappell *et al.* 2009; Margraf *et al*. 2018). With an intact glycocalyx, albumin and 6% hydroxyethyl starch both had decreased fluid extravasation in a myocardial model when compared with saline; however, after ischaemic injury, the glycocalyx was shown to be degraded and extravasation of both 6% hydroxyethyl starch and saline was observed (Jacob *et al.* 2006). There is some evidence that suggests HES molecules may 'plug' fenestrations in leaky endothelium and reduce protein loss from the vasculature (Webb *et al.* 1991; Wisselink *et al.* 1998). A recent study evaluating the effect of HES (130/0.4) administration to pigs after experimental haemorrhage identified decreased oedema formation in the small intestine when compared to resuscitation with Ringers lactate solution (Ortiz *et al.* 2017). Hydroxyethyl starch administered to mice during experimental endotoxaemia appeared to have a protective effect on the glycocalyx and may attenuate the increase in capillary permeability (Margraf *et al*. 2018). While crystalloids are a key component of restoring intravascular fluid volume, in cases where albumin and COP are decreased, colloids are used to increase oncotic pressure and maintain effective circulating volume (Glover *et al.* 2014; Cazzolli and Prittie 2015).

Natural and synthetic colloids are available for use in both human and veterinary medicine. Natural colloids include plasma, whole blood and human albumin. Of these, plasma is the most readily available for equine patients. In addition to providing albumin for oncotic pressure, plasma has the added benefit of providing immunoglobulins, macroglobulins, coagulation factors, antithrombin III, elastase and proteinase inhibitors (Pantaleon 2015). Disadvantages to plasma administration include its short shelf life, cost and risk of anaphylaxis, especially when repeated transfusions are necessary (Magdesian 2003; Pantaleon 2015). Synthetic colloids, including dextrans, gelatins and hydroxyethyl starch (HES) solutions, exert similar effects on oncotic pressure and volume expansion, but are less likely to induce anaphylaxis, are more stable and are generally more affordable than natural colloids (Magdesian 2003; Pantaleon 2015). At this time, hydroxyethyl starch solutions are the most commonly used synthetic colloids and will be the focus of this review.

Hydroxyethyl starch solutions

Hydroxyethyl starch solutions are synthetic colloid solutions made up of natural starch polymers derived from maize or potato starch that undergo the process of hydroxyethylation. During hydroxyethylation, portions of the glucose subunit are replaced by hydroxyethyl starch molecules (Baron 2000; Westphal *et al.* 2009). Adding HES molecules to natural starches increases the stability of the starch solution by increasing resistance to degradation by amylase and increasing hydrophilia of the molecule, thus creating positive forces on vascular oncotic pressure (Baron 2000; Westphal *et al.* 2009).

Hydroxyethyl starch solutions are classified by the molecular weight, molar substitution ratio, C2/C6 ratio, concentration of the solution and the carrier. The molecular weight of an HES solution is expressed as the average molecular weight (in kDa) of the molecules in the solution. Older products, such as hetastarch, have higher molecular weights, ranging from 450 kDa to 600 kDa, whereas newer formulations have much lower molecular weights (e.g. tetrastarch, 130 kDa). Molar substitution (MS) describes the ratio at which glucose molecules have been replaced by HES molecules. For example, tetrastarch (TES) has 4 HES molecules for every 10 glucose molecules and is assigned an MS ratio of 0.4. The hydroxyethylation of starch molecules is not only described by the MS ratio, but also by the C2/C6 ratio. Substitution of glucose subunits with HES molecules takes place at the C2, C6 and, to a lesser degree, the C3 positions on the carbon ring (Baron 2000; Glover *et al.* 2014).

Hydroxyethyl starch solutions are produced as 6% and 10% solutions in either 0.9% sodium chloride or balanced electrolyte solutions such as lactated Ringers. Six per cent solutions are isooncotic to plasma, and thus, administration of 1 L is expected to increase blood volume by approximately 1 L after blood loss, whereas 10% solutions are hyperoncotic and theoretically increase blood volume by 145% of the infused volume (Westphal *et al.* 2009). Hyperoncotic solutions have fallen out of favour in fluid therapy due to an association with risk of kidney injury (Schortgen *et al.* 2008).

Activity and excretion of HES solutions

The effect of a colloid on oncotic pressure is determined by the number of oncotically active particles in a solution, not the size of the particles. Therefore, solutions with a higher molecular weight have a lower number of larger particles and thus exert less force on intravascular oncotic pressure (Baron 2000; Treib *et al.* 1999; Westphal *et al.* 2009). Hydroxyethyl starch molecules are excreted primarily (approximately 70%) by the kidneys with a smaller portion being taken up from the plasma by the reticuloendothelial system. Small molecules (45–60 kDa) are excreted rapidly into the urine, whereas larger molecules must first be broken down by amylase into a size that can be filtered through the glomeruli (<60 kDa in humans) (Baron 2000; Treib *et al.* 1999; Westphal *et al.* 2009; Glover *et al.* 2014). Solutions with a lower molecular weight are more rapidly degraded into smaller particles, which in addition to increasing clearance, also have a positive effect on oncotic pressure (Westphal *et al.* 2009; Glover *et al.* 2014). The rate at which HES molecules are degraded is additionally impacted by the pattern and degree of substitution of the HES molecule. Substitution at C2 provides less access to the amylase substrate compared with C6; therefore, solutions with a higher C2/C6 ratio are degraded and excreted more slowly. Likewise, more highly substituted solutions with higher molecular weights are degraded more slowly than their lower molecular weight, less substituted counterparts (Baron 2000; Westphal *et al.* 2009; Mizzi *et al.* 2011; Glover *et al.* 2014). Many of the earlier HES solutions such as hetastarch (MW ~ 450 kDa) and pentastarch (PES, MW ~ 200 kDa) had considerably higher molecular weights than the more modern TES (MW 130 kDa). Despite being lower in molecular weight, TES often have a higher C2/C6 ratio (6:1–9:1) compared with hetastarch (4:1–5:1), but still have a shorter half-life and more rapid clearance from the plasma (Westphal *et al.* 2009; Mizzi *et al.* 2011).

Adverse effects of HES solution administration

Adverse effects of HES solution administration develop primarily from accumulation of starch molecules outside of the vascular space. Of major concern in humans is the occurrence of acute kidney injury and an increased need for renal replacement therapy (RRT) following HES administration (Myburgh *et al.* 2012; Gattas *et al.* 2013; Perner *et al*. 2012; Wiedermann and Joannidis 2014; Glover *et al.* 2014;). Damage to the kidneys can occur by multiple mechanisms. Administration of HES increases glomerular oncotic pressure, which alters the pressure gradients within the nephron and leads to decreased urine output (Honore *et al.* 2008). Starch molecules also accumulate within the nephrons, leading to swelling of the proximal tubular epithelial cells, termed osmotic nephrosis (Boldt and Priebe 2003; Honore *et al.* 2008; Cazzolli and Prittie 2015). While there is little information available regarding the effects of HES solutions on the equine kidney, TES solutions have been safely administered to critically ill nonazotemic cats and healthy neonatal foals without an increase in serum creatinine (Hepworth-Warren *et al.* 2015; Sigrist *et al*. 2017a,b). Dogs given TES were no more prone to acute kidney injury than dogs given saline, although a higher number of days of TES administration were associated with a higher AKI grade within 10 days of TES treatment (Sigrist *et al*. 2017a,b). In 201 dogs given either TES or crystalloids during hospitalisation, there was no significant difference in plasma creatinine levels between groups. Additionally, when comparing survival in the TES group between dogs with and without SIRS or sepsis, there were no significant differences (Yozova *et al.* 2016).

In addition to kidney injury, the induction of coagulopathies has been documented repeatedly in human medicine (Fenger-Eriksen *et al*. 2009). These coagulopathies have led to increased blood loss and transfusion requirements. The volume of HES solution can dilute the coagulation factors in the blood, a phenomenon that can also occur with crystalloid administration alone but appears to be more significant with HES (Fenger-Eriksen *et al*. 2009). Acquired fibrinogen deficiency secondary to dilution is thought to be the major contributor to HES induced coagulopathy and has been documented even with use of the newer generation TES (130/0.4) solutions (Fenger-Eriksen *et al.* 2009). Decreases in fibrinogen have been repeatedly documented after HES administration in horses (Jones *et al.* 1997; Hepworth-Warren *et al.* 2015). Outside of dilutional effects on coagulation factors, HES molecules can be incorporated into clots, thereby making them weaker (Blong *et al.* 2013). Platelet dysfunction can also be induced by the inhibition of glycoproteins on platelet surfaces and binding of von Willebrand factor (vWF) and Factor VIII by HES molecules (Fenger-Eriksen *et al.* 2009; Blong *et al.* 2013; Cazzolli and Prittie 2015). Transient alterations in coagulation parameters have been documented in dogs, cats and horses, but their clinical significance is unknown (Blong *et al.* 2013; Epstein *et al.* 2014; Glover *et al.* 2014; Diniz *et al.* 2018).

Accumulation in extra-renal tissues, especially the skin, is perhaps the most frequently identified adverse effect in humans. Starch molecules have been identified in skin biopsies for 8 years or more after administration of HES and lead to persistent, intense pruritus that is refractory to treatment (Treib *et al.* 1999; Westphal *et al.* 2009; Wiedermann and Joannidis 2014; Cazzolli and Prittie 2015). To date, pruritus has not been documented in veterinary species in association with HES administration, although the delay from time of administration of HES to onset would make this quite difficult to document in veterinary species.

Controversy in human medicine

Since 2012, there has been a fervent debate in human medicine over the use of hydroxyethyl starch (HES) solutions in fluid therapy. The concern over the use of these products stems from documented development of acute kidney injury and coagulopathies in patients that received HES solutions, and effects resulting from accumulation of HES molecules in extra-renal tissues (Myburgh *et al.* 2012; Perner *et al.* 2012; Glover *et al.* 2014; Wiedermann and Joannidis 2014). While veterinarians have questioned the safety of these products, studies in the veterinary literature have yet to identify lasting adverse effects (Cazzolli and Prittie 2015). There have been a number of studies examining the use of HES solutions in horses, but the majority of the studies have been performed in healthy animals, so there are not yet consistent data supporting, or refuting the safety of the use of HES products (Jones *et al.* 1997; Blong *et al.* 2013; Epstein *et al.* 2014; Hepworth-Warren *et al.* 2015; Wendt-Hornickle *et al.* 2011; McKenzie *et al.* 2016).

In 2010, leading hydroxyethyl starch researcher and anaesthesiologist Dr Joachim Boldt was charged with scientific misconduct ultimately resulting in the formal retraction from the literature of 89 of the 102 studies that he and his group had published since 1999. This prompted the re-evaluation of meta-analyses that had previously included Boldt's work, with one such study showing that risk of death and the requirement for RRT were significantly increased when Boldt's studies were excluded from analysis (Zarychanski *et al.* 2013). In 2012, it was reported that septic patients who received TES (130/0.4) had a higher 90-day mortality rate than septic patients who received Ringer's acetate (Perner *et al.* 2012). A second study later that year failed to identify a difference in mortality between patients that received TES (130/0.4) and 0.9% sodium chloride, but did document an elevated risk ratio for the development of acute kidney injury (AKI) and the need for use of renal replacement therapy (RRT) in patients that received TES (Myburgh *et al.* 2012). Following publication of these two studies, the European Medicines Agency (EMA) made a ruling prohibiting the use of HES solutions in burn patients and patients that were septic or critically ill. In 2013, the FDA followed suit and added a black box label to HES solutions advising against use of HES solutions in these populations (Wiedermann and Eisendle 2017). The EMA suspended marketing authorisation for HES solutions across the European Union in 2018. While at this time HES solutions are still available in the United States, the FDA has expanded the types of patients in which HES use is advised against to include paediatric patients, patients with hepatic disease (Wiedermann and Eisendle 2017).

Proponents of HES maintain that there are positive effects of rapid volume expansion achieved with small volume of fluids and the decreased risk of fluid overload in comparison to fluid resuscitation with crystalloids (McConell *et al.* 2018). In contrast, opposition to HES use is related to the risk of induction of acute kidney injury leading to requirement for RRT, the potential for coagulopathies and the risk for extra-renal tissue accumulation (Myburgh *et al.* 2012; Perner *et al.* 2012; Sacchet-Cardozo *et al.* 2018). It has been suggested that the

risk of adverse effects is significantly decreased when utilising newer HES solutions that have a lower molecular weight and a lower molar substitution ratio, but to date many of these claims have not been consistently substantiated (Baron 2000; Mizzi *et al.* 2011; Myburgh *et al.* 2012; Perner *et al.* 2012; Wiedermann and Joannidis 2014).

Use of HES solutions in horses

The indications for use of colloids, specifically HES solutions, in horses are analogous to those in humans and other animals. Main indications for use include maintenance of blood pressure and oncotic pressure while under general anaesthesia, fluid resuscitation, hypoproteinaemia/low oncotic pressure and hypotension (Magdesian 2003; Boscan and Steffey 2007). Monitoring of oncotic pressure is often performed in clinical settings and is used to guide decision-making in fluid therapy. Normal ranges for oncotic pressure in adults and neonatal foals have been established and range from 21 to 25 mmHg and 15 to 22.6 mmHg, respectively (Magdesian and Madigan 2003; Tennent-Brown 2015).

Anaesthesia has been shown to decrease COP in a number of species, including humans, dogs and horses (Sano *et al.* 2005; Boscan *et al.* 2007; Dismukes *et al.* 2010; Wendt-Hornickle *et al.* 2011). While a high volume of crystalloid infusion and secondary dilution of the main contributors to COP in the blood (albumin, globulins, etc.) likely contributes to this decrease, multiple studies have found that the decrease in COP cannot be directly predicted from the volume of fluids administered, nor from the drop in total solids after fluid therapy (Boscan *et al.* 2007; Dismukes *et al.* 2010; Wendt-Hornickle *et al.* 2011). Decreased total protein was found to only account for 70% of the change seen in COP in horses under general anaesthesia (Boscan *et al.* 2007). While the exact cause for the drop in COP has yet to be identified, it is likely impacted not only by the volume of crystalloids infused in perioperative fluid management, but also by direct effects of the anaesthetic agents on pressure within capillaries and arteries that alter fluid exchange (Sano *et al.* 2005).

Compared with the human and small animal literature, there is a paucity of information available regarding the potential for adverse effects on the kidneys and coagulation in horses. A significant portion of the studies that have been performed in horses investigating effects of HES solutions involve healthy anaesthetised patients undergoing elective procedures (Boscan *et al.* 2007; Wendt-Hornickle *et al.* 2011; Roska *et al.* 2018). There are few studies involving clinically ill patients; thus, it is still unclear whether the use of HES solutions in equine fluid therapy is appropriate and safe.

Multiple HES solutions, including hetastarch, PES and TES, have been shown to be effective in increasing oncotic pressure in various populations of healthy horses and ponies (Jones *et al.* 1997; Epstein *et al.* 2014; Viljoen *et al.* 2014; Hepworth-Warren *et al.* 2015; McKenzie *et al.* 2016; Gratwick *et al.* 2017). Pentastarch effectively mitigated the decrease in COP caused by anaesthesia; however, there have been conflicting findings when investigating the ability of TES to maintain COP under anaesthesia (Wendt-Hornickle *et al.* 2011; Brünisholz *et al.* 2015; Roska *et al.* 2018). Oncotic pressure has effectively been increased in horses with naturally occurring gastrointestinal disease and hypoproteinaemia by administration of hetastarch and TES (Jones *et al.* 2001; Bellazzo *et al.* 2014).

Transient alterations in coagulation have been documented after infusion of hetastarch and TES in horses (Jones *et al.* 1997; Blong *et al.* 2013; Epstein *et al.* 2014; Viljoen *et al.* 2014). Decreased vWF activity was identified for 8 h following TES infusion and 24 h following hetastarch infusion, as compared to baseline (Epstein *et al.* 2014). The control group in this study received normal saline and actually showed an increase in vWF activity 24 h after infusion. Interestingly, all three groups in this study showed mild increases in PT and PTT, and decreases in ACT and platelet count; however, values were largely within reference range. Closure time, as measured by an automated platelet analyser, was significantly prolonged for 24 h with hetastarch administration and for 8 h with TES (Epstein *et al.* 2014). Another study, evaluating platelet function, identified significantly decreased clot formation rate and decreased platelet function in vitro when platelets were incubated with hetastarch (600/0.75 in saline and 670/0.75 in lactated Ringer's) and TES (130/0.4 in saline) as compared to platelets incubated in saline or lactated Ringer's alone (Blong *et al.* 2013). When TES (130/0.4) was administered to healthy neonatal foals, fibrinogen decreased significantly as compared to foals administered lactated Ringer's, but there was no significant change seen in aPTT and PTT (Hepworth-Warren *et al.* 2015). In healthy ponies, dose-dependent decreases in vWF antigen activity and Factor VIII:C activity were identified for up to 120 h post-infusion, with a higher dose correlating with a larger effect (Jones *et al.* 1997).

To date, significant renal damage has not been documented in the horse as a consequence of HES administration, but renal parameters have been assessed in only a limited number of studies for short periods of time. In hypoproteinaemic horses, slight increases in BUN and creatinine were noted for up to 4 h following an infusion of PES, but values decreased to below baseline by 24 h after the infusion (Schusser *et al.* 2007). No changes were identified in urine GGT:creatinine ratios after infusion of TES in healthy neonatal foals for 24 h after infusion and in healthy adult horses for 4 h after infusion of PES, respectively (Schusser *et al.* 2007; Hepworth-Warren *et al.* 2015). Urine protein: creatinine ratios were significantly higher after infusions of 20 mL/kg of (130/0.4 tetrastarch) in healthy ponies, but there were no significant differences from baseline in creatinine or urine GGT:creatinine ratios (Gratwick *et al.* 2017).

Reasons for differences

The reason behind the differences seen in adverse events between humans and horses associated with use of HES solutions is likely to be multifactorial. First and foremost, the majority of equine studies, like most veterinary research, have far smaller sample sizes than those seen in human medicine. Many of the parameters investigated in human studies (renal parameters, prevalence of AKI, need for RRT) have either not been investigated or are largely irrelevant in the horse. Lastly, the doses of HES solutions used in human medicine tend to be substantially higher than those used in veterinary medicine, with 50 mL/kg being the recommended daily limit in humans, and 20 mL/kg being the maximum recommended dose in horses (Myburgh *et al.* 2012). Humans are also more likely than horses to receive HES solutions on multiple days, whereas horses are more likely to receive fewer doses (Perner *et al.* 2012). In equine medicine, the use of

repeated 50 mL/kg doses would likely be cost-prohibitive, but it is plausible to consider that the frequency of adverse events would increase if horses were given more than double the current recommended dose. The need for longer durations of monitoring for development of adverse effects is highlighted by evidence from human medicine. In a group of 26 human liver transplant patients who received HES at the time of transplant, histopathologic tubulointerstitial lesions consistent with HES administration were identified up to 10 years later (Pillebout *et al.* 2005). To the author's knowledge, there are no studies evaluating renal parameters more than one week after HES administration in horses.

Conclusion

The information presented here should serve to inform clinicians of the potential risks and benefits of incorporating HES solutions into equine fluid therapy. While studies have failed to identify lasting adverse effects of HES administration to horses, it is critical that practitioners be aware that the paucity of information available does not directly translate into documented absence of risk. It appears at this time that HES use in healthy horses is safe at the lower doses that have been studied and it has a positive effect on oncotic pressure. The effects of HES administration in horses with endotoxaemia and SIRS remain unknown, and more investigation is still needed to identify whether or not there are lasting effects on renal function, coagulation and long-term survival in horses that receive HES solutions.

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Critically Appraised Topic

In performance horses undergoing surgical treatment for nonstrangulating large intestinal displacements, will performance be reduced compared to before surgery?

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Background

While long-term survival and complications for a horse following colic surgery are important considerations, evidence regarding return to athletic function and performance can provide additional prognostic information for owners before embarking on costly treatment. Nonstrangulating large intestinal displacements have been shown as a risk factor for development of recurrent colic post-operatively (Smith and Mair 2010). However, limited research has established whether this affects return to athletic function. It is a clinical impression that horses with nonstrangulating large intestinal displacements are less likely to return to athletic function after surgery.

PICO question

In performance horses undergoing surgical treatment for nonstrangulating large intestinal displacements, is performance reduced compared to before surgery?

Patient – performance horses with surgical nonstrangulating large intestinal displacements.

Intervention – surgical treatment (via exploratory laparotomy).

Criteria – long-term follow-up in regard to athletic function.

Outcome – return to performance.

Strategy

A critically appraised topic (CAT) summarises and critically appraises the current literature related to a focused clinical question (PICO question). An electronic literature search was conducted for articles published in English on the PubMed database, the CAB Abstracts database and using Google Scholar based on terms created from the PICO criteria. Search terms included but were not limited to 'equine', 'performance', 'racehorse', 'colic', 'displacement' and 'nephrosplenic entrapment'. References from these texts were also selected for further evaluation, and recent conference proceedings were also scrutinised. The results were screened on the title and abstract to identify studies relevant to the PICO question.

Inclusion criteria: papers relevant to the PICO question with long-term follow-up and investigation of return to athletic function and performance.

Exclusion criteria: papers that did not contain original data (i.e. expert opinion) and papers that were not related to the PICO question.

For the purposes of this study, a performance horse was defined as a horse ridden or worked with competitive intent at any level for disciplines including racing, eventing, showjumping, dressage, driving or showing.

Search results

Seven studies were found to meet the inclusion criteria, and a summary of the findings is presented in **Table 1**.

Discussion

All seven studies were retrospective with four case series (Christophersen *et al*. 2011; Davis *et al*. 2013; Immonen *et al*. 2017; van Loon *et al*. 2020) which were classified level four on the Oxford Centre for Evidence-Based Medicine classification of levels of evidence (OCEBM Levels of Evidence Working Group 2011). Three studies were retrospective cohort studies with untreated controls (Tomlinson *et al*. 2013; Hart *et al*. 2014; Holcombe *et al*. 2019). The untreated controls were not randomly allocated, and these studies were classified level three (OCEBM Levels of Evidence Working Group 2011). The number of horses investigated varied between studies but were generally small numbers (n = 11–236). Three studies objectively measured return to athletic function using national database information (Tomlinson *et al*. 2013; Hart *et al*. 2014; Immonen *et al*. 2017) whereas four studies used only subjective assessment from owner questionnaires (Christophersen *et al*. 2011; Davis *et al*. 2013; Holcombe *et al*. 2019; van Loon *et al*. 2020). The types of performance investigated were racehorses in two studies and a mixture of disciplines in five studies.

Return to athletic function following colic surgery was found to be between 61 and 90%. Of note, only three studies (Davis *et al*. 2013; Hart *et al*. 2014; van Loon *et al*. 2020) specifically differentiated the long-term follow-up between nonstrangulating large intestinal disease and other types of colic. Davis *et al*. (2013) found that at one-year post-colic surgery for treatment of nonstrangulating large intestinal displacements 75% of horses were back in work. They found that horses with strangulating lesions (both large intestinal and small intestinal lesions) at a 6-month time point were significantly more likely to be in work than horses with a nonstrangulating lesion (**Table 1**). The authors hypothesised that owners were more committed to horses with strangulating lesions as these cases tend to incur greater financial costs and require more intensive care, and therefore, owners potentially

TABLE 1: Analysis of relevant papers

Study, type and level of evidence	Patient group and number	Assessment of outcome	Outcome	Significance	Limitations
Tomlinson *et al*. 2013 Retrospective cohort study 3	85 Racing TBs recovered from colic surgery 170 matched untreated controls – age- and sex-matched from treated groups last race prior to surgery	Objective – national database Assessed return to racing and racing performance	*Return to athletic function*: Total 59/85 (69%) LI lesions 33/54 (61%) *Performance*: NSD in earnings, number of starts or earnings per start between LI colic TBs and untreated controls	SD (P = 0.009) in return to racing when comparing the SI cohort and LI cohort. Colic surgery did not affect performance.	Retrospective. Sample size small – sex bias within SI group could have affected outcome. Not specific for NSLI disease.
Davis *et al*. 2013 Retrospective case series 4	195 mixed group of performance horses (dressage, SJ, showing, racing, etc.)	Subjective – Owner questionnaire	*Return to use NSLI*: 6 months 66/99 (67%) 1 year 73/97 (75%) *Return to use total population*: 6 months 133/195 (68%) 1 year 145/190 (76%) *Return to full performance NSLI*: 6 months 43/80 (54%) 1 year 49/79 (62%) *Return to full performance total population*: 6 months 85/156 (54%) 1 year 101/153 (66%)	Return to use: SD (P = 0.024, OR 0.4, 95%CI (0.2-0.9)) at 6 months – having a strangulating lesion reduced the chance of returning to athletic function. NSD at one year. NSD on lesion location or type to return to full performance at 6 months or one year.	Retrospective. Small sample sizes – wide confidence intervals. Lack of control groups. Subjective assessment of outcome – recall bias.

TABLE 1: Continued

Study, type and level of evidence	Patient group and number	Assessment of outcome	Outcome	Significance	Limitations
Christophersen *et al*. 2011 Retrospective case series 4	79 mixed group of performance horses	Subjective – Owner questionnaire	*Return to same or better level of performance*: 66/79 (83.5%) total population.	NSD for lesion location on post-surgery performance	Retrospective. No specific differentiation of NSLI lesion. Small sample size Lack of control groups. Subjective assessment of outcome – recall bias.
Hart *et al*. 2014 Retrospective cohort study 3	59 Racing TBs 90 untreated controls randomly selected from runners in each treated horse's last race immediately prior to the date of colic surgery	Objective – national database	*Return to athletic function*: 17/26 (65%) NSLI lesions. *Performance*: Assessed treated vs. not treated. No significant detrimental effects of colic surgery on performance.	SD (P = 0.02) fewer horses with NSLI lesion returned to athletic function vs. strangulating NSD of lesion location on performance.	Retrospective. Small sample size. Potential for selection bias in treated group.
Immonen *et al*. (2017) Retrospective case series 4	236 mixed group of performance horses	Subjective – Owner questionnaire and objective – national database	*Return to athletic function*: 113/135 (83.7%) - subjective 59/81 (72.8%) - objective *Performance*: 106/135 (78.5%) regained or better level	Lesion location had NSD on return to athletic function or performance	Retrospective. Subjective assessment. Lack of control groups.
Holcombe *et al*. 2019 Retrospective cohort study 3	62 mixed group of performance horses 51 – controls 11 – treated with 4-week 'CARE' rehabilitation programme	Subjective – Owner questionnaire	*Return to athletic function*: 10/11 (90%) CARE 24/51 (47%) controls *Performance*: 10/11 (90%) same or better CARE 43/51 (84%) same or better controls	SD (P < 0.001) between CARE and controls in improvement of performance after surgery	Retrospective. Small case numbers. Selection bias as treatment not randomly allocated – higher % of SSI in CARE group. Not specific for NSLI vs. other types of colic
Van Loon *et al*. 2020 Retrospective case series 4	283 mixed group (dressage and leisure)	Subjective – Owner questionnaire	*Return to equal or better performance*: 52/82(63.4%) overall population 27/38 (71.1%) NSLI	NSD calculated.	Retrospective. Subjective assessment. Lack of control groups.

CARE, core abdominal rehabilitation exercises; LI, large intestinal; NSD, no significant difference; NSLI, nonstrangulating large intestinal lesion; SD, significant difference; SI, small intestinal; SSI, surgical site infection.

have more incentive to return these horses to athletic function quickly. At one year post-operatively, no significant difference was found in return to athletic function between the nonstrangulating and strangulating intestinal lesions.

Hart *et al*. (2014) found that significantly fewer horses with nonstrangulating large intestinal displacements than strangulating displacements returned to racing (**Table 1**). The authors hypothesised that colonic dysfunction could be responsible for this occurrence. Previous studies have identified that horses with colic attributable to large colonic dysfunction had significant reductions in interstitial cells of Cajal (ICC) density within the pelvic flexure, compared to control horses which were subjected to euthanasia due to noncolic causes (Fintl *et al*. 2004). The ICC acts as pacemakers within the gastrointestinal tract co-ordinating motility, and it is thought that a reduction in ICC may lead to unco-ordinated motility and increase the likelihood of chronic or recurrent colic. Hart *et al*. (2014) theorised that the reduced performance and return to racing in horses with nonstrangulating large intestinal displacements may be attributed to chronic or recurrent colic due to reduced ICC density; however, this variable was not specifically investigated and the reasons for failure to return to racing were not stated. Two studies investigated post-operative colic incidence during the convalescence period. Immonen *et al*. (2017) found that if a large intestinal lesion was found at surgery, the horse was significantly more likely to have a colic episode than if a small intestinal lesion was diagnosed (P = 0.01, OR 3.3, 95% CI 1.3–8.2) but did not investigate whether this affected return to function. Van Loon *et al*. (2020) found that 56.4% of horses with nonstrangulating large intestinal displacements had recurrent colic episodes following discharge from the hospital, which was higher than the percentage after strangulating large and small intestinal displacements, although no statistical evaluation was performed.

Factors that were found to negatively affect return to athletic function included the horse being on stall rest for orthopaedic reasons prior to surgery (Davis *et al*. 2013), incisional complications (Christophersen *et al*. 2011), and hernia formation after surgery (Davis *et al*. 2013). Christophersen *et al*. (2011) found that hernia formation was a significant predictor of worse post-operative performance compared with horses with no incisional complications (OR 14.5, 95% CI 2.25–93.49, P = 0.0063). However, this contrasted with Immonen *et al*. (2017) who found no significant detrimental effects of hernia formation on return to athletic function.

Holcombe *et al*. (2019) found that implementation of a 4-week core abdominal muscle rehabilitation exercises (CARE) programme during the convalescence period resulted in a significant improvement in performance level from the period before to the period after surgery based on subjective owner and trainer assessment. As well as this, those horses receiving the CARE programme returned to athletic function quicker than those horses not following the rehabilitation programme. However, the CARE programme was not randomly allocated and could have led to positive selection bias, and further to this, the group sizes were dissimilar which could have skewed the results. Van Loon *et al*. (2020) also investigated the rehabilitation period and the effect on performance. Of the 64% of the overall population of horses returning to equal or better performance after colic surgery, 46% of owners reported behavioural or riding problems in their horses that were not present prior to surgery with issues such as lateral bending, collecting and extending gaits when getting the horse back into work (van Loon *et al*. 2020). This information was gathered from subjective owner questionnaires which could influence the reliability; however, it highlights that the initial rehabilitation period is important when evaluating return to athletic function. Prospective randomised clinical trials with objective measurement of performance outcomes would be useful in validating the benefit of a structured rehabilitation programme in performance after colic surgery.

The impact of colic surgery on the level of performance was also investigated. Hart *et al*. (2014) and Tomlinson *et al*. (2013) compared horses that had colic surgery to untreated controls and found no significant difference in the level of performance between treated and untreated horses. Furthermore, nonstrangulating large intestinal displacements were not detrimental to performance level compared to other types of colic. Davis *et al*. (2013) found no significant difference in performance level between nonstrangulating large intestinal displacements and other types of colic one year post-operatively. This was also confirmed with Immonen *et al*. (2017) who identified no significant difference in lesion location on performance level after colic surgery.

Further questions

Further studies are required to investigate the relationship between post-operative colic in large intestinal displacements and the effect this has on return to athletic function. As well as this, more prospective clinical trials are required to establish the relation between different rehabilitation programmes and performance.

Clinical bottom line

Return to athletic function following colic surgery to correct large intestinal displacement is generally good; however, nonstrangulating large intestinal displacements could be subject to more post-operative colic episodes that could affect this outcome. Where a horse is back competing, there seem to be no detrimental effects on performance level of having a nonstrangulating large intestinal displacement compared to other types of colic. Furthermore, the research indicates that colic surgery is only the first stage in treatment and a formulated rehabilitation plan between veterinarian and owner is important in getting performance horses back into competition.

Authors' declaration of interests

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Ethical animal research

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Both authors contributed to study design, study execution, data analysis and interpretation, preparation of the manuscript and final approval of the manuscript.

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