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FEBRUARY 2021

AAEP®

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American Edition | February 2021

BEVA

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

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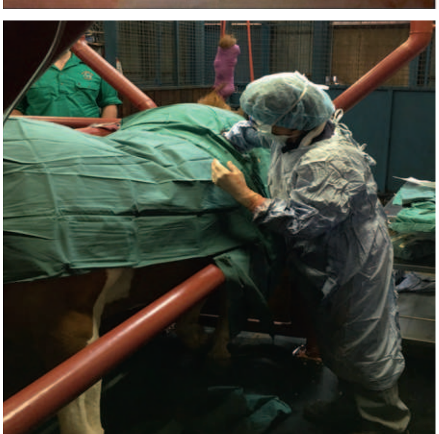

AAEP NEWS In this issue

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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
American Edition
FEBRUARY 2021 • VOLUME 33 • NUMBER 2

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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The importance of communication among colleagues in after-hours and referral cases

By Chris Wilhite, DVM

Dr. Chris Wilhite

The importance of effective communication with clients is easily recognizable. Communication between colleagues on the other hand is no longer at the forefront of people's thoughts. I see this continually cropping up in two particular areas: practices' after-hours availability and the referral of cases.

There is no doubt that work-life balance is important for our mental and physical wellbeing. With this in mind, each of us can appreciate the difficulty in trying to provide 24x7 care for our clients and patients. The past year has taught us that life happens and that there are going to be circumstances, oftentimes out of our control, that will disrupt our normal schedule. In addition, our clients and patients have issues that need attention in the evening, at night, and on weekends and holidays.

The burden of providing emergency coverage for clients and their animals is not to be taken lightly. What tends to compound this problem is when colleagues from neighboring practices decide not to share in this responsibility. It seems that some practices are becoming more comfortable with either not responding to after-hours calls or letting their clients go elsewhere for emergency care. Obviously, we all have times when we are legitimately too busy to respond to every call in a timely fashion, and this is understandable. What is most concerning is seeing and hearing about this happening in all areas of the country with increasing regularity.

Historically, when we were unable to provide emergency services—whether it be for a CE meeting, illness or vacation—we would make arrangements in advance with neighboring practices to help provide for care for our clients and patients. Asking a colleague if they are available and willing to assist while you are away and before any emergencies arise would seem to be a common courtesy. In addition, it is an added service for your clients so they know who to contact should they need after-hours help. From my experience, most clients are more understanding and remain loyal to a practice if they are made aware of when you will be unavailable. It is easy to notify clients in advance to facilitate a seamless transition should the need arise. However you choose to give notice to your clients, they will be less stressed and more likely to return to your practice once you are back.

Similarly, the lack of effective communication when referring a patient to a colleague can also have a big impact on whether or not the client returns to your practice. I have seen this firsthand time and again. Some veterinarians are great at this, and their clients are well-prepared on arrival. In these cases, the owner already has been informed of what to expect in terms of diagnostics and costs. The referral veterinarian is fully aware of the case and history of the patient, which helps put the client more at ease. These scenarios work out well for the patient, the client and the referring veterinarian. In the end, the client has more trust and appreciation for what their regular veterinarian has done to help their horse.

Asking a colleague if they are available and willing to assist while you are away and before any emergencies arise would seem to be a common courtesy.

Conversely, when the effort to communicate has not been made, the results are not always as rosy. The client can quickly lose faith in their regular veterinarian if he or she has not helped to facilitate the referral. The client might try to pass blame onto their veterinarian for not making a correct diagnosis, not providing the proper treatment or not recognizing the severity of the problem. At this point, the client is upset and may start to question the competence of and care provided by their regular veterinarian. The end result might be the loss of the client altogether. With appropriate communication prior to the referral, this type of speculation can be terminated immediately, and all attention can be focused on treating the patient.

There are numerous ways to connect with colleagues that are easy and efficient. Depending on the situation, a phone call, text message or email to a colleague can be a big help in providing proper care for your patients and retaining your clients. Many issues can be resolved or avoided completely if we strive to communicate well with each other and put the horse first.

AAEP ETHICAL PRACTICE Every Day-Every Time

Dr. Wilhite is a founding partner of Wilhite & Freese Equine Hospital in Peculiar, Mo., and a member of the AAEP's Professional Conduct & Ethics Committee.

ETHICS

Ethics in action

As an educational resource for members, the AAEP's Professional Conduct & Ethics Committee has compiled synopses of real-life ethical situations and issues addressed by the committee in recent years. The case series began in the November 2020 issue, and a different matter is being presented each month, with names omitted to protect the privacy of those involved.

Case of the month – February

"Dr. D," an AAEP member, was fined $5,000 by the state veterinary board for practicing with a suspended license. Their veterinary license was suspended for 6 months with an additional 12-month probationary period. They were also fined $5,000 for failure to keep medical records as required by the state practice act.

The AAEP's Professional Conduct & Ethics Committee became aware of this action and sent Dr. D a letter of inquiry requesting their account of what occurred. Dr. D responded and the committee requested Dr. D meet for a hearing. Dr. D did not agree to attend the hearing.

Outcome: Dr. D's AAEP membership was suspended.

Update: Six years later, Dr. D re-applied for membership in the AAEP. The Professional Conduct & Ethics Committee reviewed the application and requested Dr. D attend a hearing with the committee. Dr. D did not comply with the request.

Outcome: Dr. D's membership application was denied.

AAEP ETHICAL PRACTICE Every Day-Every Time

ASSOCIATION

What's next for recently passed Horseracing Integrity & Safety Act?

Signed into law Dec. 27 as part of the federal omnibus bill, the Horseracing Integrity and Safety Act (HISA) is intended to bring uniformity to the sport by putting medication control and safety programs under an independent, non-governmental authority. Although HISA is now law, there is much that needs to happen before it can go into effect, which must occur before July 1, 2022.

The previously formed nominating committee, of which AAEP past president Dr. Jerry Black is a member, will now determine the nine individuals who will comprise the Horseracing Integrity and Safety Authority—essentially the board of directors. This could occur by the end of the first quarter.

From there, the nominating committee will name the members of two working committees focused on racetrack safety and on anti-doping and medication control. The AAEP's Racing Committee has submitted a list of names and credentials for consideration for the authority as well as the working committees.

As a component of HISA's implementation, the Federal Trade Commission will need to approve the anti-doping and medication control program and racetrack safety

Dr. Nat White

program. The FTC will review programs developed by the authority and allow for public comment before considering approval. As such, the specific impacts of HISA on the industry and on veterinarians' ability to treat horses won't be known until later. The AAEP will continue to monitor and keep members apprised of ongoing HISA developments.

5 things to know about AAEP this month

1. Join the more than 1,400 members discussing veterinary and industry topics in the AAEP Member Vet Talk group on Facebook. Search for the group and click "Join."
2. All AAEP members can access the virtual trade show until June 30 to visit booths and download company resources at https://tinyurl.com/aaepvcts.
3. Follow the monthly AAEP Practice Life podcast series, sponsored by Boehringer Ingelheim, at podcast.aaep.org or your podcast aggregator of choice.
4. Be an ambassador for the welfare of horses at significant risk with Equine Abuse, Neglect and Abandonment resources at aaep.org/owner-guidelines/equine-welfare.
5. Double the impact of your Foundation giving by participating in the Equine Memorial Program. Learn more at foundationforthehorse.org/support/memorial-giving.

New Practice Life podcast spotlights the satisfaction of equine practice

From the challenge of solving medical puzzles to the simple pleasures of being outside and enjoying the scenery en route to appointments, equine practice has a lot going for it.

In the latest episode of the AAEP Practice Life podcast, entitled "Equine Practice is Pretty Good, Part 4," host Dr. Mike Pownall discusses the joys and challenges of the profession with Dr. Bibi Freer from North Carolina, Dr. Kathy Linde from California, Dr. Stacy Whitton from Colorado, Dr. Elizabeth Woolsey-Herbert from Australia, and Cornell University fourth-year student Liliya Becktell.

In addition to sharing their stories and experiences, the guests also dispense advice for students and new graduates on choosing the right practice and setting themselves up for success. Download or listen to the hour-long episode at podcast.aaep.org.

The AAEP Practice Life podcast is sponsored by Boehringer Ingelheim.

Deadline nears to submit papers for 2021 convention in Nashville

Papers due March 15 at 3:00 p.m. ET

Time is running out to submit a paper to be considered for presentation during the 66th Annual Convention in Nashville, Tenn., Dec. 4–8. The presenting author of selected papers will receive complimentary registration and a stipend to support travel to the meeting.

Eligible for consideration are scientific papers, "how-to" papers, review papers, abstracts ≤ 250 words and The Business of Practice papers. All paper presentations are limited to 15 minutes with an additional 5 minutes for Q&A.

Papers must be submitted by March 15, 3:00 p.m. ET, at https://s3.goeshow.com/aaep/annual/2021/AAEP_paper_submission.cfm. Authors should visit the site in advance to set up a profile and provide paper and author information before uploading the paper when it is finished. Complete considerations and ethical guidelines are available in the General Instructions area of the site. Contact Carey Ross, scientific publications coordinator, at cross@aaep.org with questions concerning educational paper submission.

Reward excellence with an AAEP award nomination

Deadline to nominate is June 1

Honor a colleague who is serving the profession, association or welfare of the horse in outstanding ways with a 2021 AAEP annual award nomination. The AAEP is accepting nominations in the following categories until June 1:

The **Distinguished Educator – Academic Award** honors an individual educator who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners.

The **Distinguished Educator – Mentor Award** honors an individual who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners through mentoring.

The **Distinguished Life Member Award** recognizes a member who has demonstrated outstanding or extraordinary service to the AAEP over the course of their career.

The **Distinguished Service Award** recognizes an individual who has provided exemplary service to the AAEP or a similar organization to the benefit of the horse, horse industry or the profession of equine veterinary medicine.

The **George Stubbs Award** recognizes the contributions made to equine veterinary medicine by individuals other than veterinarians.

The **Sage Kester Beyond the Call Award** is named in honor of its first recipient, the late General Wayne O. "Sage" Kester, DVM, and represents the highest honor bestowed by the AAEP upon a current or former member. The award is presented to an individual who has made significant and long-lasting contributions to equine veterinary medicine and the community.

The **Lavin Cup (The Equine Welfare Award)** recognizes a non-veterinary organization or individual that has demonstrated exceptional compassion or developed and enforced rules and guidelines for the welfare of horses.

Dr. Terry Swanson, left, receives the 2019 Distinguished Educator – Mentor Award from Dr. Jeff Berk during the 65th Annual Convention in Denver, Colo.

The **AAEP Research Award** recognizes an individual who has recently completed research that has or will make a significant impact on the diagnosis, treatment or prevention of equine disease. Nominations are open to all individuals whose research is acknowledged by presentation or publication and by peer review as a significant advancement in equine medicine or innovation in equine science. Nominees must have had their research presented or published during the two years prior to when nominations are submitted to the AAEP.

Visit aaep.org/about-aaep/annual-awards for nomination forms as well as additional information about the awards and selection process. Nomination forms are also available from Sue Stivers at (859) 233-0147 or sstivers@aaep.org.

Award recipients will be honored at the AAEP's 67th Annual Convention in Nashville, Tenn., Dec. 4–8, 2021.

New *EVE* podcast focuses on telehealth

In the latest episode of the *Equine Veterinary Education* podcast, Dr. Cris Navas de Solis discusses the article, "Real-time telehealth using ultrasonography is feasible in equine practice." Download or listen to the 45-minute episode at equineveterinaryeducation.podbean.com.

AVMA summary sheds light on COVID-19 vaccine access for veterinary personnel

With access to COVID-19 vaccines determined at the state, territorial and local levels, the AVMA has published a summary regarding veterinarians and vaccine eligibility based on a survey of state veterinary medical associations. The summary includes how many states are currently in each of the described phases for vaccine distribution.

The Centers for Disease Control advises that "critical infrastructure workers" should have access to the vaccine in Phase 1, following distribution to healthcare workers. Phase 1-b includes people who play key roles in keeping essential societal functions running and cannot socially distance in the workplace, as well as those at high-risk for severe COVID-19 illness. The AVMA believes that veterinary personnel would be accommodated in Phase 1-b.

Following is a breakout of vaccine access for veterinary personnel based on the 35 state VMAs that responded by Jan. 6:

- 3 during phase 1-a
- 9 during phase 1-b
- 2 during phase 1-c
- 2 during phase 2
- 1 during phase 3
- 18 did not provide information

Because need and approach to decision-making vary by state,

veterinarians are encouraged to work with their state VMA to determine how they might most appropriately support prioritized access for veterinary personnel.

For additional information, visit avma.org/covidvaccine.

AVMA shares guidance on COVID vaccine administration by veterinarians

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The AVMA's Governmental Relations Division in mid-January circulated information regarding the legal implications of veterinarians assisting in COVID vaccine administration. It is shared below to keep AAEP members informed.

There has been some discussion about the potential for veterinarians to assist in the vaccination of humans against COVID. While having veterinarians volunteer to assist in vaccinating humans is not under consideration at this time in most states, some states have had preliminary discussions or even requests for potential volunteers to identify themselves.

One important issue to keep in mind is potential legal risk. Here are some preliminary thoughts to consider:

Veterinary Malpractice Insurance – Veterinarians should not expect their veterinary malpractice insurance to cover them over human injury arising out of the administration of vaccine to humans.

Federal law protecting those who administer COVID vaccine – The federal Public Readiness and Emergency Preparedness Act (PREP Act) authorizes the HHS Secretary to issue declarations that provide limited immunity from liability arising out of, relating to, or resulting from administration or use of countermeasures such as the COVID vaccine. Veterinarians are not explicitly addressed in the Act or the current declarations. There is also reference to "volunteers," but it isn't clear at this time that veterinarians would fit under that. There is the potential that veterinarians could be addressed in future amendments to the declaration.

State immunity/agreements – There may be state-specific laws that provide immunity. They may need to be predicated by some emergency finding or declaration, and there may be specific requirements in order to be covered. It would be very good to understand if the state provides the defense as well, or if an agreement could be reached for the state to defend and indemnify volunteer veterinarians.

AAEP note: For additional information, please contact Keith Kleine, AAEP director of industry relations, at kkleine@aaep.org, and he will connect you with the appropriate individual at the AVMA.

ASSOCIATION

Protect horse welfare with abuse and neglect resources

Whether it's a high-profile case involving many horses or an isolated incident with a backyard horse, the importance of identifying potential abuse and neglect cases cannot be understated.

Resources available on the AAEP's website will help you work with clients and law enforcement to prevent equine abuse and neglect. Prepared by the Equine Abuse & Neglect Subcommittee of the AAEP's Welfare and Public Policy Advisory Council, the resources consist of:

- The Veterinarian's Role in Assessing Risk and Reporting Suspected Equine Neglect, Abuse and Mistreatment (PowerPoint)
- A Practical Guide for Law Enforcement: Equine Abuse, Neglect and Mistreatment (PowerPoint)
- Equine Abuse, Neglect and Mistreatment FAQs
- Equine Investigation Examination Form
- Equine Investigation Forensics Supply List
- Compilation of All Equine Investigative Forms, including steps for evidence collection and triage

Form a strong collaborative team when faced with a possible case of equine abuse or neglect. Download these resources at aaep.org/owner-guidelines/equine-welfare.

FOUNDATION

Support clients and horse welfare through the Foundation's Equine Memorial Program

Help ease your client's emotional burden following the death or euthanization of a horse or pet with a gift to The Foundation in the deceased animal's memory. Memorial Program gifts reinforce your appreciation of the relationship and contribute to the overall betterment of horse welfare. In addition, AAEP Educational Partner Zoetis will once again match the first $25,000 in total giving.

Upon receipt of a memorial gift, The Foundation mails a sympathy card to the client or designated contact. An empathic message conveys the donation in the horse or animal's name (amount not disclosed) and expresses The Foundation's commitment to the mission of improving the welfare of horses.

"We donate to The Foundation's Equine Memorial Program for all our patients we euthanize or that die of natural causes," said Dr. Scott Anderson of Woodside Equine Clinic in Ashland, Va. "Our clients greatly appreciate their horse is memorialized in a way that potentially helps other horses. Clients frequently comment how the gift we have made is so thoughtful. Our donations also allow us to support something we feel very strongly about as a clinic."

In 2020, Foundation memorial gifts totaled more than $114,000 thanks to gifts from participating practices, Zoetis and other donors. Since inception of the matching program in 2008, Zoetis has generously provided $300,000 in matching funds.

To participate or learn more about the Memorial Program, visit The Foundation's website at foundationforthehorse.org/support/memorial-giving or contact Elaine Young at (859) 233-0147 or (800) 443-0177 or eyoung@foundationforthehorse.org.

AAEP Educational Partner Profile: Dechra Veterinary Products

Dechra Veterinary Products has emerged as a leader in equine medicine by offering a specialized range of approved equine products. In May 2016, Dechra achieved FDA approval of OSPHOS® (clodronate injection), the only intramuscular bisphosphonate. Since then, Dechra has received approval for OSPHOS in several other countries. And most recently, the addition of Zimeta® (dipyrone injection) further expanded Dechra's equine offerings.

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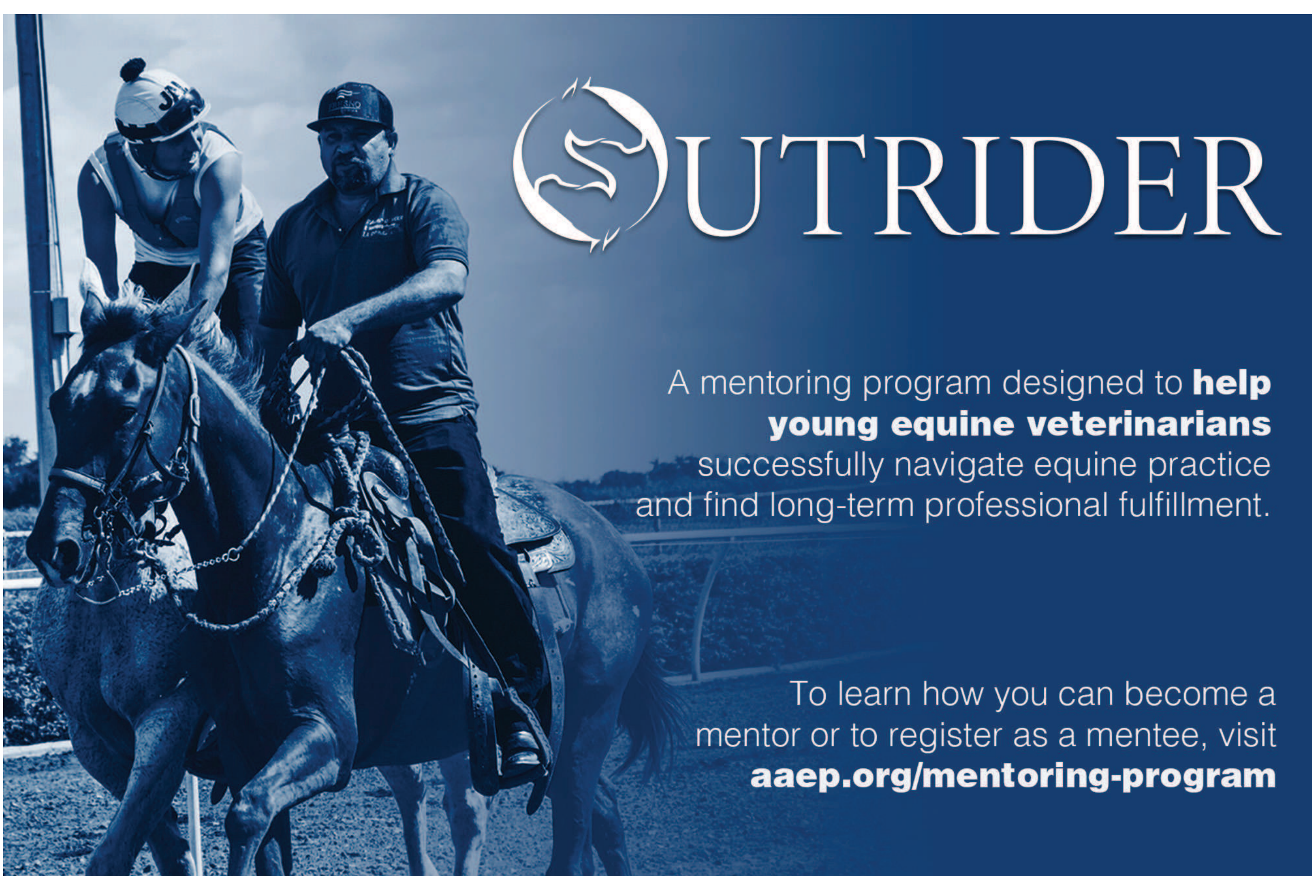
In 2016, Dechra helped to address the fluid shortage crisis by offering 3 L and 5 L fluids under the Vetivex® brand name. Now Dechra carries a complete line of 1 L, 3 L, and 5 L fluids to meet your every need, including the recently launched 5 L lactated Ringer's Injection, USP.

Technical continuing education meetings are one of the primary ways Dechra interacts with veterinarians. We have always believed in education as a platform upon which to build our company while enhancing the veterinary team's knowledge of the complex diseases that our products address. Dechra's educational offerings increase the knowledge of our customers primarily on disease states, case management, and client communication, and secondarily on Dechra's product portfolio and how it can help improve the lives of veterinary patients.

Dechra is committed to continually developing and investing in new products and services that support the work of the equine veterinarian and improve the health and welfare of the horse. As our equine team grows, we strive to be a leading educator of veterinarians, technicians, students, and horse owners and give back to an industry that has helped us reach this level.



Former AAEP officer Dr. Jim Smith dies at 86

Dr. Jim Smith

AAEP Honor Roll member and former secretary-treasurer Dr. James (Jim) Smith, a longtime partner in Hagyard Equine Medical Institute in Lexington, Ky., died Dec. 28 at the age of 86.

A 1958 veterinary graduate of Kansas State University, Dr. Smith joined Hagyard Equine Medical Institute in 1962. In the ensuing 42 years until his retirement in 2004, he focused his practice on reproductive medicine and ophthalmology while also mentoring numerous young veterinarians.

Dr. Smith actively volunteered within the AAEP and the broader equine and veterinary industry. He served as the association's secretary-treasurer from 1994–1996; chaired the Finance and the Equine Insurance committees; and was a member of the Reproduction, Sports Medicine, and Biological & Therapeutic Agents committees, among others. He also served as president of the Kentucky Equine Practitioners Association. His accolades include the Joan F. Pew Award from the Association of Racing Commissioners International and the E.R. Frank Award for Meritorious Service from his alma mater.

Racetrack practitioner Dr. Robert Corley, Jr. passes at 56

Dr. Robert Corley, Jr.

Dr. Robert Corley, Jr., founding partner of Equine Track Associates in Vinton, La., died Dec. 17 at the age of 56.

Dr. Corley received his veterinary degree from Louisiana State University in 1991. After practicing several years in New Jersey and Texas, he returned to his native Louisiana in 1994 and opened Equine Track Associates. With a focus on Thoroughbred racehorses, Dr. Corley's main professional interests were lameness evaluations, pre-purchase exams, radiology and ultrasound.

An AAEP member since 1990, Dr. Corley was active in the Louisiana and Texas veterinary medical associations.

Benefit: Keep AAEP's resources at your fingertips with the Publications App

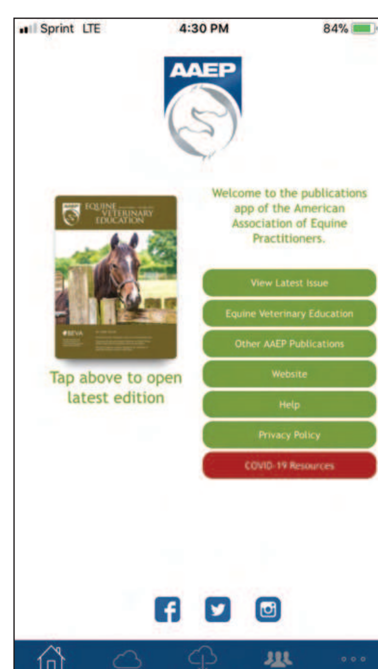
Maintain anytime access to AAEP's infectious disease guidelines, convention *Proceedings, EVE* and more by downloading the free AAEP Publications App.

Like its name suggests, the AAEP Publications App is your digital source for the association's catalog of publications, which also includes white papers, annual reports, additional guidelines, Spur and The Foundation for the Horse newsletter.

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

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

Don't get caught in the field without access to important guidelines and other resources. Download the app at no charge by searching "AAEP Publications" at the App Store or Google Play.



Members in the News

Dr. Jesse Brandon named Louisiana VMA president

Dr. Jesse Brandon

Dr. Jesse Brandon of Brandon Veterinary Clinic in Leesville, La., has been installed as president of the Louisiana Veterinary Medical Association.

An AAEP member since 2009, Dr. Brandon earned his veterinary degree from St. George's University in the West Indies.

Dr. Jean-Yin Tan named to veterinary DEI commission

Dr. Jean-Yin Tan

Dr. Jean-Yin Tan, chair of the AAEP's Diversity, Equity and Inclusion Task Force, has been appointed to the newly formed Commission for a Diverse, Equitable and Inclusive Veterinary Profession, a joint initiative of the AVMA and the Association of American Veterinary Medical Colleges.

Dr. Tan, who received her veterinary degree from Cornell University, is a senior instructor of equine clinical sciences at the University of Calgary Faculty of Veterinary Medicine.

Dr. John Schumacher receives ACVS Merit Award

Dr. John Schumacher

The American College of Veterinary Surgeons and the ACVS Foundation in November bestowed the ACVS Merit Award upon Auburn University Professor Emeritus Dr. John Schumacher. The award recognizes Dr. Schumacher's contributions to the profession, not only in the clinical practice of equine medicine and surgery but also in support of his collaborative research and focus on equine lameness.

A veterinary graduate of Kansas State University, Dr. Schumacher served on faculty at Auburn from 1982 until his retirement in 2019. He was equine section head from 1994–1997 and again in 2000, and he received the Carl J. Norden Distinguished Teacher Award in both 1995 and 1998.

Drs. Steve Adair and Monty McInturff appointed to equine health commission

Dr. Steve Adair

Dr. Monty McInturff

Drs. Steve Adair and Monty McInturff have been appointed to the newly formed Tennessee Equine Health Advisory Commission by Governor Bill Lee. The nine-member commission will work to promote horse health and to encourage sound agricultural practices with equine activities and the breeding of equine livestock.

Dr. Adair, who received his veterinary degree from Auburn University, is associate professor of equine surgery at the University of Tennessee College of Veterinary Medicine, where he also serves as an AAEP student chapter advisor.

Dr. McInturff, who was appointed commission chair, is owner and practice manager of Tennessee Equine Hospital. He served on the AAEP's board of directors from 2013-2015 and is a current member of the Foundation Advisory Council. He received his veterinary degree from Auburn University.

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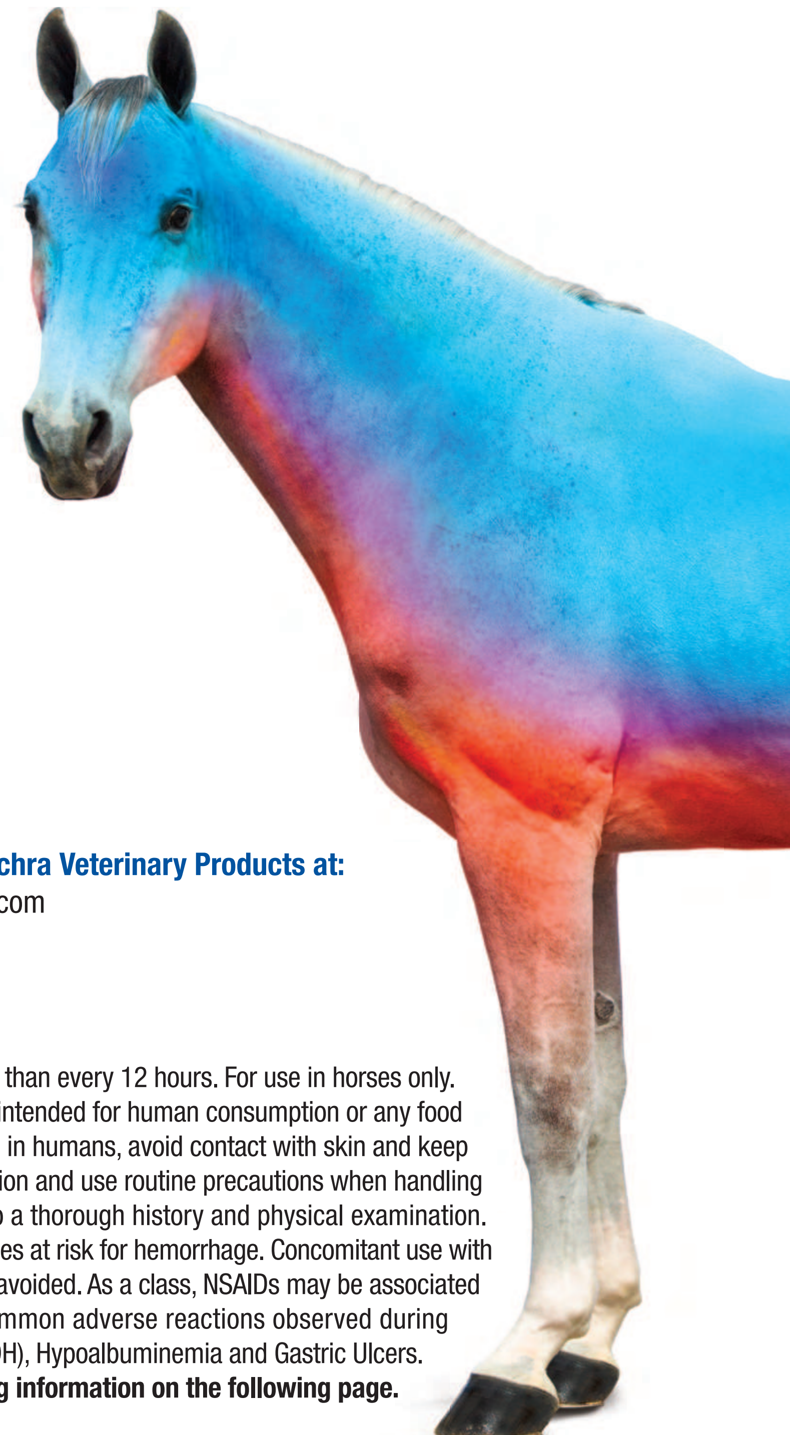

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For additional information, see brief summary of prescribing information on the following page.

References: 1. Zimeta® (dipyrone injection). [Full Prescribing Information], Kindred Biosciences, Inc. (Burlingame, CA). Revised: 03/2019. **2.** Morresey PR, et al. Randomized blinded controlled trial of dipyrone as a treatment for pyrexia in horses. *Am J Vet Res.* 2019;80(3):294-299.

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EQUINE VETERINARY EDUCATION
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Highlights of recent clinically relevant papers

Equine influenza vaccination in the UK

This survey of equine veterinarians by Amie Wilson and colleagues aimed to describe current vaccination practices advised by vets treating horses in the UK and compare practices with manufacturer datasheets and current guidelines.

A survey completed by 304 UK equine vets working with a variety of horse populations identified that the recommendations given to owners by the majority of respondents (92%) were not consistent with datasheet guidelines. Vaccination guidelines from the British Horseracing Authority and the Fédération Equestre Internationale were most commonly used. Variation was also identified in vaccine protocols for competition and non-competition horses, with 57% of respondents reporting variation in advised 'booster' frequency. This most commonly consisted of advising 6-monthly vaccination in competition horses and annual vaccination in non-competition horses.

Adverse events following vaccination in the previous year were encountered by 66% of respondents, representing 2760 adverse events in total. Only 526 (19%) of reactions were reported to the Veterinary Medicines Directorate. The most common reactions were transient, including stiffness (n = 931), localised swelling (n = 835), lethargy (n = 559) and pyrexia (n = 355). A large proportion (86%) of respondents reported vaccine hesitancy from horse owners, most commonly due to perception of over-vaccination, cost and concerns regarding adverse events.

A discrepancy exists between datasheet guidelines and those issued by industry governing bodies. Non-compliance with the datasheet guidelines is common, risking suboptimal immunity to equine influenza.

Control of endoparasites on stud farms

This longitudinal randomised field trial by Martin Nielsen and colleagues in the USA and New Zealand evaluated egg count levels, bodyweight, and equine health under defined parasite control protocols in foals and mares at four stud farms in New Zealand.

Foals (n = 93) were divided into two treatment groups; Group A were dewormed at 2 and 5 months of age with a fenbendazole/ivermectin/praziquantel product, while Group B were dewormed monthly, alternating between the above-mentioned product and an oxfendazole/pyrantel embonate product. Mares (n = 99) were divided into three groups; Group A were dewormed twice (early summer and winter) with fenbendazole/ivermectin/praziquantel, Group B were dewormed with the same product only when egg counts exceeded 300 eggs per gram, and Group C were dewormed every 2 months, alternating between the two products. Health data was collected at 2-monthly intervals for 13 months.

Foals in Group A had significantly higher ascarid and strongylid faecal egg counts compared to Group B, but no significant differences were observed between mare groups. There were no differences between groups with regards to body weight and body condition score. One foal in Group B developed diarrhoea during the monitoring period. No colic signs were reported in any group during the study.

Reducing anthelmintic treatment intensity can lead to higher ascarid and strongylid egg counts in foals on stud farms; however, no negative health consequences were observed within the timeframe of this study. Longer monitoring periods are needed to assess the effects of increased egg shedding on subsequent foal crops.

Gastrointestinal microbiome and weight-loss

In this study Philippa Morrison and colleagues in the UK investigated the impacts of weight-loss on the gastrointestinal microbiome.

Gastrointestinal-derived bacteria play a fundamental role in host-health and have been associated with obesity and weight-loss in other species. This study evaluated the faecal microbiome of 15 obese Welsh Mountain pony mares, in the same 11-week period across 2 years. A 4-week acclimation period (pre-diet phase) during which individuals were fed the same hay to maintenance (2% body mass (BM) as daily dry matter (DM) intake), was followed by a 7-week period of dietary restriction (1% BM hay as daily DM intake). Faeces were sampled on the final 3 days of both the pre-diet and the dietary restriction phases. Bacterial communities were determined using next-generation sequencing of 16S rRNA genes.

Losses in body mass ranged from 7.11 to 11.59%. Changes in the faecal microbiome composition following weight-loss included a reduction of *Firmicutes* and *Tenericutes* and a reduction in indices of bacterial diversity.

Weight-loss in this group of ponies was associated with lower pre-diet faecal bacterial diversity and greater pre-diet acetate concentration. Overall, these data support a role for the faecal microbiome in weight-loss propensity in ponies and provide a baseline for research evaluating elements of the faecal microbiome in predicting weight-loss success in larger cohorts.

Endocrine dysfunction testing and pain

The aim of this study by Heidrun Gehlen and colleagues in Germany was to evaluate (i) the effects of different intensities and types of treated pain on the basal concentrations of adrenocorticotropic hormone (ACTH) and cortisol, and (ii) the thyrotropin-releasing hormone (TRH) stimulation test, to determine whether treated pain caused a marked increase of ACTH, which would lead to a false positive result in the diagnosis of pituitary pars intermedia dysfunction (PPID).

This study included 15 horses with treated low to moderate pain intensities which served as their own controls as soon as they were pain-free again. The horses were divided into three disease groups (disease group 1 = colic, disease group 2 = laminitis, disease group 3 = orthopaedic problems). The intensity of the pain was evaluated using a composite pain scale which contained a general part and specific criteria for every disease. ACTH and cortisol were measured before and after the intravenous application of 1 mg of TRH.

There was no significant difference in the basal or stimulated ACTH concentration in horses with pain and controls, between different pain intensities or between disease groups. Descriptive statistics revealed that pain might decrease the effect of TRH on the secretion of ACTH. There was an increase of ACTH 30 min after TRH application in the treated pain group, but this difference could not be statistically confirmed. Measuring the basal ACTH concentration and performing the TRH stimulation test for the diagnosis of PPID seem to be possible in horses with low to moderate pain.

Mepivacaine prior to carpal arthroscopy

This experimental, analytical, cohort study by Angela Gaesser and colleagues in USA evaluated the effects of intra-articular (IA) mepivacaine administration prior to carpal arthroscopy on anaesthetic drug requirements, blood pressure support, haemodynamic variables, and quality of recovery in horses.

Twenty-two horses were anaesthetised by using the same protocol. The treatment group (n = 11) were administered an IA injection of mepivacaine and the control group (n = 11) were administered saline before carpal arthroscopy was performed on all horses. End-tidal isoflurane concentration, heart rate, and mean arterial pressure were recorded at specific time points. Quality of recovery was scored by the anaesthetist, who was unaware of group assignment. Data were analysed by using two-way repeated-measures analysis of variance.

Mean arterial pressure was higher during joint distension in the control group compared with baseline (7% higher) and with the treatment group (10% higher). Heart rate was higher in the control group compared with the treatment group during joint distension (8% higher) and chip removal (11% higher). Heart rate was higher in the control group compared with baseline during chip removal (5.5% higher). Two horses in the control group required additional ketamine vs. none in the treatment group. Quality of recovery was not different between groups.

Intra-articular mepivacaine resulted in fewer detectable reactions to surgical stimulation, with similar recovery scores and blood pressure support requirements. Intra-articular anaesthesia prior to arthroscopy can be used safely in the horse and should be considered as a part of balanced anaesthetic protocols.

Topical treatment of equine sarcoids

In this study Carina Pettersson and colleagues in Sweden evaluated the efficacy and safety of topical imiquimod 5% cream and Sanguinaria canadensis + zinc chloride for treatment of equine sarcoids and investigated possible systemic effects on distant untreated sarcoids.

Twenty-five client-owned horses with a total of 164 tumours were included in the study; 57 tumours were treated and 107 tumours were left untreated.

Skin biopsy samples were collected from a minimum of one tumour per horse and the rest were diagnosed based on clinical appearance as likely sarcoids. Imiquimod 5% (A) was applied three times weekly, while *Sanguinaria canadensis* + zinc chloride (X) was applied every fourth day after a 6-day daily initiation phase. Treatment continued until clinical remission or for a maximum of 45 weeks, with a long follow-up period (mean 34 months). Skin biopsy samples of sarcoid lesions were re-taken before treatment termination and at follow-up if the owner gave consent.

Complete remission was recorded in 84.4% (A) and 75.0% (X) of the tumours. Relapse was recorded in 7.3% (A) and 21.4% (X). Spontaneous remission was observed in 1.9% of untreated tumours. No systemic effect on untreated tumours was detected. During treatment varying degrees of local inflammatory reaction were common.

Both treatments were considered effective and safe. Smaller tumours responded more favourably to treatment. Relapse rate was low and not observed in sarcoids with repeat biopsies before treatment termination.

Conditions seen ‘out-of-hours’

This retrospective study by Adelle Bowden and colleagues described first opinion ‘out-of-hours’ cases seen at two UK equine practices between 2011 and 2013.

Data including case presentation, diagnostic testing, treatment administered and outcome were retrieved from 2602 cases and diseases were categorised using a systems-based coding system. Outcome of ‘critical’ cases was classified as required hospitalisation or euthanasia or died.

The most common reasons for ‘out-of-hours’ visits were colic (35%), wounds (20%) and lameness (11%). The majority of cases required a single treatment (58%), 26% needed multiple treatments and 13% were euthanased. A critical outcome was recorded in 18% of cases. Increased heart rate at primary presentation was associated with critical outcome in both practices. Further research is required into out-of-hours euthanasia decision-making.

S. WRIGHT
EVE Editorial Office

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Case Report

The effects of endometrial damage on placental and fetal development in a mare

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Keywords: horse; mare; uterus; endometrium; placenta; fetal development; progestagens

Summary

A 13-year-old ex-polo pony maiden mare examined by rectal palpation exhibited an enlarged and irregularly textured uterus. Subsequent ultrasound examinations revealed an uneven echogenic appearance and many intramural cyst-like structures in the endometrium. Hysteroscopy showed transluminal adhesions, layers of fibrous tissue covering areas of the endometrium, numerous small craters in the endometrial surface and inspissated pus-like material, predominantly in the uterine body and base of both horns. It was assumed the endometrial damage had resulted from previous intrauterine administration of a highly irritant solution, possibly enrofloxacin or povidone-iodine (**Fig 1**). She nevertheless produced four normal Day 8 blastocysts during embryo recovery before being left pregnant to produce a small but viable foal after a 360-day gestation during which maternal serum progestagen concentrations were raised over the last 80 days, likely reflecting the placental pathology and fetal stress.

The allantochorion had grown to occupy the whole uterine lumen but was lighter than normal at 1.28 kg, and it showed numerous discrete areas which had overlain the regions of endometrial damage and were either completely devoid of microcotyledons or showed blunt microcotyledons with minimally branched primary villi (**Fig 2**). Between these areas, however, microcotyledons were particularly dense and showed a complex branching pattern, suggesting that some degree of compensatory growth may have occurred to compensate for the deficiencies elsewhere.

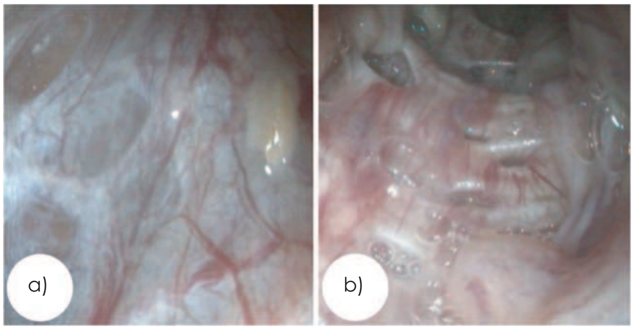

Fig 1: The interior of the mare's uterus showing a) transluminal adhesions and inspissated material and b) general fibrosis and multiple craters in the endometrium.

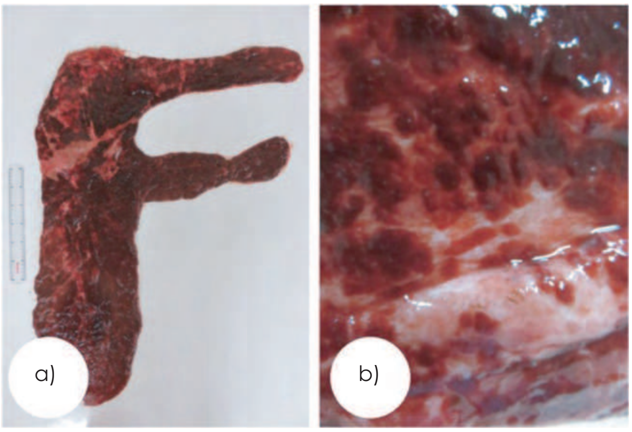

Fig 2: a) The term placenta showing extensive avillous areas especially in the body and gravid horn. b) Close-up view of the chorionic surface showing the variation in development of the microcotyledons.

Key points

- Severe endometrial damage need not necessarily prevent a mare being an embryo donor.
- Localised placental pathology resulting in a shortfall in the total area of feto-maternal interdigitation may stimulate compensatory growth and branching of the microcotyledons in other normal parts of the uterus.
- Abnormal maternal serum progestagen profiles in later pregnancy may be a useful indicator of placental compromise and resulting fetal stress.

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Case Report

Abortion due to *Bacillus safensis* in a mare

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Keywords: horse; *Bacillus safensis*; abortion; mare

Summary

A 16-year-old Westphalian mare presented after having aborted a 7-month gestation fetus. There were no prodromal signs prior to abortion. The fetus was stillborn. The fetus and fetal membranes were also presented by the owner. A uterine swab specimen was obtained and submitted for aerobic bacterial culture. The uterus was lavaged twice using 10 L of isotonic saline with 5 mL of 10% povidone–iodine solution added, and 40 iu of oxytocin was given i.m.

On evaluation, the chorioallantois was diffusely thickened and mottled dark red, with a 30 × 12 cm sharply demarcated pale area, covered with pinpoint coalescing fibrinous plaques, and surrounded by a bright red area of congestion and haemorrhage, near the junction of the gravid horn and body of the placenta. The nongravid horn was also diffusely thickened and was friable and contained thick, brown, turbid fluid. The cervical star could not be clearly identified. The fetus had a 6.5 × 6.5 cm fracture of the frontal bone and the thoracic and abdominal cavities contained 200 mL of red serosanguineous fluid, presumably associated with post-mortem trauma. Samples of placental and fetal tissues were fixed in 10% neutral-buffered formalin and processed for histopathology. A section of fetal lung was submitted for aerobic bacterial culture.

On histological examination, a locally extensive area of the chorionic epithelium and chorionic villi was overlaid by an exudate characterised by moderate numbers of degenerative neutrophils admixed with necrotic debris and fibrin. Small colonies of 1 μm, Gram-positive bacilli were scattered throughout the exudate and within macrophages (**Fig 1**). The associated chorionic epithelium was often moderately hyperplastic, with sloughing of epithelium in the most severely affected areas. The submucosa was diffusely oedematous and superficially infiltrated by large numbers of macrophages with fewer lymphocytes, and fibrin. Multifocally, small blood vessels contained microthrombi. The bronchi and bronchioles of the fetal lungs multifocally contained few degenerative neutrophils admixed with fibrin and cellular debris (mild bronchopneumonia consistent with aspiration). The uterine aerobic culture resulted in a mild growth of what was originally identified as *B. pumilus*, while the aerobic lung culture resulted in a heavy growth of what was initially identified as *B. pumilus* and four colonies of *Pseudomonas putida*. The genome was sequenced and submitted for NCBI average nucleotide identity (ANI) analysis. The ANI analysis found 97% identity to *B. safensis* and 91% identity to *B. pumilus*. This highlights the importance of genomic sequencing in identifying bacteria and represents the first case of a *B. safensis*-associated equine abortion and infection caused by this bacterium.

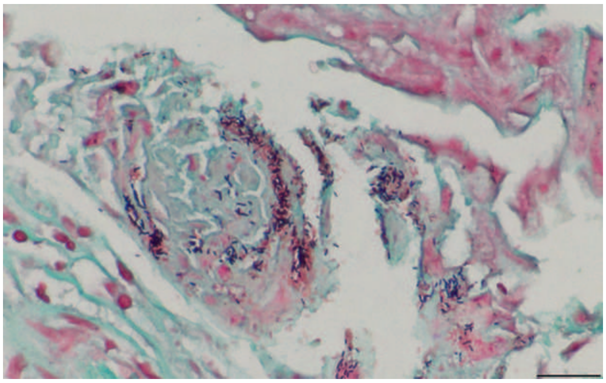

Fig 1: Photomicrograph of chorion. Small colonies of 1 μm, Gram-positive bacilli (staining dark purple) were scattered throughout the exudate and within macrophages. Gram Stain, 60 × magnification, scale bar = 20 μm.

Key points

- To the best of our knowledge, this is the first report of abortion associated with *B. safensis* in a mare.
- The route of transmission is unknown; similar distribution of placental lesions is seen in nocardioform placentitis.
- This strain represents the first case of a *B. safensis*-associated equine abortion and the first case of any infection caused by this bacterium.

[Correction added on 20 May 2020, after first online publication: Bacillus pumilus has been changed to Bacillus safensis throughout, and the Refences section has also been changed in this version.]

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Case Report

Strangulation of the duodenum just oral to its caudal flexura caused by a volvulus

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Keywords: horse; duodenum; volvulus; laparoscopy; hand-assisted laparoscopy

Summary

An 8-year-old Haflinger mare with a 10-day-old foal at foot was referred with mild abdominal pain. On the basis of clinical examination, blood and peritoneal fluid analysis, the cause of pain was suspected septic peritonitis. The horse was initially managed medically, with the horse placed in box confinement under close monitoring. For the next 2 h, the pony continued to show slight persistent abdominal pain and gastric reflux. Palpation per rectum and abdominal ultrasonography were repeated, with no additional significant findings, and surgical intervention was recommended. As the cause of pain was suspected either in the cranial part of the intestine or in the uterine horn and no permission was given for an exploratory laparotomy, it was decided to perform a diagnostic laparoscopy in the standing horse.

The laparoscopy revealed a 360 degree anticlockwise partial duodenal volvulus of the caudal descending duodenum (**Fig 1**), which was manually reduced (hand-assisted laparoscopy). After the release, the mesentery of the duodenum showed an ischaemic band (yellowish white and dark red with a hyperaemic side) and the duodenum a distinct ischaemic ring (orally and aborally) marking the incarcerated part from the normal duodenum. Ten minutes after the release, the colour remained the same. In conjunction with the owner, it was decided to euthanise the pony. Pathology confirmed the presence of a strangulation ring and the ischaemic condition of the involved duodenum.

Duodenal volvulus is a life-threatening condition that results from the rotation of the duodenum on its mesenteric axis leading to a closed-loop obstruction causing abdominal pain and rarely considered as an underlying diagnosis in horses showing abdominal pain. The duodenum is anchored at the pylorus and fixed by the hepatoduodenal ligament, the mesoduodenum, the hepatorenal ligament and the duodenocolic ligament with consequently restricted mobility. In this specific case, the mesoduodenum at the caudal part of the descending duodenum was elongated and near the caudal flexura at the base of the caecum short, offering the opportunity for rotation.

Due to the inaccessibility of the duodenum by celiotomy, the laparoscopic technique in the standing horse offers a better view of the region of interest and the possibility to evaluate the size, shape and character of the duodenum, and in this specific case led us to the diagnosis. If the strangulation had not been that severe, the hand-assisted approach might have resulted in a more favourable outcome.

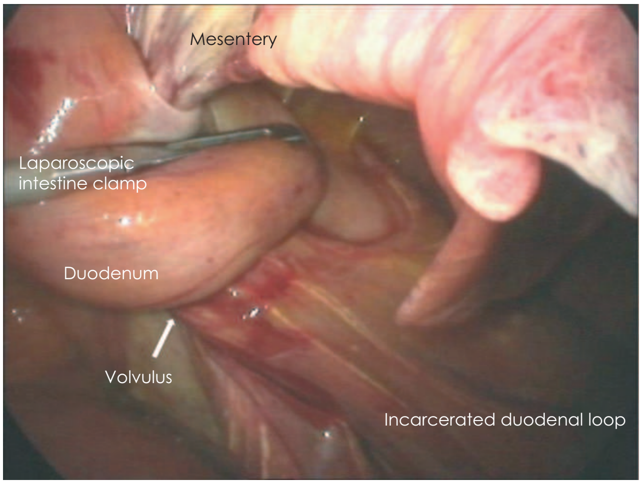

***Fig 1:** Laparoscopic view of the right side of the abdominal cavity showing the volvulus.*

Key points

- Duodenal volvulus should be considered as an underlying diagnosis in equines showing abdominal pain.
- Laparoscopy in the standing horse allows us to visualise duodenal problems.
- Hand-assisted laparoscopy might be helpful in the reduction in a duodenal volvulus.

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Case Report

Removal of a fragmented nasogastric tube from the transverse colon of a horse undergoing exploratory celiotomy for colic

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Keywords: horse; surgery; nasogastric; complication; colic

Summary

A 5-year-old Warmblood gelding presented for evaluation of colic at the UC Davis Veterinary Medical Teaching Hospital. The horse had been in the current owner's possession and current veterinarian's care for approximately 12 months. The gelding had suffered intermittent mild to moderate colic episodes in the previous months which had responded to medical management. No complications associated with nasogastric intubation were encountered by the current veterinarian. During initial work-up, a soft impaction in the large colon was palpated per rectum. A nasogastric tube was passed and no net reflux was obtained. The horse was hospitalised and placed on i.v. fluid therapy. The horse continued to pass diarrhoea overnight and continued to be intermittently painful. Based on this response to therapy, the decision was made to take the horse to surgery for an exploratory celiotomy. Upon exploration, a large tubular structure was palpated in the transverse colon. The foreign body was coiled with feed material surrounding it. Manipulation of the intestines revealed a feed impaction in the right dorsal colon. A pelvic flexure enterotomy was performed and the impaction was cleared orally to the foreign body. The linear foreign body was manipulated orally from the transverse colon to the right dorsal colon (**Fig 1**). Due to the shape and difficulty in exteriorising it, it was decided to make an additional enterotomy in the left dorsal colon to remove the foreign body. A 10- to 12-cm incision was made over the foreign body aboral to the pelvic flexure and the linear foreign body was removed. A black discoloured tubular structure that measured approximately 1 m in length was exteriorised from the left dorsal colon (**Fig 2**). On further inspection, it appeared to be the distal section of a nasogastric tube that had been severed at the proximal end. No complications were encountered in the immediate post-operative period and the horse was discharged from the hospital 5 days after surgery.

To the authors' knowledge, this is the first case report to describe removal of a fragmented nasogastric tube from the intestinal tract of a horse. While this case report highlights the consequences of not removing a fragmented tube at the time of fragmentation, it also highlights the importance of client communication when complications during nasogastric intubation do occur.

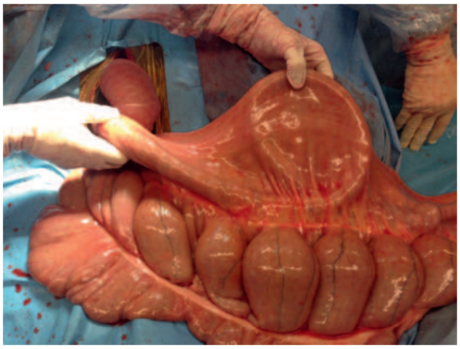

***Fig 1:** Intraoperative photograph showing a long linear foreign body within the right dorsal colon.*

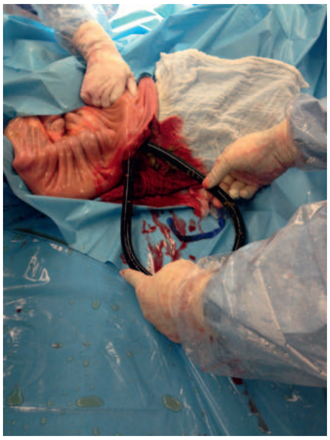

***Fig 2:** Intraoperative photograph showing the removal of an approximately 1 m segment of nasogastric tubing from the right dorsal colon through an enterotomy incision.*

Key points

- Nasogastric intubation, while a routinely performed procedure, can have serious complications.
- Fragmentation of a nasogastric tube can occur with pliable tubes especially if exposed to sunlight, chemical agents and extremes of temperature. Regular inspection of nasogastric tubes is important as well as correct technique in passing the tube to avoid retroflexion and potential chewing which could result in fragmentation.
- Prompt recognition of nasogastric tube fragmentation followed by localisation and removal of the fragment is essential in order to prevent further complications and avoid possible obstruction.

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Case Report

Traumatic injury to the parotid salivary gland or duct and the subsequent development of ipsilateral severe peripheral dental caries in two horses

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Keywords: horse; saliva; parotid salivary gland; dentistry; peripheral caries

Summary

This report describes two cases of unilateral traumatic injury to the parotid salivary gland or duct and the subsequent development of severe ipsilateral peripheral dental caries. Case 1 was an 8-year-old Australian Stock horse gelding with a history of a fibrosarcoma being removed from the right side of the face, over the area where the parotid salivary gland enters the mouth. Following surgery, a salivary fistula formed, which resolved after 6 weeks. A routine dental examination performed 17 months later revealed sharp enamel points and maxillary 6 overgrowths but no peripheral caries or uneven wear of teeth were noted. Nine months later, the right parotid salivary gland and duct became visibly distended, thickened and painful. A subsequent dental examination performed 4 months later noted peripheral caries with a significant difference in severity between the 106-11's and 206-11's.

On dental examination performed 6 months later, the horse was noted to have severe (grade 2–4) peripheral caries, extending on to the occlusal surface on the majority of the Triadan 100 and 400 arcades with mild to moderate (grade 1.1–2) changes on the 200 and 300 arcades (**Fig 1**). Transcutaneous ultrasound examination confirmed the right parotid salivary gland to be smaller, more homogenous and hyperechoic compared to the left. The right parotid duct could not be identified ultrasonographically.

Case 2 was a 6-year-old Thoroughbred mare who presented for routine dental examination. The horse had undergone a routine dental examination and treatment 12 months earlier with no dental abnormalities noted other than sharp enamel points and buccal ulceration. No evidence of peripheral caries or periodontal disease was noted at that time. Approximately 6 months later, the horse sustained a traumatic injury to the region of the right parotid salivary duct which drained a 'clear, thick liquid' believed to be saliva. The wound had subsequently healed; hence, no further investigation was undertaken. Six months following the injury, a routine dental examination revealed the mare to have severe (grade 3–4) peripheral dental caries affecting the Triadan 100 and 400 dental arcades, with only mild to moderate peripheral caries (grade 1.1–2) on the 200 and 300 dental arcades. Obvious right parotid duct distention was evident, extending from the right parotid salivary gland to the most ventral aspect of the mandible, where it abruptly stopped. Transcutaneous ultrasound examination revealed a hyperechoic soft tissue structure within the parotid duct at this level, measuring approximately 6 mm in length by 6 mm in width. This structure, considered likely to be scar tissue which had developed secondary to the previously described traumatic injury, resulted in a partial obstruction of the right parotid duct.

While it is difficult to prove an association between the damaged parotid gland or duct and the development of severe, ipsilateral peripheral caries, the clearly abnormal gland and duct on the affected side demonstrated via ultrasound, as well as the knowledge that both horses had no significant dental pathology prior to the injury are highly suggestive.

These cases highlight a previously unrecognised potential complication associated with the loss of function of the parotid salivary gland and highlight its importance in the maintenance of oral health in the horse. The authors feel that potential side effects should be considered and discussed with owners prior to the parotid salivary gland being ablated, particularly in areas where peripheral caries are prevalent.

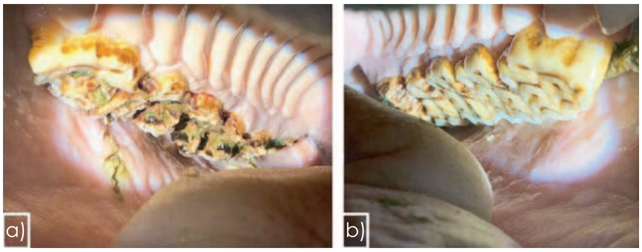

***Fig 1:** a) Oral view of the 100 arcades and b) the 200 arcades of Case 1. Note the severe peripheral caries and buccal ulceration affecting all dental components and extending across the entire occlusal surface of the 108-11 and also affecting the 106 and 7 teeth. This is compared to the mild to moderate peripheral caries on the 200 arcade.*

Key points

- Peripheral caries involves the demineralisation and destruction of the calcified dental tissues and can predispose to dental fracture, premature dental wear, periodontal disease and soft tissue trauma.
- Saliva plays a critical role in caries prevention, and loss of function of the parotid salivary gland can have serious deleterious effects.
- Surgeons should be aware, and owners should be counselled of potential consequences of parotid salivary gland ablation.


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Case Report

Unusual pathophysiological mechanisms of ptyalism in two horses

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Keywords: horse; salivation; mediastinal; vestibular; neurological

Summary

Case 1

A 9-year-old Thoroughbred gelding presented acutely with moderate left-sided head tilt; ataxia and left-sided paresis; serous discharge from the left external ear canal; and ptyalism, apparently associated with increased arousal levels of the horse. He was treated with corticosteroids, nonsteroidal anti-inflammatory drugs and antimicrobials for 2 weeks and referred 7 weeks after onset. Radiography of the skull identified increased size and opacity of the left tympanic bulla, consistent with bone remodelling (**Fig 1**). Trauma was suspected as the primary cause of the left-sided peripheral vestibular disease and injury to the parasympathetic innervation of the salivary glands, which is closely anatomically associated with the tympanic bulla. The ptyalism was attributed to either denervation hypersensitivity (to sympathetic stimulation) or excessive parasympathetic activation caused by focal inflammation.

Case 2

A 7-year-old Dutch Warmblood mare presented with self-resolving oesophageal obstruction; subsequent progressive ptyalism; and laryngeal paralysis, which progressed from right sided to bilateral over a few days. Computed tomography of the head and upper neck was unremarkable. Thoracic ultrasonography showed a progressive pleural effusion. Due to continued deterioration, the mare was subjected to euthanasia. Partial post-mortem examination identified a large mass within the mediastinum and involving the heart base, compressing the adjacent structures of the trachea, cranial vena cava and the aorta (**Fig 2**). This was identified by immunohistopathology to be T-cell lymphoma. The bilateral laryngeal paralysis was attributed to compression of the recurrent laryngeal nerves in the cranial thorax. The ptyalism was suspected to be due to partial extra-luminal obstruction of the oesophagus affecting the ability to swallow saliva and resulting in drooling, although the possibility of vagal afferent associated salivary gland stimulation was also considered.

***Fig 1:** Radiographic dorsoventral image of the skull demonstrating increased mineral opacity caudal and medial to the left petrous temporal bone (arrow), closely associated with the tympanic bulla.*

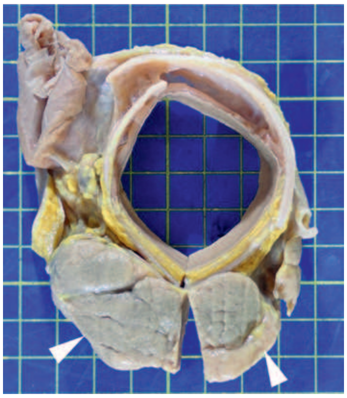

***Fig 2:** Transverse section of the trachea at the level of the hilus, showing the lobulated mass on the ventral aspect of the trachea (arrowheads). Grid = 1 cm.*

Key points

- Ptyalism is usually secondary to a physical obstruction to swallowing; dysphagia; or equine dysautonomia
- It is important to consider the neuroanatomy controlling salivary gland activation and to consider lesions affecting the intrathoracic oesophagus as well as those involving the head and cranial neck.
- Parasympathetic stimulation of salivary glands evokes secretion of salivary fluid and mucin whilst sympathetic stimulation augments salivary production and increases protein exocytosis; therefore, stimulation of either can increase salivation.

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Case Report

Standing flank laparotomy for the treatment of small colon impactions in 15 ponies and one horse

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Keywords: horse; small colon; colic; impaction; laparotomy

Summary

This case series reports the use of standing flank laparotomy (SFL) in 15 ponies with focal small colon impactions (SCIs) and one large breed horse with a generalised small colon impaction. Performing SFL for SCI reduces the costs and eliminates complications associated with general anaesthesia. The horses/ponies presented with signs of colic of 1–4 days duration and were initially vigorously treated with both enteral and parental fluids to relieve the impaction but failed to pass faeces and resolve the abdominal distention and pain. In some cases, trocarisation was attempted to reduce abdominal pressure but, in the cases presented, this did not resolve the colic. Despite the delay in diagnosis and eventual surgery in some cases and despite the inability to visualise some of the intestinal segments, all the impactions were resolved by SFL involving extraluminal massage. The incisions were closed in three to five layers, depending on the surgeon's preference. Routine perioperative treatment with fluids, analgesics, antibiotics and wound care was provided. All animals survived to discharge. The time from surgical resolution of the impaction to passing faeces was less than 2 h in all but one case. Median duration of hospitalisation was 2 days, and all animals returned to their original use by 2 months. The encouraging results of this case series suggest that SFL is a viable alternative to ventral laparotomy for ponies and horses with either focal SCI (faecalith) or general, elongated, SCI. However, case selection is important, as other causes of colic such as small intestinal strangulation, may not be suitable candidates for SFL. While complications such as evisceration or recumbency during surgery are a possibility, none were noted in this study. Despite concurrent, extensive feed accumulation in the large colon, once the small colon impactions were emptied, the colic resolved, and the horses regained normal passage of ingesta. Clients were advised of the potential limitations and possible reoccurrence of impaction colic but readily agreed to the procedure and were satisfied with the outcome. Overall, the results of this small case series are encouraging and SFL should be considered as a viable option for SCI necessitating surgery (**Fig 1**).

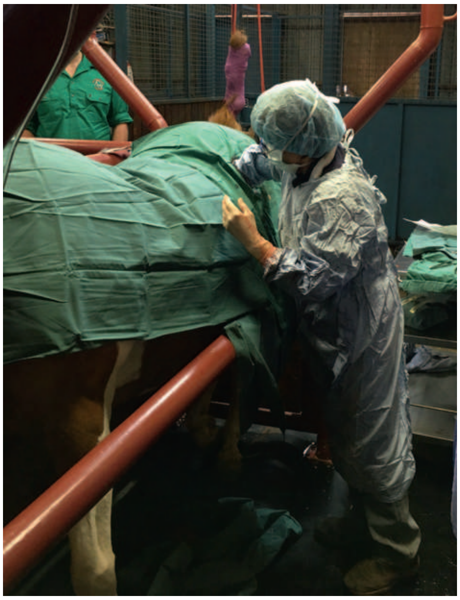

***Fig 1:** Preoperative abdominal radiographs of a 6-year-old pony with a faecalith causing complete obstruction of the small colon. Multiple gas distended small and large colon segments are demonstrated.*

Key points

- Standing flank laparotomy is a viable solution to small colon impactions that fail to respond to medical treatment.
- The procedure does not require extensive personnel or a specially equipped surgical facility.
- Despite concurrent large colon impactions, the resolution of the primary small colon impactions was curative.
- Owners must be advised that a ventral laparotomy may be required if the problem cannot be resolved by standing flank laparotomy and that these impactions can reoccur.

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Clinical Commentary

Standing surgery versus general anaesthesia for resolution of acute abdomen; useful enough to become routine?

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Keywords: horse; standing surgery; colic; small (descending) colon; flank laparotomy; ventral midline laparotomy

The development of standing surgical procedures has gained increasing momentum in recent years, with a variety of procedures previously performed exclusively under general anaesthesia, now routinely taking place on standing sedated horses. Some of the surgical techniques offer very real advantages when performed on the standing horse, in terms of anatomical access and real-time functional visualisation and assessment following surgical manipulation. Others have even been exclusively developed as standing procedures only. Prosthetic laryngoplasty (Rossignol *et al.* 2015), paranasal sinus surgery (Schumacher *et al.* 2000; Quinn *et al.* 2005), cheek tooth extractions (Dixon *et al.* 2005; Langeneckert *et al.* 2015; Rice and Henry 2018), lower limb fracture repair (Perez-Olmos *et al.* 2006; Russell and Maclean 2006; Smith *et al.* 2009; Payne and Compston 2012), laparoscopic and laparoscopic-assisted procedures (Hendrickson and Wilson 1997; Hanson and Galuppo 1999; Mariën *et al.* 2001; Röcken *et al.* 2005; de Bont *et al.* 2010; Goodin *et al.* 2011; Wilderjans *et al.* 2011; Vitte *et al.* 2014; van Bergen *et al.* 2016), arthroscopy either standard or flexible needle (Elce and Richardson 2002; Frisbie *et al.* 2014; Bonilla 2019), along with dorsal spinous process ostectomies and desmotomies (Perkins *et al.* 2005; Coomer *et al.* 2012), are just some of the procedures routinely performed under standing sedation.

The recent report by Herbert *et al.* (2021) highlights very well that certain cases of acute abdomen are amenable to surgical correction on the standing sedated animal, with an excellent outcome. The authors should be commended for their innovative approach. For those animals with a presurgical diagnosis of small colon impaction, the report highlighted an appropriate and viable treatment option in 15 ponies and one horse. Standing laparotomy for correction of left-sided colonic displacement (nephrosplenic entrapment) has been previously reported, albeit in a small number of horses (Krueger and Klohnen 2015). The principle is good. However, problems can arise with the unknown element of abdominal surgery and the difference between a solely elective and an emergency intervention. Regarding standing laparotomies for the acute abdomen, a number of important questions should be considered preoperatively. Is your presurgical diagnosis accurate? Can you ever be 100% sure? Could you have missed something? What if you find something else or a concurrent lesion? And herein lies the main limitation of standing laparotomy, the risk of unexpected findings. In general, most standing surgical techniques are performed on an elective basis with a definitive diagnosis and planned surgical technique in mind. There remains a large element of the unknown to any abdominal surgery for treatment of the acute abdomen, even more so when performing a standing flank approach.

A ventral midline laparotomy permits the most complete examination of the abdomen possible and lends itself to the resolution of the vast majority of operable lesions. It allows for the most extensive visual and tactile exploration of the abdomen available, in a controlled environment and sterile field and therefore remains the gold standard for exploration and resolution of surgical colic lesions. In reality, without the aid of a laparoscope, the relative ability to fully explore the abdominal contents in a standing horse is reduced and mostly limited to palpation. Some parts of the intestinal tract can be safely exteriorised through a flank incision, allowing for biopsy, enterotomy and even resection and anastomosis. However, the abdominal contents as a whole are less accessible than via a ventral midline approach. In addition excessive traction on mesenteric attachments can cause considerable discomfort to the standing animal and will not be tolerated, resulting in movement and adverse reactions. The safe handling of intestine outside the abdomen in the standing horse is also more challenging. In general, without a preoperative diagnosis, standing laparotomy procedures result in greater risks and should not be routinely encouraged. However, there are specific situations where standing laparotomy is strongly indicated. Underlying disease processes, concurrent limb injury, prohibitive financial restraints, the absence of general anaesthetic facilities or when the only alternative option is euthanasia, are all potential indications for standing laparotomy.

Standing surgical procedures can offer a variety of advantages to the owner, horse and surgeon, but can also present with a number of disadvantages. The major difference is the avoidance of general anaesthesia, which is perceived by many as a real risk to the animal. Advances in medication, monitoring systems and assisted recovery systems (Mee *et al.* 1998; Vigani and Garcia-Pereira 2014; Niimura del Barrio *et al.* 2018), along with increasing veterinarian experience, have reduced anaesthetic risks over the years. In most cases, if in the horse's best interest, the risk of anaesthesia should not be used as an excuse not to perform a surgery under general anaesthesia. Shorter convalescence periods have been reported with standing flank approaches when compared to ventral midline incisions, with reduced incisional site complications. There is however more visible scar formation in the paralumbar fossa when compared to the linea alba.

It must be noted that standing surgical procedures are also not without risk to the horse, surgeon or medical equipment. A properly sedated horse placed in standing stocks will, in general, tolerate most of what we want to achieve. As we all know, even though the vast majority of procedures go smoothly, the risk of an animal suddenly jumping out of stocks or collapsing to the ground remains a real concern. Many standing procedures result in placing the surgeon at relative risk of injury, in particular when undertaking procedures involving the distal limbs. In addition the relative positioning of the patient is static, meaning that the surgeon is often working with a sub-optimal posture, resulting in undue strain on the neck, back and shoulders in particular. Working on the standing animal may also mean compromises are made in sterile technique, either due to the location of the stocks within a multi-purpose room, movement of the horse and consequently the sterile drapes, or the proximity of the surgical field to the floor.

Reduced cost to the client is often quoted as a real positive aspect of standing surgery. However, for some surgeries the length of the procedure may in fact be increased due to the set-up time and decrease in surgical speed, due to reduced patient compliance. Extra assistants and nursing staff are often required for both restraint and during surgery itself, so the difference may not be as great as assumed. As a profession, we are inherently poor at charging properly for our time. Beware that a standing procedure may result in a lower bill for your client on the one hand, but could actually be costing your practice more to perform, therefore reducing profit margins.

More specifically, disorders involving the small (descending) colon account for a relatively small percentage (2.8–4.2%) of all cases of colic treated surgically (Edwards 1992; Mair and Smith 2005), with enteroliths and impactions reported to be the most frequently encountered lesions (Dart *et al.* 1992; Frederico *et al.* 2006; de Bont *et al.* 2013). In general, surgical resolution of small colon lesions carries a good prognosis for both short- and long-term survival and compare favourably to many other forms of colic (de Bont *et al.* 2013). A flank approach in select cases may therefore be very well justifiable in terms of both surgical outcome and potential long-term survival. The most distal and proximal portions of the small colon cannot be exteriorised via a standard ventral midline approach, due to their relatively short mesentery and fixed positions within the abdomen (de Oliveira Dearo *et al.* 2009; Barrett and Munsterman 2013). In 88% of cases euthanased on the surgery table in one study, the decision to euthanase was based on the inoperable nature of the lesion, due to an inability to exteriorise healthy tissue margins in order to perform a resection (de Bont *et al.* 2013). Paramedian and parainguinal approaches allowing increased access to portions of the small colon that cannot be exteriorised via a conventional midline laparotomy have been described (de Oliveira Dearo *et al.* 2009; Barrett and Munsterman 2013). Based on observations via laparoscopic explorations in standing horses, I am unsure whether a flank approach would allow for further exteriorisation of inaccessible small colon further distally, compared to either the paramedian or parainguinal approaches. It may however allow for exteriorisation of more proximal aspects of the small colon. The possibility of recovering a horse from general anaesthesia to then perform a flank approach on the standing animal, in order to try and exteriorise as much of the small colon as possible and allow for resection, could be considered in select cases if the alternative involves euthanasia on the table.

It is widely accepted that laparoscopic procedures in the horse are greatly suited to standing sedation, allowing for direct visualisation and manipulation of tissues within the dorsal aspect of the abdomen in particular. Under general anaesthesia, these areas are obscured by viscera and cannot be directly visualised. Pure laparoscopic or laparoscopic hand-assisted ovariectomy (Hanson and Galuppo 1999; de Bont *et al.* 2010; Goodin *et al.* 2011), abdominal cryptorchidectomy (Hendrickson and Wilson 1997), peritoneal flap hernioplasty (Wilderjans *et al.* 2011), exploratory laparoscopy with small intestinal biopsy (Coomer *et al.* 2016), nephrosplenic space ablation (Mariën *et al.* 2001; Röcken *et al.* 2005), epiploic foramen ablation (Munsterman *et al.* 2014; van Bergen *et al.* 2016), hysterectomy (Gablehouse *et al.* 2009) and nephrectomy (Keoughan *et al.* 2003) have all been reported and are routinely performed. Hand-assisted laparoscopic surgery (HALS) procedures are becoming increasingly popular in order to enjoy the positive benefits of both techniques (Rodgerson *et al.* 2002; Keoughan *et al.* 2003; Witte *et al.* 2013; Vitte *et al.* 2014). In fact, the addition of a laparoscope if available may be hugely beneficial in allowing for increased visualisation of intestinal lesions in flank laparotomies performed for resolution of acute abdomen.

In summary, in selected cases with an accurate preoperative diagnosis, standing flank laparotomy procedures can offer a very good practical alternative to a ventral midline approach and save a horse's life. As always, owners should be fully informed of the potential pitfalls prior to surgery.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable.

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Case Report

Transient bilateral blindness associated with presumptive idiopathic pachymeningitis in a 22-year-old Irish Sport Horse

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Keywords: horse; basophils; cerebrospinal fluid; meningitis

Summary

A 22-year-old Irish Sport Horse presented following a period of bilateral blindness with subsequent spontaneous resolution. The owner noted an apparent loss of vision initially in the left eye, approximately 5 months prior to presentation followed by loss of vision in the right eye approximately 2 months later. Examination by the referring veterinarian at that time identified a bilaterally absent menace response with bilaterally reduced pupillary light reflexes. No other significant abnormalities were detected on the ophthalmic examination, and both optic nerve heads appeared normal. The blindness was localised to either the optic nerves, chiasm or bilateral optic tracts. Haematology and biochemistry identified no clinically significant abnormalities. On presentation at the Royal Veterinary College 3 weeks later, a menace response was present in both eyes and direct and indirect pupillary light reflexes were normal. Further ophthalmic and neurological examinations were unremarkable. Magnetic resonance imaging of the brain was performed under general anaesthesia. This identified diffuse, marked thickening and moderate contrast enhancement of the pachymeninges overlying the cerebrum, particularly at the rostral aspect, measuring up to 2.5 mm in thickness. Generalised widening of the sulci and reduced size of gyri throughout the cerebral cortex and an apparent increase in the cerebrospinal fluid (CSF) volume, particularly dorsal to the cerebrum, were also observed. The interthalamic adhesion was subjectively small (13 mm thick dorsoventrally), with an increased CSF volume in the third ventricle, mesencephalic aqueduct and quadrigeminal cistern. The CSF had a normal appearance throughout. The optic nerves and chiasm were within normal limits. These findings were interpreted as marked pachymeningitis of unknown aetiology with generalised evidence of brain atrophy (**Fig 1**). The latter was thought to be an incidental ageing change. The cerebrospinal fluid analysis revealed increased numbers of basophils, suggestive of an immunologic or neoplastic aetiology. It was suspected that the enlarged meninges led to compression of the optic nerves in the optic canals, causing bilateral blindness. Initial spontaneous remission, as seen in this case, has been reported in human patients with this condition. Further diagnostics including biopsy of the meninges were discussed with the owner but declined due to the invasiveness of the procedure and questionable benefit for the horse. Follow-up conversations with the owner 4 months after examinations confirmed that the horse continued to wax and wane with recrudescence of clinical signs which were partially responsive to dexamethasone therapy (0.1 mg/kg bwt i.v. s.i.d.).

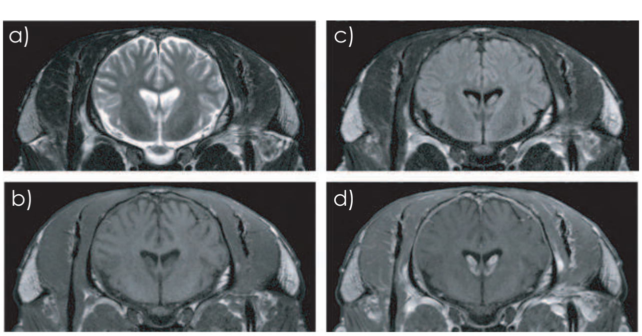

***Fig 1:** Transverse T2-weighted (W) fast spin echo (FSE) (a), T1w FSE (b), T2 fluid attenuating inversion recovery (c) and post-contrast T1w FSE (d) magnetic resonance images at the level just rostral to the interthalamic adhesion. Right is to the left. Note the diffuse, marked thickening of the pachymeninges overlying the cerebrum, which shows moderate contrast enhancement*

Key points

- Basophilic inflammation in the CSF is extremely rare and has been reported during the course of inflammatory disease of the nervous system in human patients.
- Pachymeningitis should be considered as a possible cause of cranial nerve deficits, including bilateral and unilateral blindness, in horses.
- Spontaneous remission of pachymeningitis may occur. Systemic therapy with corticosteroids and other immunomodulating drugs has achieved remission in other species, but recurrence is common.

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Clinical Commentary

Neurogenic blindness in the horse: Possible causes and tips for evaluation

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The case report by McGilvray *et al*. (2021), 'Transient bilateral blindness associated with idiopathic pachymeningitis in a 22-year-old Irish Sports Horse,' describes an unusual case of neurogenic blindness in a horse in moderate work under saddle. The first problem noted by the owner was unilateral vision loss, which progressed to bilateral blindness. Obviously, loss of vision in a riding horse poses major safety concerns for the horse and rider, and owners frequently seek veterinary attention for concerns of decreased visual acuity. In many horses, an ocular explanation for decreased vision is apparent. A common ocular disease that causes blindness is chronic uveitis, which can result in cataracts, severe synechiae formation, glaucoma and retinal detachment.

Horses that show behavioural abnormalities consistent with vision loss but do not have ocular abnormalities frequently pose a diagnostic challenge. The challenge begins with confirming that the horse truly has vision loss, rather than behavioural abnormalities and normal vision. In the author's practice, horses scheduled for ophthalmological examination because of excessive spookiness or perceived loss of visual acuity frequently have normal vision and another reason, such as chronic pain or neurological disease, causing the behaviour change. Partial loss of vision is very difficult to assess in horses, particularly if this loss of vision occurs as a chronic disease process. Most horses compensate very well for partial loss of vision, and many compensate well for complete loss of vision if onset is gradual and they remain in a familiar environment. Complete blindness in one or both eyes is easier to detect, particularly when acute, simply by observation of the horse bumping into structures on the affected side(s). Maze testing can be performed, with a unilateral blindfold to test one eye at a time.

Visual pathway and pupil control

Clinicians must have a basic understanding of relevant neuroanatomy (de Lahunta and Glass 2009) to diagnose neurogenic blindness accurately. Vision requires impulses generated by the retina to travel through the optic nerve and its pathway to the visual cortex of the brain. The optic nerve is more accurately described as a tract; it originates from a rostral extension of the neural tube that forms the prosencephalon, is myelinated by oligodendroglia rather than Schwann cells, and is surrounded by meninges and a subarachnoid space. The optic nerves course caudally in the orbits from their origins at the optic discs through the retrobulbar areas. They enter the skull through the optic canals of the presphenoid bone and join at the optic chiasm, which is ventral to the rostral aspect of the hypothalamus and rostral to the pituitary. At the optic chiasm of the horse, most (80–90%) of the axons in each optic nerve cross to enter the opposite optic tract. These optic tracts course caudodorsolaterally over the diencephalon (thalamus) to the lateral geniculate nuclei, where most of the optic tract axons terminate. Neurons with cell bodies in the lateral geniculate nuclei have axons that project into the internal capsule and course caudally as the optic radiation before terminating in the visual cortex of the occipital lobe.

Pupillary size is affected by both environmental light and level of arousal. Parasympathetic general visceral efferent neurons regulate response to light and sympathetic general visceral efferent neurons regulate response to stress. Constriction of the pupil in response to light requires stimulation of retinal receptors, which generate impulses that are transmitted through the optic nerve, optic chiasm and optic tracts to the pretectal nuclei in the midbrain where synapse occurs. Most axons from the pretectal neurons cross in the caudal commissure and synapse on the parasympathetic lower motor neurons in the contralateral oculomotor nucleus in the midbrain, although some axons synapse on the ipsilateral oculomotor nucleus. The preganglionic neurons (with cell bodies in the parasympathetic nuclei of the oculomotor nerves) travel through the orbital fissure into the orbit within the periorbita, temporarily adjacent to the optic nerve. When the oculomotor nerve branches to the extraocular muscles, the preganglionic parasympathetic axons synapse at the ciliary ganglion, and short ciliary nerves carry the postganglionic parasympathetic axons along the optic nerve to the eyeball, where they innervate the ciliary muscle and the sphincter of the pupil.

Clinical examination and tests to assess vision

Evaluation of an acutely blind horse usually starts with an ophthalmic examination. Most ocular causes of blindness prevent the practitioner from visualising the fundus or obtaining a tapetal reflex. If a tapetal reflex can be visualised through retroillumination (shining a light at arm's length into the eye and looking for the tapetal reflection), the cause of blindness can be localised either to the retina or the visual pathway. If the fundus appears normal, a neurogenic cause of blindness should be strongly suspected.

The visual pathway is routinely assessed by menace responses and pupillary light reflexes performed alone or as part of a neurological examination. The menace response is a crude evaluation of vision but an easy test to perform, as the examiner simply makes a menacing gesture towards one eye, with the expected response being closure of the eyelids. In the absence of facial nerve dysfunction or cerebellar disease, loss of menace response indicates severe visual loss. The menace response is learned and requires integrity of the entire peripheral and central visual pathway as well as connections from the cerebrum to the brainstem, activation of facial neurons and coordination from the cerebellum. The pupillary light reflex is a brainstem reflex that tests the visual components of the eyeball and the central visual pathway to the level of the midbrain (mesencephalic pretectal nuclei). The motor response requires oculomotor nerve integrity from the oculomotor nuclei in the midbrain through the orbital fissure into the periorbita and ciliary ganglion, as well as short ciliary nerves from the ganglion to the eye. Due to decussation of neurons at the optic chiasm and again at the caudal commissure, light directed into one eye stimulates both oculomotor nerves such that pupillary constriction should occur in both eyes. Although excited or stressed patients can have dilated pupils, pupillary light reflexes should remain present. If there is any doubt about integrity of the pupillary light reflex, seek a darker environment and brighter light source to repeat the test.

Localisation of lesions in the visual pathway

Accurate localisation of neurological deficits facilitates efficient diagnostic testing and accurate disease diagnosis. **Table 1** provides information to aid in the assessment of a horse with neurogenic blindness.

Lesions that destroy the retina or optic nerve in one eye cause blindness with a normal to slightly dilated pupil (due to light entering the normal eye and stimulating both oculomotor nuclei). If light is directed into the blind eye, neither pupil constricts; light directed into the normal eye causes both pupils to constrict. If the retinas or optic nerves are destroyed bilaterally, the horse is totally blind with both of the pupils widely dilated and unresponsive to light in either eye. Vision is usually lost prior to loss of pupillary light reflexes, so partial or incomplete lesions of the retina or optic nerve will can cause blindness with preservation of pupillary light reflexes. Retrobulbar lesions often affect both the optic nerve and oculomotor nerve of one eye; the affected eye will be blind with a dilated pupil, and light directed into the affected eye does not cause constriction in either eye, whereas light directed into the unaffected eye causes constriction only in that eye. Unilateral forebrain lesions in the optic tract, lateral geniculate nucleus, optic radiation or visual cortex cause blindness in the CONTRALATERAL eye because of the degree of decussation in the optic chiasm. Pupillary light reflexes generally remain normal in both eyes. Bilateral forebrain lesions cause bilateral blindness with preservation of pupillary light reflexes.

In addition to evaluating ocular responses and reflexes, clinicians should pay close attention to any additional neurological signs that might affect lesion localisation. For example, a unilateral forebrain lesion might also cause proprioceptive deficits on the contralateral side of the lesion (same side as the visual deficit), decreased nociception on the contralateral side of the lesion, or seizure activity.

The horse described by McGilvray *et al*. (2021) showed unilateral loss of vision that progressed to bilateral blindness characterised by absent menace response bilaterally and reduced pupillary light reflexes bilaterally. Ophthalmic examination was normal, and the optic nerve heads appeared normal. The authors appropriately localised the horse's problems to bilateral optic nerves, optic chiasm or bilateral optic tracts. However, bilateral lesions in the optic tracts that are severe enough to cause bilateral blindness are highly unusual, and this possibility should be considered much less likely than bilateral optic nerves or optic chiasm (de Lahunta and Glass 2009).

Causes of neurogenic blindness in the horse

Table 1 includes disease processes to consider for various lesion localisations. Optic nerve disease can occur due to trauma, compression, hypoxia or inflammation. Traumatic optic neuropathy most commonly occurs after head trauma sustained during falls or collisions (Martin *et al*. 1986). One common scenario is the horse that rears and flips over backwards (due to tying, fear or another reason), causing shearing or severing of the optic nerves as the brain moves away from the fixed, intracanalicular optic nerves. Alternatively, presphenoid or basisphenoid fractures can cause compression of the optic nerves or chiasm by bony fragments or haemorrhage. Compressive optic neuropathy can occur with abscesses or tumours that invade the retrobulbar area or optic canals within the presphenoid bone (Gaughan *et al*. 1991). Lesions in the retrobulbar area might also affect oculomotor nerve function. One important anatomical feature to remember is that the optic nerves are located immediately dorsal to the sphenopalatine sinuses, which are relatively thin-walled. Infections, inflammatory processes, granulomas or neoplasia in the sphenopalatine sinuses can cause blindness that is slowly progressive or acute in onset (Barnett *et al*. 2008; Radcliffe *et al*. 2016). Additional deficits can be observed due to involvement of cranial nerves III, IV, V and VI since these nerves are adjacent laterally to the sphenopalatine sinuses. Notably, clinical signs can be variable with waxing and waning visual deficits and pupillary light reflexes. Ischaemic optic neuropathy is associated with sudden hypoxia as might occur during severe hypovolaemia or hypotension (as can occur with acute severe blood loss) or surgical occlusion of the external and internal carotid arteries (Freeman *et al*. 1990; Hardy *et al*. 1990). Optic neuritis can occur due to extension of local inflammatory disease or primary central nervous system diseases (Hatziolos *et al*. 1975). As aforementioned, the optic nerves are surrounded by three layers of meninges and cerebrospinal fluid, just as the rest of the CNS. Bacterial, viral, parasitic or fungal meningitis can affect the optic nerves, as can CNS neoplasia. Finally, toxic insults have been implicated in optic nerve degeneration (Glastonbury *et al*. 1985).

Diseases of the forebrain can cause partial to complete unilateral or bilateral blindness depending on severity and extent. Metabolic encephalopathies are probably the most common cause of bilateral central blindness and can occur due to hepatic disease, renal disease, intestinal disease (hyperammonemia), electrolyte derangements or other metabolic abnormalities. Infectious, inflammatory, neoplastic and toxic CNS diseases can cause blindness and common regional diseases should be considered when evaluating cases. Unintentional intracarotid injections can cause acute cerebral toxicity or infarction of the ipsilateral forebrain resulting in contralateral blindness. Any disease that causes seizure activity can cause post-ictal central blindness that might persist for several days. Rarely, horses show transient (<5 days) central blindness following routine myelography; it is

TABLE 1: Evaluation of neurogenic blindness in a horse

Left eye (OS) menace response	Right eye (OD) menace response	Left eye (OS) pupil	Right eye (OD) pupil	Lesion localisation	Disease processes to consider
Absent	Present	Normal to mildly dilated; light in OS → no response OU	Normal; light in OD → constriction OU	LEFT retina, optic nerve	Retinal detachment or degeneration; optic nerve inflammation or compression due to orbital extension of inflammatory disease or space-occupying mass; trauma; severe unilateral ischaemia (external/internal carotid artery ligation)
Absent	Present	Dilated; light in OS → no response OU	Normal; light in OD → only OD constricts	LEFT retrobulbar (affecting optic nerve and oculomotor nerve)	Inflammation or compression due to retrobulbar extension of inflammatory disease or space-occupying mass; trauma
Absent	Present	Normal; light in OS → constriction OU	Normal; light in OD → constriction OU	RIGHT forebrain (optic tract, lateral geniculate nucleus, optic radiation, visual cortex)	Diseases that affect CNS focally or multifocally: encephalitis due to infectious disease (bacterial, viral, fungal, protozoal, parasitic); space-occupying mass; trauma; unintentional right-sided intracarotid artery injection; post-ictal or post-myelography state
Present	Absent	Normal; light in OS → constriction OU	Normal to mildly dilated; light in OD → no response OU	RIGHT retina, optic nerve	Retinal detachment or degeneration; optic nerve inflammation or compression due to orbital extension of inflammatory disease or space-occupying mass; trauma; severe unilateral ischaemia (external/internal carotid artery ligation)
Present	Absent	Normal; light in OS → only OS constricts	Dilated; light in OD → no response OU	RIGHT retrobulbar (affecting optic nerve and oculomotor nerve)	Inflammation or compression due to retrobulbar extension of inflammatory disease or space-occupying mass; trauma
Present	Absent	Normal; light in OS → constriction OU	Normal; light in OD → constriction OU	LEFT forebrain (optic tract, lateral geniculate nucleus, optic radiation, visual cortex)	Diseases that affect CNS focally or multifocally: encephalitis due to infectious disease (bacterial, viral, fungal, protozoal, parasitic); space-occupying mass; trauma; unintentional left-sided intracarotid artery injection; post-ictal or post-myelography state
Absent	Absent	Dilated; light in OS → no response OU	Dilated; light in OD → no response OU	BILATERAL retinas or optic nerves; optic chiasm	Trauma; inflammatory or space-occupying disease in region of sphenopalatine sinuses/presphenoid bone (sinusitis, space-occupying mass); severe ischaemia due to blood loss or hypotension; possibly toxic insult
Absent	Absent	Normal; light in OS → constriction OU	Normal; light in OD → constriction OU	BILATERAL forebrain (optic tracts, lateral geniculate nuclei, optic radiations, visual cortices)	Metabolic encephalopathy; electrolyte or glucose derangements; post-ictal or post-myelography state; post-anaesthetic cerebral necrosis; toxic encephalopathy (e.g. leukoencephalomalacia from mouldy corn); encephalitis due to infectious disease (bacterial, viral, fungal, protozoal, parasitic) or immune-mediated inflammation; large or bilateral space-occupying mass(es) (e.g. bilateral cholesterinic granulomas)

sometimes unclear whether this is a post-ictal phenomenon or unrelated to seizure activity.

Blindness in the horse described by McGilvray *et al*. (2021) was attributed to idiopathic pachymeningitis, potentially due to an underlying immunologic or neoplastic condition. The authors speculated that thickened meninges led to compression of the optic nerves in the optic canals, causing a compressive optic neuropathy and bilateral blindness. The optic nerves and chiasm appeared normal on the MRI and at the time of manuscript submission the horse was still alive, so a definitive conclusion cannot be made regarding cause of blindness.

Diagnostic assessment

Complete ophthalmological and neurological examinations are essential for acutely blind patients. Additional diagnostic testing depends on historical information and clinical examination findings. Basic imaging, such as orbital radiographs and retrobulbar ultrasonography, might be helpful for certain cases. Upper respiratory tract and guttural pouch endoscopy can be used to identify pathology that might extend to ocular or central nervous system structures. However, cross-sectional imaging of the head provides vastly more information and better understanding of potential lesions and complicated anatomy. For horses with known trauma, CT offers superior bony resolution and identification of traumatic lesions. However, the superior soft-tissue resolution provided by MRI can be of substantial benefit for horses with primary neurological disease, particularly of infectious or inflammatory aetiology. For the horse described by McGilvray *et al*. (2021), MRI showed a marked pachymeningitis with generalised brain atrophy but normal optic nerves and chiasm. Cerebrospinal fluid analysis, including cytology and specific immunologic testing, is often beneficial to include or exclude potential inflammatory, infectious or neoplastic disease conditions. The gelding mentioned above had a normal CSF cell count and low protein level at the time of testing. However, cytology showed 3 (10%) basophils, an uncommon finding in CSF, potentially suggestive of an immune-mediated or neoplastic process.

Prognosis

Prognosis for return of vision is generally poor for patients who become blind immediately following traumatic injury; the damage to the optic nerves is usually irreversible. Prognosis for compressive optic neuropathies depends on the cause and reversibility of the compressive disease, as well as the time interval between onset of blindness and decompression. Blindness due to ischaemia or thromboembolism is usually permanent. On the contrary, central blindness due to metabolic or infectious causes is often reversible if the primary disease condition is treatable.

The horse with idiopathic pachymeningitis initially showed spontaneous resolution of blindness; in fact, the horse's vision had returned prior to evaluation by the authors and performance of the MRI. However, clinical signs waxed and waned following discharge, suggesting that the underlying disease process had not resolved.

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Original Article

Molecular characterisation of *Theileria equi* and risk factors associated with the occurrence of theileriosis in horses of Punjab (Pakistan)

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Summary

***Theileria equi* (*T. equi*) is an obligate intra- and extra-erythrocytic parasite that causes equine theileriosis (ET) in equids. Equine theileriosis is considered a notifiable disease of global significance, a major constraint to the international movement of horses, and endemic in many countries. This disease may be difficult to diagnose, as it can produce variable and nonspecific clinical signs. A cross-sectional study was designed for the molecular characterisation of *T. equi* and to investigate the associated risk factors of ET accompanied by its consequences on haematological and sero-biochemical parameters. A convenience sampling of 500 blood samples were collected from ET suspect horses from January to December 2017. PCR was performed on all blood samples targeting the 18S rRNA gene of *T. equi* followed by sequencing; 9% animals tested positive with confirmed sequences. The isolates of this study showed high homology with Cuban, Russian and Brazilian isolates of *T. equi* (accession numbers KY111762.2, MG551915.1 and KY952237.1, respectively). Based on multivariate analysis, the principal risk factors consisted of absence of dogs on the premises and presence of tick infestation. The haemato-biochemical parameters showed a decrease in granulocytes and erythrocytes, and an increase in lymphocytes, monocytes, mean corpuscular volume, mean corpuscular haemoglobin, mean platelet volume, glucose, phosphorus and aspartate aminotransferase in positive horses. This is the first study which identified ET in Punjab (Pakistan) using molecular techniques and risk factors together with the haemato-biochemical variations in horses.**

Introduction

There are approximately 90 million equids in the developing world (FAO 2003), accounting for 60% of all horses and over 95% of all donkeys and mules of the world (Fielding 1991). The horse population of Pakistan has increased from 0.344 million in 2006 (Anonymous 2006–2007) to 0.4 million in 2016–2017 (Anonymous 2016–2017). Equine theileriosis is included in a single list of notifiable terrestrial and aquatic animal diseases, infections and infestations of the Office International des Epizooties/The World Organization for Animal Health (OIE). It is caused by tick-borne apicomplexan protozoan *Theileria equi,* and is considered endemic in tropical and subtropical regions including Asia, Middle East, Commonwealth countries, Africa, southern Europe, South and Central America, and Cuba. Only the United States, Canada, Australia, Japan and Iceland are not considered to be endemic areas. Four forms of the disease exist: peracute, acute, subacute and chronic. The peracute cases are rare, with the only clinical presentation of moribund animals. Acute cases are characterised by fever, anaemia, reduced appetite and malaise, elevated respiratory and pulse rates, small and dry faecal balls, and congestion of mucous membranes. Subacute cases manifest in a similar fashion except for loss of weight, and intermittent fever. Chronic cases are characterised by nonspecific clinical signs including poor performance, mild inappetence and loss of body condition (Salib *et al*. 2013; OIE 2018).

Species-specific PCR techniques principally targeting the 18S rRNA gene (Criado-Fornelio *et al*. 2003) have been employed for the diagnosis of *T. equi*-infected equids in Europe. However, PCR-based diagnosis has not yet been established in Pakistan. Moreover, only limited numbers of microscopic and serological studies of ET in Pakistan have been conducted (Kokab 1986; Khan *et al*. 1987; Rashid *et al*. 2009; Goraya *et al*. 2013; Hussain *et al*. 2014; Afridi *et al*. 2017). Past studies for investigating the risk factors linked with ET were restricted to other regions of Pakistan (Hussain *et al*. 2014; Afridi *et al*. 2017). This is the first work of molecular evidence of ET in two districts of Punjab (Pakistan) having different geo-climatic conditions and a high population of horses (**Table 1**) according to livestock census (Anonymous 2006).

The objectives of the study were to estimate the true status of ET of suspect horses in the study area, describe the haemato-biochemical profile of infected horses, to determine the genetic similarity of *T. equi* to other regions both locally and globally, and identify risk factors associated with ET in this cohort of horses. It was hypothesised that the prevalence of ET would be high in the study area and risk factors specific to infection on premises would be identified.

TABLE 1: Coordinates, climatic characteristics and horse population of the two districts of Punjab (Pakistan) included in the study

District	Coordinates		Elevation (from sea level – m)	Temperature and rainfall						Horse population*
				Summer			Winter			
	Latitude (○N)	Longitude (○E)		Max. temp (○C)	Min. temp (○C)	Rainfall (mm)	Max temp (○C)	Min temp (○C)	Rainfall (mm)	
Sargodha	32°10′00″	72°30′00″	190	41	26	48–87	20	4	12-36	11,720
Lahore	31°25′0″	74°19′60″	224	41	26	36–189	21	5	12-24	8,196

*Source: Anonymous (2006).

Materials and methods

Sampling strategy

The time period of the study was one year (January to December 2017). A cross-sectional study was designed to detect positive cases of theileriosis and to identify various risk factors associated with the disease. A total of 377 animals were calculated from Win Episcope version 2 computer package (Thrusfield *et al*. 2001) assuming 50% prevalence of unknown disease status in the study area with confidence interval of 95% in horse population of two districts (**Table 1**). For the convenience of risk factors analysis, sample size was increased to 500. The horses exhibiting any of the following clinical presentations including persistent or intermittent fever, anaemia, history of or current tick infestation, and chronic loss of body condition (from the districts of Sargodha and Lahore, situated in the northwest and northeast of Punjab province as given in **Fig 1**) were included in the study. A convenience sampling technique was adopted to collect samples from hospitals and clinics of the public and private sectors, field, studfarms, racecourses and polo clubs.

The study plan was duly approved by the Advanced Studies and Research Board (ASRB), University of Veterinary and Animal Sciences (UVAS) Lahore, for ethical use of animals in research. Owner consent was obtained prior to inclusion of animals in the study. Measures were taken to avoid any accidental injury to the horse during blood collection. Blood samples, obtained by jugular venepuncture, were collected in two different vacutainers: one for DNA extraction and haematological analysis and the other for serum biochemical analysis. After collection, the blood samples were transferred in iceboxes to the Medicine Laboratory, UVAS Lahore. The blood samples were collected to check the disease status of the animal. Every individual sample was also accompanied by a questionnaire to collect information related to risk factors for theileriosis in horses consisting of month, season, area, sex, age, breed, body condition, nutrition, management, rearing system, presence of dogs, ruminants and birds on the farm, use, and tick infestation.

Blood smear examination

Since thick blood smears are a valuable diagnostic test when parasitaemia is very low (Böse *et al*. 1995; de Waal and van Heerden 2004), thin and thick blood smears were prepared and stained with Giemsa, air-dried and then fixed in methanol (OIE 2018). Blood smears were screened for protozoan parasites under the 40× or oil immersion (100×) objectives by three experienced observers (Zajac and Conboy 2012). The horses were declared microscopically positive on observing protozoan parasites in the stained blood smears.

DNA extraction

A DNA extraction kit (GeneAll®, Exgene™, Catalog # 105-101)[1], was used for extraction of DNA from all blood samples according to the manufacturer's instructions using 200 μL of each sample. Gel electrophoresis was performed on extracted DNA to confirm sufficient DNA extraction, and concentration was measured by spectrophotometry (NanoDrop)[2]. All samples were stored at −20°C until analysis.

Molecular detection of Theileria and *Babesia* species

A pan-*Babesia* set of primers (Sarwar 2016) designed for amplification of an approximately 220 bp target was used to detect *T. equi* infection. These primers amplify the 18s ribosomal gene and consist of forward primer, (5′-TTCTTAGAGGGACTTTGCGGT-3′), and reverse primer, (5′-TGACTTGCGCATACTAGGCA 3′).

The PCR was performed in a 20 μL mixture comprising of 3 μL of the template DNA, 2 pmol (2 μM) of each primer, 10 μL of 2× AmpMaster™ Taq GeneAll®[1] 2× Taq PCR master mix (comprising 0.2 U of Taq DNA polymerase/μL, reaction buffer, dNTP, gel loading dye, stabiliser, and sediment) and UltraPure™ diethylpyrocarbonate (DEPC) treated water to fulfill remaining volume.

The Taq DNA polymerase was activated by heating the PCR mixture at 96°C for 10 min, and 40 cycles were repeated in the following fashion: denaturation at 96.0°C for 1 min, annealing at 57.0°C for 1 min, extension at 72.0°C for 1 min, and a final extension at 72.0°C for 10 min described by Sarwar (2016). A negative control (2 pmol of each primer, 10 μL of 2× Taq PCR master mix and DEPC-treated water except template DNA) was also included in the PCR.

Electrophoresis of the amplified DNA samples on 1.5% agarose gel stained with ethidium bromide (50 μg per 100 mL gel) was performed to visualise the amplified DNA fragments of 220 bp against a 100 bp DNA ladder under ultraviolet (UV) light (Battsetseg *et al*. 2002).

Sequencing and phylogeny

Positive bands from the gel were sliced using a sterilised knife under UV light. The positive DNA samples were purified using a gel purification kit (Invitrogen® PureLink™ Quick Gel Extraction Kit, Catalog # K210012)[3]. The purified DNA samples

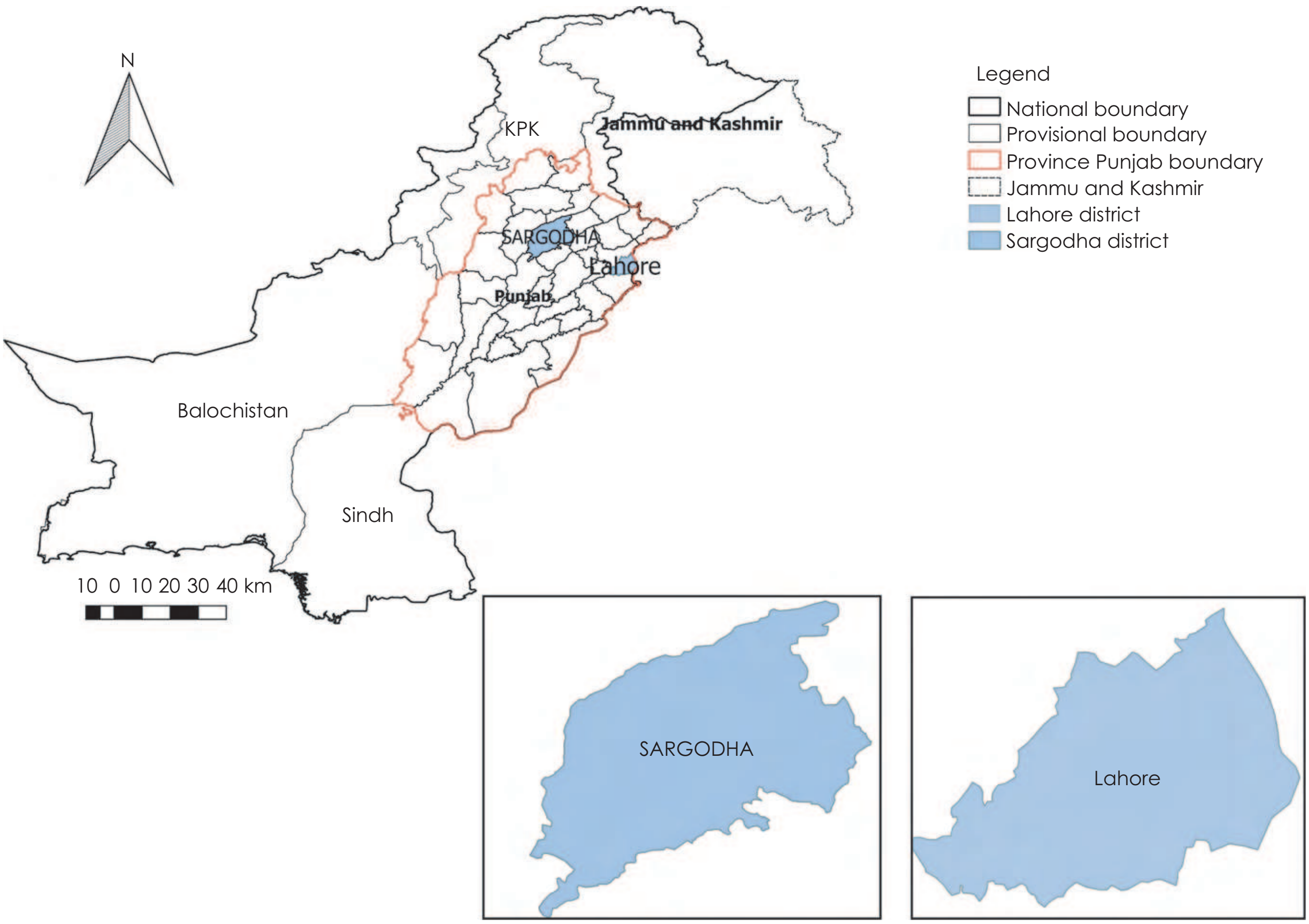

Fig 1: GIS map of study area showing districts Sargodha and Lahore.

were sequenced in forward direction from Tsingke Biological Technology (China). Geneious™ version 11.0.5 for Windows[4] was employed to construct phylogenetic tree.

Sequencing was performed for the 18S rRNA gene (220 bp) of *Theileria* local isolates obtained through PCR. Sequences were analysed using Clustal W Alignment Tool and Basic Local Alignment Search Tool (BLAST). The 18S rRNA sequences from GenBank were incorporated for comparison.

Haemato-biochemical analysis

A total of 15 horses (n = 10 positive; n = 5 negative for *T. equi*) were selected for haematologic and biochemical analyses. The blood samples were collected in BD Vacutainer®[5] K_2EDTA tubes for haematologic analysis. Haematologic analysis including leucocytes (WBC), lymphocytes (LYM), monocytes (MON), granulocytes (GRA), erythrocytes (RBC), haemoglobin (HGB), haematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), platelets (PLT) and mean platelet volume (MPV) was performed using haematology analyser. The blood samples were collected in the BD Vacutainer® SST™ II Advance tubes[5] for serum for biochemical studies. Biochemical analysis including glucose, calcium, phosphorus, iron, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) was performed using a biochemistry analyser.

Statistical analysis

Entry of data from data-capture form into EpiData Entry version 3.1 was done. The data were analysed using IBM® Statistical Product and Service Solutions (SPSS) version 20.0.[5] All the predictive variables were first tested with univariable analysis at a significance level of $P<0.2$ to determine the association of potentially associated risk factors with the occurrence of equine theileriosis. Afterwards, the predictors, which had produced $P<0.2$, were selected in the multivariable logistic regression model. Subsequently, all the nonsignificant variables were removed one by one with a backward stepwise selection approach and the final model contained significant variables only. The final model was fitted with glm() function with family = binomial.

Shapiro–Wilk test using SPSS version 20.0 was applied to test the normality of data regarding haemato-biochemical parameters. The data of the parameters that had normal distribution were analysed by independent sample *t* test; the data of the parameters that deviated from normal distribution were analysed by Mann–Whitney *U* test; parameters having a P-value less than 0.05 were considered significant.

Results

Epidemiology of equine theileriosis in horses

Of the horses with a clinical suspicion of ET, 9% (45/500) of the horses sampled in the Sargodha and Lahore districts tested positive by PCR. Eight blood smear negative horses also tested positive by PCR. Four other blood smear positive horses tested negative by PCR.

Potential risk factors associated with equine theileriosis were identified using the multivariable logistic regression model. At first, all six variables which had produced P<0.2 in univariable analysis (**Table 2**) were included in the multivariable logistic regression model. The results of statistically significant variables (n = 2) are presented in **Table 3**.

On the basis of univariable analysis (**Table 2**), tick infestation was significant (P<0.05). However, multivariable analysis (**Table 3**) identified absence of dogs on the farm and tick infestation as principal risk factors (P<0.05).

The presence of dogs at the farm was significant (P<0.05, OR: 0.47, CI: 0.25–0.89) and inversely related with infection percentage in the horses. Tick infestation in the horses significantly (P<0.05, OR: 3.10, CI: 1.16–7.46) increased the likelihood of infection when compared with those without tick infestation.

Theileria 18S rRNA gene analysis

When aligned with other known sequences, the isolates analysed phylogenetically were most similar to those detected in Cuba, Russia and Brazil. The insertions, deletions and substitutions in the 18S rRNA gene were found when compared the isolates of this study (**Fig 2**).

TABLE 2: Univariable analysis of the potential risk factors associated with equine theileriosis

Variable	Variable levels	Positive (%)	Negative	95% CI	P-value
Month	Jan	06 (10.34)	52	0.61–104.9	0.325
	Feb	03 (10.00)	27	0.15–37.6	
	Mar	02 (02.94)	66	0.16–12.0	
	Apr	02 (08.33)	22		
	May	00 (00.00)	04	<0.001–2.1	
	Jun	04 (13.33)	26	0.37–17.0	
	Jul	09 (11.25)	71	1.11–97.2	
	Aug	08 (12.90)	54	0.91–74.3	
	Sep	06 (09.84)	55	0.38–69.5	
	Oct	01 (02.00)	49	0.16–36.2	
	Nov	04 (13.33)	26	0.69–152.3	
	Dec	00 (00.00)	03	<0.001–5.3	
Season	Winter	13 (10.74)	108	0.62–5.09	0.104
	Spring	04 (04.35)	88	0.23–1.92	
	Summer	21 (11.93)	155	0.70–5.73	
	Fall	07 (06.31)	104		
Area	Sargodha	29 (10.86)	238	0.55–2.71	0.116
	Lahore	16 (06.87)	217		
Sex	Male	42 (09.42)	404	0.48–6.94	0.320
	Female	03 (05.56)	51		
Age	≤6 years	29 (08.87)	298		0.312
	7–12 years	13 (11.61)	99	0.71–2.81	
	>12 years	03 (04.92)	58	0.32–5.43	
Breed	Nondescriptive	45 (09.51)	428	2.3–1.0	0.073
	Crossbred	00 (00.00)	27		
Body condition	≤3	04 (13.79)	25		0.383
	>3	41 (08.70)	430	0.19–2.63	
Nutritional status	Unsatisfactory	41 (08.70)	430		0.383
	Satisfactory	04 (13.79)	25	0.2–1.7	
Management	Stabled	45 (09.11)	449	5.52–44.9	0.286
	Grazing	00 (00.00)	06		
Rearing system	Same breed	10 (12.20)	72	0.35–63.7	0.136
	Different breeds	02 (03.33)	58		
	Different species	33 (09.22)	325	0.18–4.31	
Dogs in the farm	No	26 (11.40)	202		0.086
	Yes	19 (06.99)	253	0.25–0.76	
Ruminants in the farm	No	04 (09.76)	37		0.861
	Yes	41 (08.93)	418	0.14–29.3	
Birds in the farm	No	07 (06.42)	102		0.270
	Yes	38 (09.72)	353	0.23–6.28	
Use	Work	04 (16.67)	20	1.2–Inf	0.329
	Sport	41 (08.69)	431	3.9–Inf	
	Pet	00 (00.00)	04		
Tick infestation	No	38 (08.17)	427		0.0367
	Yes	07 (20.00)	28	0.59–11.6	

TABLE 3: Summary of risk factors associated with the occurrence of horse theileriosis: variables included in the final logistic regression model

Variable	Response categories	Odds ratio	95% CI	P-value
Presence of dogs on the farm	No	1	–	0.021
	Yes	0.47	0.25–0.89	
Tick infestation	No	1	–	0.025
	Yes	3.10	1.16–7.46	

Phylogenetic analysis

High homology of the amplicons with the nucleotide sequences of this gene deposited in the GenBank was found. Phylogenetic tree was constructed based on 18S rRNA gene sequences of isolates of Pakistan, Cuba, Russia, Brazil and others (**Fig 3**). The isolates of the study showed degree of similarity with each other and three previously identified groups: Cuban (KY111762.2), Russian (MG551915.1) and Brazilian (KY952237.1) isolates.

Effect of equine theileriosis on haematological parameters

Negative and positive horses for theileriosis were compared in terms of their haematological parameters (**Table 4**). The GRA and RBC were significantly ($P < 0.05$) lowered in affected horses compared to healthy ones. The LYM, MON, MCV, MCH and MPV were significantly ($P<0.05$) increased in positive horses compared to negative horses.

Effect of equine theileriosis on biochemical parameters

Serum biochemical parameters in negative and positive horses for theileriosis were compared (**Table 5**). The glucose, phosphorus and AST were significantly ($P<0.05$) augmented in *T. equi*-infected horses compared to healthy mates.

Discussion

Epidemiology of equine theileriosis in horses

An overall infection percentage of theileriosis in horses with a clinical suspicion of *Theileria* was 9% based on PCR. However, prevalence of theileriosis in the general horse population would be lower based on the results of this study. The primers used in this study can detect all species of *Theileria* and *Babesia*. The presence of blood parasites other than *Theileria* and *Babesia* may be the possible reason of false-positive (microscopic positive but PCR negative) results. These findings are in agreement with outcomes of Zanet *et al*. (2017) who reported 13.33% prevalence of *T. equi* in randomly selected horses in northwestern Italy using PCR. Sant *et al*. (2016) reported *T. equi* prevalence of 24.3% and 4.5% by conventional PCR and 6.8% and 8% by real time PCR, in mares at the start of fifth month of pregnancy and their foals within the 36 h post-parturition, respectively, reared in Trinidad. Rampersad *et al*. (2003) also recorded similar results in 105 horses including both sick and apparently healthy animals in Trinidad (15.24% and 34.29% of horses were positive for *T. equi* using primary PCR and nested PCR, respectively). Mahmoud *et al*. (2016) detected 36.4% prevalence of *T. equi* in horses in Cairo, Egypt, using nested PCR. Ayala-Valdovinos *et al*. (2017) reported 19.7% prevalence of *T. equi* in 1000 horses in Jalisco, Mexico, using nested PCR. Nested PCR is considered more sensitive than conventional PCR and likely detected horses with low parasitemia. Zobba *et al*. (2008) recorded high prevalence of *T. equi* (72.7%) among suspected horses in Sardinia (Italy) using PCR. Abedi *et al*. (2014) also detected *T. equi* in 48% of randomly selected horses in North Khorasan, Iran, using multiplex PCR. Grandi *et al*. (2011) found lower prevalence (2.71%) in horses reared

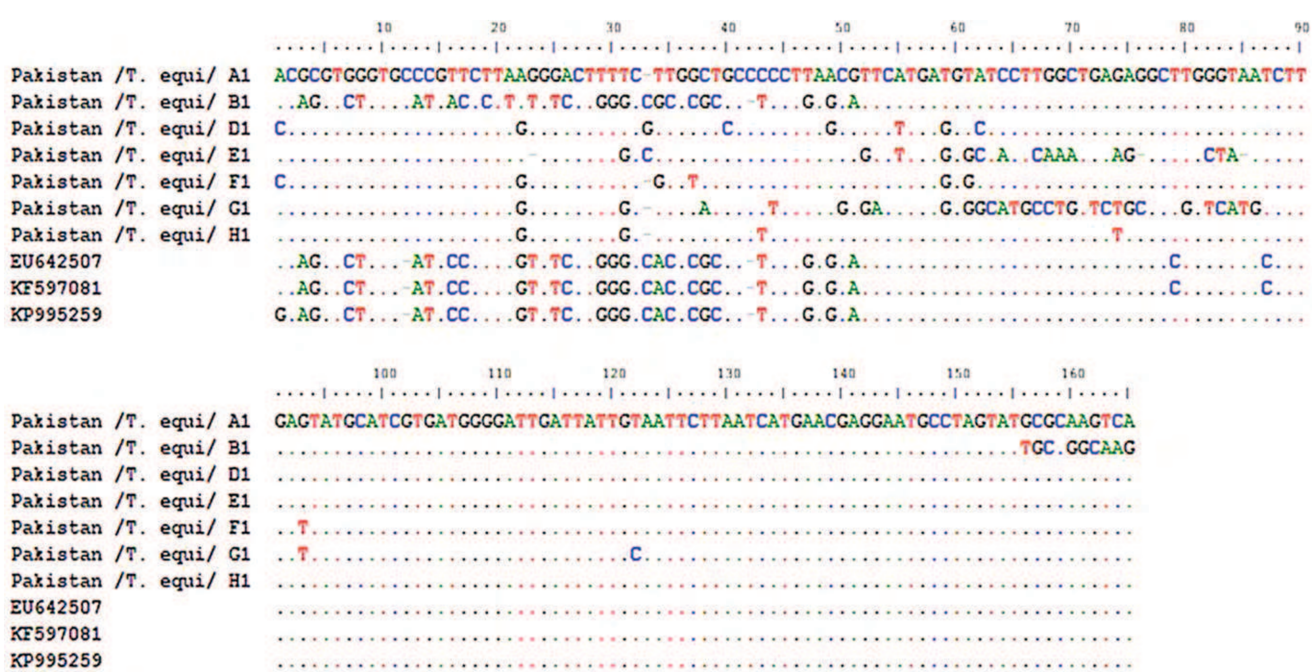

Fig 2: BLAST alignment of local isolates with reported isolates of T. equi.

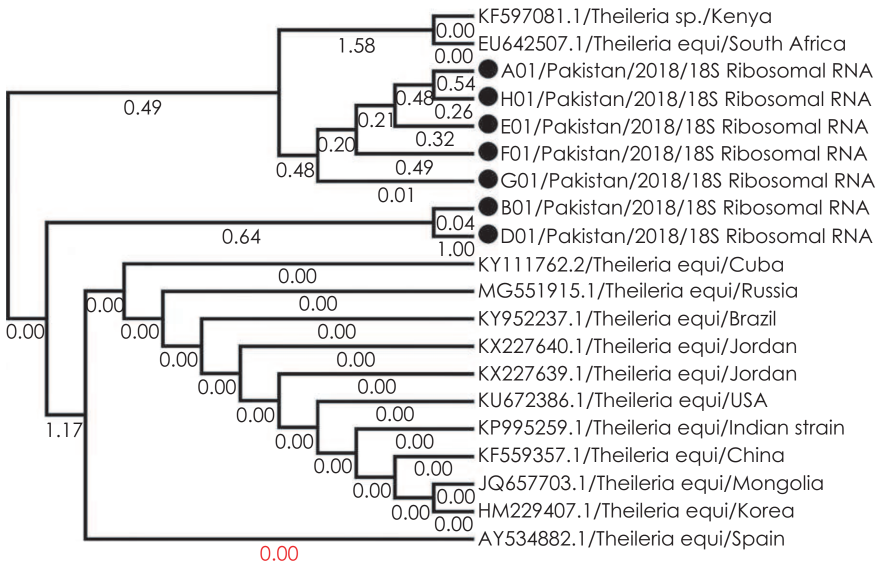

Fig 3:* *Phylogenetic tree showing relationship of study isolates of* Theileria *with reported isolates

TABLE 4: Comparison of haematological parameters between infected and noninfected horses

Variable (SI Unit)	Level	Mean	s.d.	Mean difference	P-value
WBC ($\times10^9$/L)	Positive	9.34	3.01	2.18	0.14
	Negative	7.16	0.9		
LYM (%)	Positive	59.69	13.22	28.87	<0.01*
	Negative	30.82	4.26		
MON (%)	Positive	9.3	1.86	7.5	<0.01*
	Negative	1.6	1.16		
GRA (%)	Positive	30.99	13.17	−29.07	<0.01*
	Negative	60.06	5.69		
RBC ($\times10^{12}$/L)	Positive	3.79	1.36	−3.93	<0.01*
	Negative	7.72	0.63		
HGB (g/L)	Positive	115	38.9	−15.6	0.4
	Negative	130.6	11.5		
HCT (%)	Positive	27.52	9.75	−4.54	0.08
	Negative	32.06	4.03		
MCV (fL)	Positive	72.99	7.57	28.99	<0.01*
	Negative	44	2.99		
MCH (pg/cell)	Positive	32.12	10.17	16.04	<0.01*
	Negative	16.08	1.65		
MCHC (g/L)	Positive	430.9	100.1	58.5	0.22
	Negative	372.4	14.4		
PLT ($\times10^9$/L)	Positive	101.9	84.61	−61.1	0.12
	Negative	173	29.93		
MPV (fL)	Positive	8.23	1.03	3.51	0.01*
	Negative	4.6	0.75		

*Significant difference (P-value <0.05).

TABLE 5: Comparison of serum biochemical parameters between infected and noninfected horses

Variable (SI Unit)	Level	Mean	s.d.	Mean difference	P-value
Glucose (mmol/L)	Positive	20.8	13.77	15	0.03*
	Negative	5.65	1.68		
Calcium (mmol/L)	Positive	2.06	1.52	−1.01	0.18
	Negative	3.06	0.33		
Phosphorus (mmol/L)	Positive	3.11	1.61	2.13	0.01*
	Negative	0.98	0.43		
Iron (μmol/L)	Positive	27.72	11.5	6.81	0.23
	Negative	20.91	3.39		
ALT (units/L)	Positive	10.7	7.87	4.7	0.23
	Negative	6	3.16		
AST (units/L)	Positive	350.9	109.42	109.1	0.0498*
	Negative	241.8	25.36		

*Significant difference (P-value <0.05).

in northern Italy using PCR. Munkhjargal *et al*. (2013) also reported less prevalence of *T. equi* (6.4%) in randomly selected horses from three districts of Tov province in central Mongolia using nested PCR. The variations and similarities in disease distribution can be attributed to the similarities in season, farm management systems and availability of suitable disease vectors.

Serological tests are of low clinical diagnostic value in endemic areas where most horses have been in contact with ET agent (Tamzali 2013). The complement fixation test has many disadvantages such as the occurrence of false-negative results, cross-reactivity between *T. equi* and *Babesia caballi,* and low sensitivity in chronic cases (Rothschild and Knowles 2007; USDA-APHIS 2010; OIE 2018). IFAT requires dilution of sera to reduce nonspecific binding which leads to a decrease in its sensitivity (OIE 2018). The competitive ELISA was also found to have a sensitivity if a horse had been recently infected (Tamzali 2013).

Sumbria *et al*. (2016) reported *T. equi* prevalence by nPCR ranges in equids of various districts of Indian Punjab from 0 to 43.24%, particularly 13.79% in the district Amritsar which is adjacent to district Lahore. Hussain *et al*. (2014) reported 41.2% and 56.9% seroprevalences of *T. equi* in all horse species and horse populations of five districts of Punjab province, respectively. The district Lahore, Gujranwala, Faisalabad, Multan and Bahawalpur had respective seroprevalences of 66.7%, 28%, 42%, 35.3% and 33.8% in horses, mules and donkeys. Afridi *et al*. (2017) documented 27.5% and 50.3% seropositivity (combined 26.7%) to theileriosis in horses and donkeys of districts Peshawar and Charsadda districts, respectively, of the Khyber Pakhtunkhwa province.

The absence of dogs at the farm was found to be significantly associated with a high infection rate of *T. equi* in horses. The tick species that transmit *T. equi* in the equids in Asia (*Hyalomma anatolicum anatolicum*) also infect dogs (Chaudhuri *et al*. 1969; Kumar *et al*. 2007; Ul-Hasan *et al*. 2012; Abedi *et al*. 2014). The chances of horses being bitten by an infected tick may be increased in the absence of dogs at the farm. Tick infestation in horses was observed significant and directly related to *T. equi* infection rate. This is in agreement with results of Sumbria *et al*. (2016) who reported equids with tick infestations had more infections than equids without tick infestations. Afridi *et al*. (2017) also stated significant high seroprevalence of *T. equi* in tick-infested horses. A previous study reported *Hyalomma*, the most common ticks in the tick-infested horses, mules and donkeys of Lahore district followed by *Boophilus* and both (Javed 2013). Rehman *et al*. (2017) recorded 78.3% tick prevalence in livestock farms of nine districts covering both semi-arid and arid agro-ecological zones of Punjab and identified four tick species: *H. anatolicum*, *Rhipicephalus* (*R*) *microplus*, *H. dromedarii* and *R. turanicus*. *R. microplus* was the predominant species in the semi-arid zone, whereas *H. anatolicum* was the most abundant species in the arid zone. Karim *et al*. (2017) conducted a study in different ecological regions of Pakistan to identify tick species infesting livestock and tick-borne pathogens, and identified 19 different tick species belonging to three genera of hard ticks, *Rhipicephalus*, *Haemaphysalis* (*Ha*) and *Hyalomma*, and two soft ticks, *Ornithodorus* and *Argas*. *H. anatolicum*, *Ha. bispinosa*, *Ha. montgomeryi* and *R. microplus* comprised over 80% of the total samples.

Steinman *et al*. (2012) found a higher prevalence of equine theileriosis in Quarter and local breed horses compared with Thoroughbreds, ponies, Arabians and Warmbloods in Israel. However, in the current study, a significant difference could not be observed.

Factors such as deforestation and land use practices, climate change, diverse migratory bird population, population densities, decreasing wildlife habitats and increasing livestock farms have been speculated to play a vital role in the resurgence of tick-borne diseases (TBD) at a higher frequency in endemic regions and its emergence in newer areas (Singh and Gajadhar 2014). Climate change exerts a transient impact on TBDs epidemics by increasing hosts, reservoirs and vectors. Climate is a critical element of temporal and geographic distribution of ticks, their life cycle, tick-borne pathogens and transmission to vertebrate hosts (Ogden *et al*. 2005).

Effect of equine theileriosis on haematological parameters

In this study, the most frequent haematological alterations in *T. equi*-infected horses include a significant ($P<0.05$) reduction of the GRA and RBC, and a significant increase of LYM, MON, MCV, MCH and MPV. Similar findings were reported by Mahmoud *et al*. (2016) and Zobba *et al*. (2008). Three mechanisms of haemolysis are defined: mechanical by the trophozoite intra-erythrocytic binary fission (Knowles *et al*. 1994), immune-mediated by the auto-antibodies directed against components of the membranes of infected and uninfected erythrocytes, and toxicity by the haemolytic factors from the parasite (de Gopegui *et al*. 2007; Zygner *et al*. 2007).

Effect of equine theileriosis on biochemical parameters

The most notable serum biochemical alterations in *T. equi*-infected horses included significant elevations in glucose, phosphorus and AST. Hyperglycaemia, also reported by Sumbria *et al*. (2016), is due to stress and increased mobilisation of glucose in this hypermetabolic disease (Nel *et al*. 2004; Camacho *et al*. 2005). Zobba *et al*. (2008) also detected decreased blood phosphorus in *T. equi*-positive horses and de Waal *et al*. (1987) observed lowered serum concentrations of phosphorus in horses experimentally infected with *T. equi*. Three main causes of hypophosphatemia include redistribution of phosphorus from the extracellular fluid into cells, decreased intestinal absorption of phosphorus, and increased urinary phosphorus excretion (Subramanian and Khardori 2000; Gaasbeek and Meinders 2005).

As far as the authors are aware, this is the first molecular study (PCR) used to detect distribution of *T. equi* infection in Pakistan. So, it is not possible for us to perform a comparative analysis with any previous study in the country at the present time. Our findings are helpful in formulating effective control strategies because infectious diseases are a serious threat for animal health in developing countries (Farooqi *et al*. 2017; Luo *et al*. 2017; Mehmood *et al*. 2017; Wu *et al*. 2017).

Conclusion

This study identified *T. equi* as the chief aetiological agent of equine piroplasmosis in suspected horse populations of Punjab (Pakistan). The absence of dogs on the premises and presence of tick infestations were identified as potential risk factors associated with equine theileriosis in horses. Granulocytes and erythrocyte were decreased, whereas lymphocytes, monocytes, mean corpuscular volume, mean corpuscular haemoglobin, mean platelet volume, glucose, phosphorus and aspartate aminotransferase were increased in the positive horses. These findings will be helpful in formulating futuristic effective control strategies and further research work.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

This study was ethically reviewed and approved at the first stage by experts at the university and at the second stage by experts across the country. All owners were informed clearly and in detail before their consent for the study.

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Authorship

S. Ali and M. Ijaz designed the study. S.H. Farooqi, A.Z. Durrani, M.I. Rashid, A. Ghaffar, A. Ali, A. Rehman and S. Aslam contributed to the study execution. I. Khan, A. Masud and K. Mehmood contributed to data analysis and interpretation. S. Ali, S.H. Farooqi and A.Z. Durrani contributed to the preparation of the manuscript, and all the authors gave final approval of the manuscript. S. Ali, A. Rehman and K. Mehmood handled the revisions.

Manufacturers' addresses

[1]GeneAll Biotechnology Co. Ltd., Geneall Bldg, Ogum-dong, Sonpa-gu, Seoul, South Korea
[2]Thermo Scientific, Waltham, MA, USA.
[3]Invitrogen, Carlsbad, CA, USA.
[4]Geneious, Auckland, New Zealand.
[5]IBM Software, Armonk, NY, USA.

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Original Article

Equine duodenal motility, assessed by ultrasonography, as a predictor of reflux and survival following colic surgery

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Keywords: horse; post-operative colic; duodenal motility; reflux; survival

Summary

Intestinal dysmotility following equine colic surgery contributes negatively to financial and prognostic outcomes. This study assessed duodenal contractility as a predictor of post-operative reflux and survival to discharge in horses following colic surgery. Duodenal contractility was assessed using daily transabdominal ultrasound examinations in 49 horses for up to 7 days (Day 1 scan performed between 6 and 36 h post-surgery and sequential daily scans performed between 08.00 and 20.00 h) following colic surgery (September 2014–April 2017). The duodenum was visualised ventral to the right kidney, and duodenal contractions were measured over 2 min. The signalment of each horse and surgical findings were noted. Outcomes were defined as horses that refluxed (>5 L/24 h beyond 24 h) or did not reflux post-operatively and those that were survivors or were nonsurvivors. A significant difference in duodenal contractions at Day 1 post-operatively was identified between horses that refluxed (n = 8) and those who did not reflux (n = 32; P = 0.013) but not between those who were nonsurvivors (n = 7) and survivors (n = 32; P = 0.113). Horses in the reflux group had reduced duodenal contractility comparatively. There were no significant differences in duodenal contractions in the sequential days after the Day 1 scan or between duodenal contractions and surgical findings. A significant association was identified between duodenal contractions and survivors (P = 0.039; odds ratio 1.88). The main study limitations were the single centre design with consequent small numbers of horses included. The study did not account for other factors that may contribute to alterations in motility such as drug administration or stages of re-feeding. This preliminary study indicates that Day 1 (6–36 h post-operatively) duodenal contractions may predict reflux (>5 L/24 h beyond 24 h) and that increased duodenal contractions are associated with survival. However, there was no clear distinction or cut-off between groups. Future studies with greater numbers of horses yielding better statistical power are required.

Introduction

Gastrointestinal dysmotility is poorly understood, contributes to a significant number of fatalities and is a fundamental concern in the post-operative (PO) period following colic surgery in horses. This form of dysmotility is commonly referred to as post-operative ileus (POI) and is associated with hypomotility of the gastrointestinal tract due to a functional inhibition of propulsive motility (Livingston and Passaro 1990). The pathophysiology is poorly defined and controversial, and the classification of POI has not been consistent between studies.

Post-operative ileus has been identified as a significant cause of death (13-86%) and its incidence ranges between 10 and 47% of colic surgery cases (Hunt *et al.* 1986; Blikslager *et al.* 1994; Freeman *et al.* 2000; Morton and Blikslager 2002; Cohen *et al.* 2004; Torfs *et al.* 2009). In surveys of the clinical features and management of equine POI, 91% of respondents from European colleges (equine internal medicine and veterinary surgeons) and 94% of respondents from the American large animal colleges (diplomates in medicine, surgery and emergency critical care) rated the presence of reflux on nasogastric intubation extremely important in the diagnostic classification of POI (Lefebvre *et al.* 2016a,b). Greater or equal to 4 L of reflux at any one nasogastric intubation (37% of respondents from American colleges and 31% of respondents from European colleges) or a volume of >2 L/h on repeated intubations (35% of respondents from American colleges and European colleges) are the most common parameters adopted by clinicians to diagnose POI (Lefebvre *et al.* 2016a,b). This definition is similar to that used by Freeman *et al.* (2000). It has been noted this may overestimate the incidence of POI (Merritt and Blikslager 2008). In the most recent studies, it has been suggested that the term post-operative reflux (POR) is adopted because without a repeat laparotomy, for the majority of cases, it is not possible to determine the pathophysiology behind the POR (Salem *et al.* 2016).

Anecdotally, as well as in recent surveys of clinical practice, respondents have expressed the importance of ultrasonographic evidence of distended small intestines, small intestinal motility and duodenal contractility in monitoring for POR (Lefebvre *et al.* 2016a,b; Hassel 2017). Equine gastrointestinal motility has been assessed at the cellular level, using electromyographic studies, mechanical studies, transit markers, ultrasonography, abdominal auscultation and assessment of defaecation frequency (Hudson and Merritt 2008). In a clinical setting, it is most practical to assess motility with ultrasound. However, this would not be the 'gold standard' assessment and may not equate to transluminal movement of ingesta.

The utility of a transabdominal ultrasound guided approach to assess duodenal contractility in the monitoring of horses with POR has not been thoroughly documented. Studies have assessed duodenal motility in normal horses as well as following other procedures in an experimental setting (Kirberger *et al.* 1995; Merritt *et al.* 1998; Epstein *et al.* 2008a,b; VanderBroek *et al.* 2019). In an equine experimental model of POI, there was a reported reduction and asynchronous migrating myoelectric complexes of the stomach and duodenum (Gerring and Hunt 1986).

This study was designed to determine whether duodenal contractility assessed using transcutaneous ultrasound was reliable when evaluated by different observers, and secondly, to assess whether duodenal contractility can be utilised to predict reflux and survival in PO colic cases. The hypothesis of this study was that reduced duodenal contractility would predict POR and would be associated with nonsurvival post-operatively.

Materials and methods

Inter-observer reliability

Twenty clinically normal horses were included (n = 20 horses; n = 29 observations). The horses underwent transabdominal ultrasound of the duodenum at the consistent topographic locations, just ventral to the right kidney at the 16th and 17th intercostal spaces on a line joining the olecranon and tuber sacrale (Kirberger *et al.* 1995). The horses underwent ultrasound examination with a curvilinear probe (GE Logiq e with 4C-RS 2.0–5.0 MHz probe[1] or Chison Eco 3 Expert Vet with C3A 3.5 Mz probe[2]) by either one of the authors (T.S.M. or A.L.) and duodenal contractions over 2 min were determined independently by each observer. Duodenal contractions were defined on a binary scale of a complete contraction or no contraction and only complete, full contractions that expelled the luminal contents from the segment of intestine were counted (**Supplementary Item 1** demonstrates a contractile duodenum).

Duodenal contractility in the PO colic

Forty-nine horses were included in the prospective study. Inclusion criteria were that the horse was ≥1-year-old and had undergone colic surgery. The results for horses following a second colic surgery during hospitalisation were excluded. All horses were treated routinely post-operatively, with doses and duration of medications determined by the senior clinician. All horses received PO flunixin meglumine at a tapering dose (0.25–1.1 mg/kg bwt b.i.d. i.v.), procaine benzylpenicillin (17 mg/kg bwt b.i.d. i.m.) and gentamicin sulphate (6.6 mg/kg bwt s.i.d. i.v.) for 1–7 days. All horses were administered polyionic intravenous fluid, and some received intravenous continuous rate infusion of lidocaine (with a loading dose of 1.3 mg/kg i.v. followed by 0.05 mg/kg/min). The horses underwent daily transabdominal ultrasound examination with a curvilinear probe (GE Logiq e with 4C-RS 2.0–5.0 MHz probe[1], GE Logiq P5 with 3.5C 2.0–5.0 MHz probe[1] or GE Logiq E9 with C2-9 - D 2.0–9.0 MHz probe[1]) to measure duodenal contractions/2 min for up to 7 days post-operatively (Day 1 scan performed between 6 and 36 h post-operatively and sequential daily scans performed between 08.00 and 20.00 h) (September 2014–January 2017). The duodenum was visualised just ventral to the right kidney at the 16th and 17th intercostal spaces on a line joining the olecranon and tuber sacrale (Kirberger *et al.* 1995). The ultrasound examination was performed by a hospital intern, resident or senior clinician; all were trained in ultrasonography of the duodenum at this location. The signalment of each horse (age, breed and gender) and surgical findings (small intestinal/large intestinal/both; resection/no resection; strangulating/nonstrangulating) were noted. Outcomes were defined as horses that refluxed (>5 L/24 h beyond 24 h) or did not reflux post-operatively, and those that survived or did not survive to hospital discharge (survivors or nonsurvivors).

Statistical analysis

IBM SPSS 24[3] was used for statistical analysis of results. Normality of distribution was tested using the Shapiro–Wilk and Kolmogorov–Smirnov test. The data were not normally distributed and therefore underwent nonparametric statistical analysis. The inter-observer reliability was determined for the duodenal contractility using a weighted kappa correlation coefficient. Mann–Whitney test $\alpha = 0.05$ was used to assess the difference in duodenal contractions between each day. Mixed effects logistic regression model was used to test an association between statistical comparisons. Values with $P \leq 0.05$ denoted significant associations.

Results

Inter-observer reliability

Duodenal contractions in the 20 normal horses (29 observations) ranged from 2 to 10 per 2 min (mean and median were 5 duodenal contractions per 2 min). The inter-observer reliability was excellent with a weighted kappa coefficient of 0.871.

Duodenal contractility in the PO colic cases

Descriptive

Horses (n = 49) included in this study had an age range from 1.5 to 24 years (mean 13.7 years old, median 14 years); there were 29 geldings/17 females/3 stallions, and the breeds included a broad range. The horses included in this study spanned a 32-month time frame, and there were small numbers in the reflux and nonsurvivor groups (three horses between September and December 2014, 16 horses in 2015, 18 horses in 2016 and 12 horses between January and April 2017). The surgical findings of these cases were as follows: small intestinal (n = 28)/large intestinal (n = 17)/both (n = 4); strangulating (n = 26)/nonstrangulating (n = 23); resection (n = 18)/no resection (n = 31). Of these 49 horses, 40 did not reflux/9 refluxed and there were 41 survivors (n = 5 refluxed)/8 nonsurvivors (n = 1 subjected to euthanasia for noncolic causes) (n = 4 refluxed). Four horses underwent a second surgery and 3 of these horses were nonsurvivors. For horses in the reflux category (>5 L/24 h), the mean time to first scan was 19.7 h (median 18 h) and the mean time to first reflux (≥2 L) was 13.9 h (median 12.5 h) (**Supplementary Item 2**).

The causes of death in the nonsurvivors (n = 8) included caecal impaction (n = 1), gastrointestinal rupture (n = 2), adhesions (n = 2), mesenteric haematoma (n = 1) and intestinal musculature pathology (n = 1) and was un-related to colic (respiratory cause) in one horse. All horses that refluxed >72 h were nonsurvivors.

Duodenal contractions per 2 min ranged from 0 to 24 for horses that refluxed/nonsurvivors and 6–27 in those that did not reflux/survivors across 7 days post-operatively. Duodenal contractions at Day 1 post-operatively ranged from 0 to 18 for horses that refluxed (median 9 contractions per 2 min)/nonsurvivor (median 10 contractions per 2 min) and 6–24 in those that did not reflux (median 14 contractions per 2 min)/

survivor (median 13.5 contractions per 2 min). **Table 1** displays the data of duodenal motility in the post-operative period. Video clips of transcutaneous ultrasound cine-loops of the duodenum are provided in **Supplementary Items 1** and **3**.

Statistical analyses

A statistically significant difference in duodenal contractions at Day 1 post-operatively was identified with reduced duodenal contractions in horses that refluxed (n = 8) compared to those who did not reflux (n = 32; P = 0.013; **Fig 1**). Additionally, there were reduced duodenal contractions in horses that were nonsurvivors (n = 7) compared to survivors (n = 32); however, this was not statistically significant (P = 0.113; **Fig 1**). The reduced number of horses in these groups at Day 1 is due to missing data (n = 1) or attributed to being unable to identify the duodenum (n = 8), and this was the case for in total 9 horses. No significant difference in duodenal contractions in the sequential days after the Day 1 scan was identified. Equally, there was no significant association between duodenal contractions and surgical findings. Mixed effects logistic regression using the horse as a random effect and accounting for multiple time points, adjusting for number of days' PO, there was a significant association between number of duodenal contractions and whether or not a horse survived (P = 0.039; odds ratio 1.88). For every extra duodenal contraction, the odds of survival increased by 1.88 times.

Discussion

The results of this preliminary study suggest that the duodenal contraction rate measured ultrasonographically on Day 1 (6–36 h post-operatively) may be useful as a predictor for horses that will reflux (>5 L/24 h beyond 24 h) and that an increased frequency of duodenal contractions is associated with survival. The utility of duodenal contractility in monitoring horses following colic surgery has been demonstrated to be beneficial in this study. Post-operative complications, such as reflux, and survival not only have welfare considerations but also have significant financial repercussions. For this reason, the development of predictors and monitoring strategies to detect the occurrence of such complications are important to utilise.

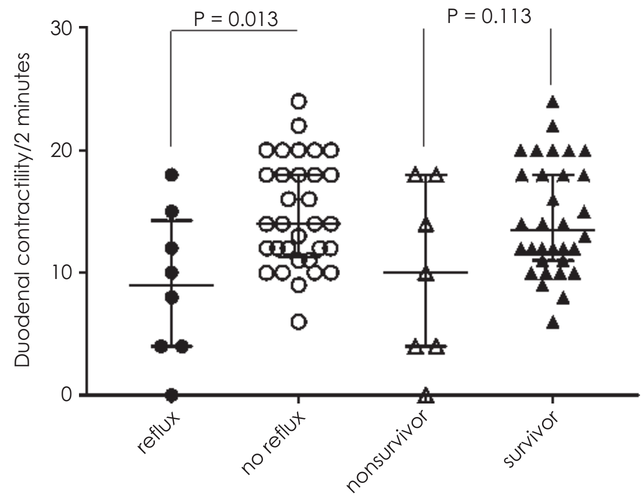

***Fig 1:** Scatter plot of duodenal contractility measured over 2 min for horses that refluxed and those that did not reflux and for horses that survived and those that did not survive. The median with interquartile range are plotted. P values are expressed.*

Although there was no clear distinction or cut-off for duodenal contractions in the reflux/nonreflux group, there was a significant difference between the median values of the reflux/nonreflux group. Therefore, duodenal contraction rates monitored in the PO period after colic surgery that fall in the over-lapping regions should be interpreted with caution. Interestingly, the published ranges of duodenal contraction rates in normal horses (0.5–2.8 contractions per minute) (Kirberger *et al.* 1995) and ponies (3.8 ± 1.1 contractions per minute) (Epstein *et al.* 2008a) were similar to the normal horses (median 2.5 contractions per minute, range 1–5 contractions per minute) utilised to determine the inter-observer reliability in this study. These contraction rates were lower than those recorded in the current study of PO colic in both survivors and horses that did not reflux; these horses would be considered to be hypermotile by comparison (median of 7 per minute). However, horses that refluxed and did not survive had contraction rates closer to those reported in the healthy adult horse and pony (median of 4.5 contractions per minute in the

TABLE 1: Duodenal motility in the post-operative period

	Duodenal contractions per 2 min			
Days following colic surgery	Reflux median (CI) n	No reflux median (CI) n	Survivor median (CI) n	Nonsurvivor median (CI) n
1	9 (0-18) n = 8	14 (12-18) n = 32	13.5 (12-18) n = 32	10 (0-18) n = 7
2	10 (0-24) n = 7	14.5 (12-16) n = 34	15 (12-16) n = 35	10 (0-24) n = 5
3	13.5 (11-16) n = 6	16 (14-20) n = 25	16 (14-20) n = 25	12 (10-16) n = 5
4	12 (0-20) n = 6	16 (13-18) n = 21	16 (13-18) n = 24	10 (0-12) n = 3
5	17 (8-19) n = 4	16 (12-18) n = 15	18 (13-18) n = 17	9 (8-10) n = 2

CI, lower and upper confidence limit with an approximate 95% confidence interval of the median; n, number of horses.
All results are to 1 decimal place.

reflux group and 5 per minute in the nonsurvivor group). Duodenal contractility has been recorded with serial assessments in normal adult ponies following exploratory laparotomy as part of a student surgery course (Epstein *et al.* 2008b). They reported that duodenal contractions were greater at Day 1 (3.9 ± 1.1 contractions per minute), although not statistically significant, compared to those of normal ponies. Our results in the PO colic cases indicate relative hypermotility of the duodenum compared to Epstein *et al.* (2008b); however, the ponies in the latter study had no gastrointestinal lesions, pathology or compromised bowel necessitating surgery and therefore did not require correction of any colic lesion which applied to the clinical cases in this study. This may account for the higher contraction rates in this paper compared to those in previous published studies.

There were a number of horses in the study in which it was not possible to identify the duodenum at the standard location (just ventral to the cranial pole of the right kidney). For example, at Day 1 following colic surgery, in 8 (16%) horses the duodenum was not identified. Kirberger *et al.* (1995) reported that visualisation of the duodenum may be obscured by gas distention and motility of the large bowel (likely base of caecum or right ventral colon) in the adjacent regions, and this was noted to be the case particularly with horses following fasting; this could be expected to be the case in the horses 24 h post-operatively. Owing to the short mesenteric attachments yielding a consistent anatomic location of the duodenum, it is also possible to identify the duodenum in the location of the intercostal spaces 13–15 in the same field as the liver and just deep to the hepatic tissue. It has, however, been reported to be more difficult to visualise the duodenum further cranially due to increasing thickness of the liver as well as lung field interference (Kirberger *et al.* 1995). The duodenum was consistently visualised by Epstein *et al.* (2008b) following exploratory laparotomy in the normal horse deep to the liver; however, in 2/14 horses it was not visualised at Day 1 at the location adjacent to the right kidney. Therefore, it may have been appropriate to attempt to visualise the duodenum in the location deep to the liver in those cases where it was not identified at the cranial pole of the right kidney, and this may have reduced missing data accrued. Alternatively, there is a possibility that the intra-abdominal gas may have obscured our ability to visualise the duodenum in the earlier post-operative assessment. This has been reported in small animal patients; in one study, at Day 1 post-operatively 95% of dogs had either localised or generalised pneumoperitoneum, and progressive post-operative resolution was noted, but at Day 10 this was identified in only 15% of dogs (Matthews *et al.* 2008). The incidence of pneumoperitoneum is a well-established limitation when considering the utility of ultrasound in evaluating the post-operative gastrointestinal tract. If this was the case in the present study, we would have expected that the percentage of horses in which the duodenum was positively identified would increase as the days' increase in the post-operative period. It is difficult to assess this factor in the present study, owing to the fact that a reducing number of horses were scanned as the days increased in the post-operative period, and in certain cases, the scan may not have been performed for practical reasons, euthanasia or earlier discharge home as opposed to the inability for the duodenum to be visualised.

A possible limitation to this single centred study is that the results only apply to the clinic demographic, clinicians and caseload and may not be transferable to other clinics. Additionally, on sequential days there were a reducing number of horses imaged and this may account for the lack of association between duodenal contractility and reflux seen on sequential days (beyond Day 1). The incidence of reflux (22.5%) was similar to previous studies that range from 10 to 47% (Hunt *et al.* 1986; Roussel *et al.* 2001; Cohen *et al.* 2004; Mair and Smith 2005b; Torfs *et al.* 2009). Similarly, the short-term survival rate to discharge (80.5%) was similar to the 70.3% reported for all horses in one study (Mair and Smith 2005a).

Post-operative reflux was defined as >5 L/24 h and beyond 24 h; it was defined over and beyond a 24 h time period in an attempt to capture the population of horses that truly reflux PO from mechanical or functional causes, as opposed to horses that reflux transiently post-operatively from stomach distention preoperatively and/or small intestinal distension that was not decompressed perioperatively. There is no universal definition of PO reflux, and there was a risk that using the current definition of >5 L/24 h beyond 24 h could have overestimated the true incidence. However, every horse that fell into the aforementioned definition for reflux in this study refluxed ≥11 L over a 24 h period (the greatest volume of reflux for each horse ranged between 11 and 91 L over 24 h) and all horses refluxed beyond 24 h.

The ultrasonographers were not blinded to the horse's surgical lesion or clinical picture post-operatively. This may have created observer bias; however, this was a necessary limitation to ensure correct PO care was attained. For practical reasons, there was a broad time frame for the initial scan from 6 to 36 h post-operatively. It is unclear if the ultrasound examination to assess duodenal contractility would be a better predictor of reflux or survival at a more defined time period.

The stage of re-introduction of feed and water was not considered for these cases, and the potential effects of this on duodenal motility are unknown. One study found that horses that were fasted for 24 h had a reduction in the intensity of gastrointestinal sounds in comparison to when they were refed (Naylor *et al.* 2006). There are anecdotal reports that early enteral nutrition is associated with a reduced incidence of intestinal dysmotility; however, there is a lack of controlled studies.

The effects of drug administration were not accounted for in this study. The deleterious effects of sedation on gastrointestinal motility are well documented (Lester *et al.* 1998; Merritt *et al.* 1998; Freeman and England 2001; Gomaa *et al.* 2011) but should not have had any influence on the results of this study as horses were not sedated for the ultrasound examinations. There may have been some confounding effect on duodenal motility of the constant rate infusion of lidocaine that was administered in some cases. The value of lidocaine as a prokinetic agent is controversial; in-vitro, lidocaine has been reported to increase motility in the proximal duodenum (Nieto *et al.* 2000), but other studies report that lidocaine has no effect on small intestinal motility (Okamura *et al.* 2009) and even may decrease jejunal motility (Milligan *et al.* 2006).

The outcome of short-term survival is also dependent on the underlying disease, cardiovascular status and post-operative complications. Although there was no significant association between duodenal contraction rates and surgical findings, there was only a small number of a variety of lesions that may have precluded identifying associations. In some cases, financial constraints may contribute to the reasons for a horse becoming a nonsurvivor. The outcome of POR is dependent on the underlying disease, development of a functional obstruction due to motility disorders (such as POI) or a mechanical obstruction. Therefore, it is possible that duodenal contractility may be a secondary effect as a result of, for example, aboral distention and not necessarily a primary predictive cause for hypomotility of the small intestines.

Further study should focus on the investigation of transcutaneous ultrasonography to measure duodenal contractility during the first day in the post-operative colic horse at a more refined time point. It would be appropriate to include greater numbers of horses to achieve a greater power of study. It may also be pertinent to encompass more complex modelling of data to consider different times/ dosages of drug administration and stages of re-introduction of feed and water.

Conclusion

This preliminary study indicates that measuring the duodenal contraction rate at Day 1 (6–36 h post-operatively) may be valuable in predicting reflux (>5 L/24 h beyond 24 h) and that increased frequency of duodenal contractions is associated with survival. Further study will be required to determine the magnitude of benefit in a clinical setting.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Informed owner consent was obtained for inclusion in the study from client owned animals. The study was approved and conducted in accordance with the Ethical Review Committee of Bell Equine Veterinary Clinic.

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Authorship

All authors contributed to the study design, data collection and study execution, data analysis and interpretation and preparation of the manuscript.

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Supporting information

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

Supplementary Item 1: Contractile duodenum. Visualised just ventral to the right kidney.

Supplementary Item 2: The table outlines the hours following recovery from anaesthesia to the first scan and to first reflux (≥2 L) for all horses (n = 9) in the reflux category (>5 L/24 h). The hours are expressed to the closest 0.5 of an hour. *unable to visualise the duodenum.

Supplementary Item 3: Amotile, distended duodenum with evidence of sedimentation of luminal content. Visualised just ventral to the right kidney.

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Review Article

Diagnosis, management and prognosis of large colon impactions

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Keywords: horse; large colon; impaction; management

Summary

The majority of large colon feed impactions occur in the left ventral colon at the pelvic flexure. Sand and enterolith impactions most commonly occur in the left ventral colon at the pelvic flexure or in the right dorsal colon; however, sand can accumulate anywhere along the gastrointestinal tract. Enteral fluid therapy can, in most cases, supplement or even replace i.v. administration of fluids and it appears effective and safe to soften large colon contents and resolve simple large colon impactions. Surgical intervention is indicated when a concurrent displacement is suspected, as lengthy medical treatment of large colon impaction secondary to large colon displacements would not be indicated and may increase the risk of colonic rupture. Other indications for surgical intervention include uncontrollable pain, when cardiovascular parameters deteriorate, or when there is evidence of intestinal devitalisation. The prognosis for horses undergoing large colon enterotomy is dependent on the extent and type of impaction, but is generally excellent.

Introduction

Feed impaction

After spasmodic colic, large colon feed impaction is the second most commonly reported cause of colic in horses, and it is the most frequent type of simple intestinal obstruction (White 1990; Proudman 1991; Cohen *et al*. 1995; Dabareiner and White 1995). Large colon feed impactions most commonly occur in the left ventral colon at the pelvic flexure; the right dorsal and transverse colons are other common sites of feed impaction (Dabareiner and White 1995). Large colon feed impactions were diagnosed in approximately 15% of horses with colic in a primary ambulatory care practice (Proudman 1991). Most affected horses do not require referral for intensive care (Proudman 1991; Dabareiner and White 1995; Abutarbush *et al*. 2005; Voigt *et al*. 2009; Jennings *et al*. 2014). Horses <1 year old seldom develop large colon feed impaction, but miniature horses may be predisposed to feed impactions as foals (Dabareiner and White 1995).

Change in management within 2 weeks prior to the development of large colon impaction and recent or current musculoskeletal injury are predisposing factors. Large colon impaction is often preceded by change in diet, high grain diets, administration of an anthelmintic, dental care, weather changes related to decreased water intake, hospitalisation and general anaesthesia (Clarke *et al*. 1990; Dabareiner and White 1995; Hillyer and Mair 1997; Little *et al*. 2001; Jennings *et al*. 2014). The incidence of large colon impaction is seasonal with a 12-month cyclical pattern peaking in December and January in the northern hemisphere (Hillyer and Mair 1997; Archer *et al*. 2006; Jennings *et al*. 2014).

Sand impaction

Sand including gravel or bluestone shale can be inadvertently consumed when grazing. Sand impactions typically occur in the left ventral colon at the pelvic flexure or in the right dorsal colon; however, sand can accumulate anywhere along the gastrointestinal tract causing a sand enteropathy with clinical signs of diarrhoea, weight loss or colic (Hart *et al*. 2013). Sand or gravel impaction can occur in horses pastured on sandy soils or when gravel is used around gates and fence posts or when the horse is fed directly on the ground (Husted *et al*. 2005). Horses with sand impaction often have a history of being underfed (Rollins and Clement 1979). Pasture quality is a risk factor as both short and long grass on sandy soil predispose to ingestion of sand (Husted *et al*. 2005). Although most horses with sand impaction are older than a year, sand accumulation has been reported in foals (Specht and Colahan 1988; Ragle *et al*. 1989a).

Enteroliths

In some regions, enteroliths are a common cause of obstruction of the large colon in the horse. Enteroliths (**Fig 1**) are smooth-surfaced spherical or polytetrahedral with wide variation in shape, texture and size (Rakestraw and Hardy 2012). Solitary enteroliths are spherical whereas the finding of a polytetrahedral enterolith is indicative of multiple enteroliths. Rock or mineral fragments are commonly the central nidus of the enterolith; however, other materials such as feed, plastic rope, horse hair, cloth, wire or nails can also serve as the central aggregating core (Hassel *et al*. 2001). Horses with enteroliths were found to have a higher colonic pH, and higher mineral concentration in colonic ingesta than horses without enteroliths (Cohen *et al*. 2000; Hassel *et al*. 2004, 2008, 2009).

Risk factors for enterolithiasis include geographic location with Florida and California having the highest incidence of enterolith-induced colic (Hassel *et al*. 1999). Horses that spend <50% of time at pasture and are fed alfalfa hay are predisposed to enterolithiasis. Some breeds such as Arabians, Arabian crosses, Morgans, American Saddlebreds, donkeys and Miniature Horses appear to be predisposed to enterolithiasis (Hassel *et al*. 1999; Cohen *et al*. 2000).

Diagnosis

Feed impaction

Horses with a large colon feed impaction (**Fig 2**) typically have signs of mild to moderate abdominal pain, decreased

Fig 1: Enteroliths are smooth-surfaced spherical or polytetrahedral with a wide variation in shape, texture and size. Solitary enteroliths a) are spherical whereas the finding of a polytetrahedral enterolith is indicative of multiple enteroliths b). Rock or mineral fragments are commonly the central nidus of the enterolith.

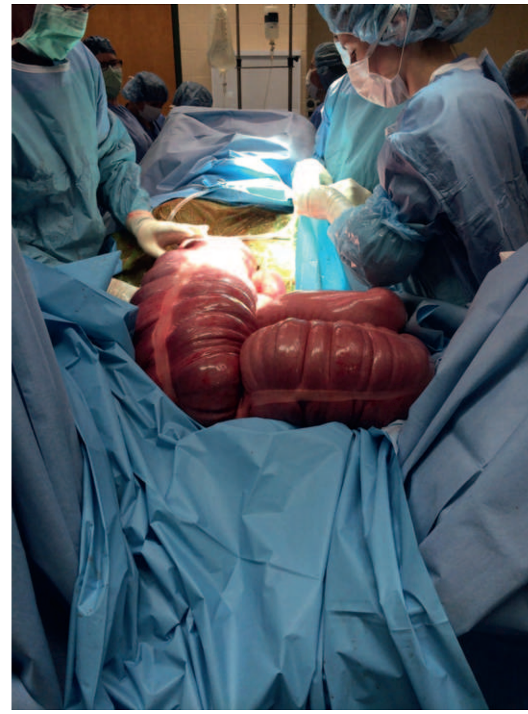

Fig 2:** **A large colon feed impaction is displayed. The impaction extended across midline caudal to the caecum.

or absent intestinal sounds on the side of the abdomen where the impaction is located (Dabareiner and White 1995). Some affected horses have mild to moderate abdominal distention (Dabareiner and White 1995). Faecal output is typically decreased and vital signs are normal or only slightly elevated. Nasogastric reflux is rarely present. Transrectal abdominal palpation is diagnostic for detection of a pelvic flexure impaction, but impactions of the right dorsal and transverse colons can be difficult to palpate in large horses. Mild to moderate dehydration, a normal leukogram, and normal serum electrolyte concentrations and blood gas analysis are typically observed in horses with large colon impaction. The results of peritoneal fluid analysis are usually normal.

It is important to differentiate a pelvic flexure feed impaction from a large colon displacement with secondary right dorsal colon impaction in which the large colon has dehydrated content with prominent tenia and haustra and has a corrugated feel on transrectal examination (Mueller and Moore 2000). Prolonged treatment of a large colon displacement with fluids and cathartics could result in colonic rupture (Mueller and Moore 2000). Dehydrated solid ingesta in the left ventral colon often can be palpated per rectum in horses with a small intestinal strangulating obstruction and may be confused with a primary impaction. Deteriorating cardiovascular status, abnormal peritoneal fluid and abdominal ultrasound of small intestine with a wall thickness of 0.2–1.8 cm and a diameter of 3.6–13.5 cm without evidence of motility are an indication that a large colon impaction is a secondary condition to primary small intestine strangulating obstructions (Dabareiner and White 1995; Klohnen *et al*. 1996). Detecting increased large colon wall thickness by ultrasonography is a reliable and accurate preoperative test for large colon torsion in horses with surgical colic localised to the large colon by signalment, history and physical examination (Schumacher *et al*. 1985; Pease *et al*. 2004).

Sand impaction

Horses with sand impaction display signs similar to those horses with large colon impaction. Occasionally, horses with sand impaction show signs of endotoxaemia, presumably as a result of intestinal mucosal damage associated with abrasiveness of the sand (Ruohoniemi *et al*. 2001). When the sand is nonobstructive, horses are responsive to analgesics, and signs of colic can be present for several weeks. The horse's cardiovascular status will likely be normal unless the horse is endotoxaemic or intestinal necrosis has occurred.

A sand impaction is unlikely to be identified during palpation of the abdomen per rectum, but gas distension of the caecum or large colon is often palpated. Horses with intestinal sand accumulations can have nonspecific clinical signs ranging from chronic poor performance, weight loss, diarrhoea, and recurrent colic to acute colic of mild to moderate severity (Bertone *et al*. 1988; Specht and Colahan 1988; Ragle *et al*. 1989a; Hart *et al*. 2013). Abdominal auscultation for the detection of sand is performed on the ventral portion of the abdomen, with emphasis on the area caudal to the xiphoid process (Ragle *et al*. 1989b). The sounds are generated by sand particle friction created during waves of colonic movement. The intensity of the sound is loudest with accumulations of coarse as opposed to fine sand. The sound produced has been described as similar to the sound produced by sand in a partially filled paper bag that is slowly rotated (Ragle *et al*. 1989b). Sand sounds are 'gritty' sounds of variable intensity and duration (Ragle *et al*. 1989b). In an experimental study where horses were administered sand, all horses had, at some time, typical sounds that could be auscultated, but in most cases only after they had been administered several doses of sand (doses were approximately 2 kg administered every 24 h, up to 5 days) and only after several repeated 5-min periods of auscultation (Ragle *et al*. 1989b).

Sand may be visible when the faeces are removed from the rectum prior to abdominal palpation per rectum. A standardised faecal sand sedimentation test was reported to be highly effective at predicting the presence of faecal sand, and that over 5 mm of sand sediment is likely to be clinically relevant (Husted *et al*. 2005). This test involves suspending 200 g of faeces in one litre of water in a rectal palpation sleeve suspendered vertically (**Fig 3**); the fingertips are observed for sand sediment after 20 min (Husted *et al*. 2005). The presence of sand on sedimentation, however, may be incidental, and conversely, horses with sand impaction may not have sand in their faeces at the time of examination. The appearance of sand in the faeces during treatment is a good indication of clearance of the sand (Ruohoniemi *et al*. 2001). Faecal sand sedimentation was useful for identifying sand in about half of horses that had sand identified radiographically or found during exploratory laparotomy (Ruohoniemi *et al*. 2001; Hart *et al*. 2013). In one study, 23 of 40 horses (58%) were diagnosed with intestinal sand before surgery by one or more of the following methods: observing sand in the faeces, obtaining or feeling sand with a needle during accidental enterocentesis, abdominal auscultation, rectal palpation of a sand filled intestinal viscus, or abdominal radiography or ultrasonography (Ragle *et al*. 1989a).

Peritoneal fluid collected from horses with intestinal sand is often normal but may show an increased concentration of protein indicting some degree of intestinal compromise. Abdominocentesis is not a technique that will give a definitive diagnosis for a sand impaction but rather an idea of intestinal deterioration (Hardy 2017). The weight of the sand in the colon makes it easy to perform an unintentional enterocentesis during the procedure. In one study, 13 of 23 horses with correctly diagnosed sand impaction before surgery were identified by the presence of sand obtained or felt with a cannula or needle during abdominocentesis (Ragle *et al*. 1989a). Enterocentesis is a benign occurrence when sand is collected through a hypodermic needle or even a teat cannula (Schumacher *et al*. 1985; Siex and Wilson 1992).

Abdominal radiography of the cranioventral abdomen is a very useful means of evaluating the amount of sand accumulation and for monitoring the passage of sand with treatment and is the diagnostic image modality of choice (**Fig 4**) (Ruohoniemi *et al*. 2001). Abdominal ultrasonography can be used in conjunction with radiography to monitor the clearance of sand (Korolainen and Ruohoniemi 2002). Ultrasonographic evidence of sand accumulation includes increased contact of the large colon with the ventral body wall, decreased to absent intestinal motility and hyperechoic acoustic shadowing (Korolainen and Ruohoniemi 2002). Abdominal radiographic and ultrasonographic interpretations positively correlated in about half of the horses found to have intestinal sand (Korolainen *et al*. 2003). Ultrasonography is a useful tool for monitoring horses with intestinal sand once a diagnosis has been made because it can be readily performed and easily repeated (Korolainen and Ruohoniemi 2002). Repeated radiographs to monitor elimination of sand may be indicated when results of ultrasonography are equivocal (Korolainen *et al*. 2003).

Enteroliths

Enterolithiasis can result in acute, severe signs of colic if luminal obstruction is complete or, if obstruction is incomplete, cause intermittent, mild signs of colic. Horses with

***Fig 3:** Sand settling in the fingers of a rectal sleeve after adding water to faeces placed in the sleeve is evidence of a sand impaction as a cause of colic.*

***Fig 4:** In this lateral abdominal radiograph, sand is seen in the most dependent portion of the ventral colon.*

enterolithiasis often have a history of intermittent colic and enteroliths can occasionally be found in the faeces in affected horses (Hassel *et al*. 1999). Compared to horses having colic surgery for other reasons, horses with enteroliths in one retrospective study were more likely to have a longer presurgical duration of colic (>12 h), possibly because the presumptive clinical diagnosis was partial nonstrangulating obstruction prompting medical management until lack of response to medical treatment became obvious (Cohen *et al*. 2000).

An enterolith is rarely detected during abdominal palpation per rectum; rather, findings are usually nonspecific with gas distention of the large colon (Hassel *et al*. 1999). In a retrospective study, enteroliths were found in the right dorsal colon (32%), transverse colon (23%), or small colon (45%) (Hassel *et al*. 1999). Enteroliths in the large colon usually occupy the right dorsal colon and cause mild signs of intestinal discomfort. Once an enterolith migrates into the transverse or small colon, signs of acute luminal obstruction develop as distension of the colon with gas and feed progresses. Although an enterolith causes simple colonic obstruction, transmural pressure necrosis also can occur. Enterolith-induced pressure necrosis is more likely to occur when it obstructs the small colon (Hassel *et al*. 1999). Increase in total protein and neutrophils, predominantly degenerative neutrophils, in peritoneal fluid indicates colonic necrosis (Schaer and Orsini 2014). The passage of mineral oil without faeces in a horse with acute abdominal pain often occurs in horses with enterolithiasis when blockage is not complete (Evans *et al*. 1981; Foerner 1982). Often, the diagnosis of enterolithiasis is only made during exploratory celiotomy, particularly in geographic regions where enterolithiasis is uncommon and seldom considered.

Radiographs are useful for detecting enteroliths, but the sensitivity and specificity vary depending on the location of the enterolith and the frequency of enterolithiasis-induced colic in the geographic area (Yarbrough *et al*. 1994). Radiography generally has an excellent specificity (>90%) for diagnosing enterolithiasis, but underexposure and the difficulty of identifying enteroliths in the small colon can decrease the sensitivity of radiographic diagnosis (Yarbrough *et al*. 1994; Hassel *et al*. 1999; Maher *et al*. 2011; Kelleher *et al*. 2014). Abdominal ultrasonographic examination can occasionally detect the presence of an enterolith; however, its accuracy has not been evaluated and it would likely be dependent on the location of the enterolith (Southwood 2019).

Medical treatment

Feed impaction

Medical treatment of large colon feed impaction includes enteral and/or i.v. fluid therapy, withholding feed, and administration of cathartics and analgesics. Enteral fluid therapy can, in most cases, supplement or even replace i.v. administration of fluids. Benefits of enteral fluid therapy include administration of fluid directly to the gastrointestinal tract, stimulation of colonic motility through the gastrocolic reflex, minimal expense, and reduced need for precise adjustment of fluid electrolyte composition (Lopes *et al*. 2002). Hydration of ingesta in the right dorsal colon was significantly greater in horses receiving enteral fluid therapy compared with that of horses receiving a combination of i.v. fluid therapy and enteral administration of magnesium sulfate (Lopes *et al*. 2002). Enteral fluid therapy with a balanced electrolyte solution administered at 10 L/h in normal horses was found to hydrate colonic contents more effectively than i.v. fluids administered at the same rate (Lopes *et al*. 2002).

Enteral fluids can be administered by intermittent or indwelling nasogastric intubation or by placement of an indwelling 18-French equine enteral feeding tube (**Fig 5**) for continuous administration of enteral fluid (Lopes *et al*. 2002). Water alone, or water with electrolytes can be administered for enteral therapy. When large volumes of fluid are administered enterally, electrolytes should be added to the fluid to prevent deficiencies of serum electrolytes (Lopes *et al*. 2002; Southwood 2019). Although normal horses can tolerate the administration of up to 10 L of fluid hourly by nasogastric intubation, it is not prudent to administer more than 5 L every 2 h to horses with large colon impactions, because the stomach empties more slowly in horses with colonic impaction (Lopes *et al*. 2002). As a result, enteral fluid is best administered in small amounts intermittently. It is possible to administer 60 L of fluid by nasogastric tube in a day even when being cautious not to over-fill the stomach. Care should be taken to prevent gastric rupture by periodically siphoning the stomach or examining it ultrasonographically for excessive enlargement. Even horses that reflux intermittently can be treated with enteral fluid (Lopes *et al*. 2002). Enteral fluid therapy with an isotonic electrolyte solution, with or without i.v. fluid therapy was successful in resolving 99% of colonic feed impactions (Monreal *et al*. 2010). It is important to recognise that horses with a colonic impaction often experience moderate pain following administration of enteral fluids; this increase in pain may cloud the decision of whether to continue with medical management or to pursue surgery (Dabareiner and White 1995).

Administration of i.v. fluids is usually reserved for treatment of horses with impactions not responding within 24 h to more conservative treatment, those clinically dehydrated, or those with nasogastric reflux that prevents the administration of enteral fluids. Balanced electrolyte solutions administered i.v. at twice the maintenance rate, or 120 mL/kg per day have been recommended to treat horses with a colonic impaction, both to restore circulating blood volume and to promote rehydration of ingesta (Rakestraw and Hardy 2012). High volume i.v. fluid administration, however, has been shown to provide little benefit in terms of hydration of intestinal contents because much of the i.v. administered fluid is rapidly excreted through the urinary tract (Lester *et al*. 2013). Additionally, many horses will suffer a rebound period of dehydration after cessation of i.v. fluid therapy due to inadequate oral fluid intake in the face of continued sodium and fluid wasting through the urinary tract. This is because thirst is not stimulated because serum osmolality and sodium are often normal (Lester *et al*. 2013).

Osmotic or saline cathartics such as magnesium sulfate (0.5–1 g/kg bwt) or sodium sulfate (0.5–1 g/kg bwt) effectively increase colonic water content (Freeman *et al*. 1992; Hallowell 2008). Because of their efficacy in drawing water to the gastrointestinal tract, these products should not be used in dehydrated horses.

Raw linseed oil produced from flaxseed was a commonly used laxative for the treatment of impactions before the advent of mineral oil (Freeman 1999). The readily available 'boiled' linseed oil product contains plasticisers, hardeners

Fig 5: Enteral fluids can be administered via an indwelling nasogastric tube as treatment of a large colon feed impaction. Water alone, or water with electrolytes can be administered for this enteral therapy. Although normal horses can tolerate the administration of up to 10 L of fluid hourly by nasogastric intubation, it is not prudent to administer more than 5 L every 2 h to horses with large colon impactions, because the stomach empties more slowly in horses with colonic impaction.

and heavy metals (Freeman 1999). Because these additives are highly toxic, only raw linseed oil should be administered to horses (Rakestraw and Hardy 2012). Dosages > 2.5 mL/kg bwt to normal horses cause watery diarrhoea, anorexia, mild signs of colic and neutropenia (Schumacher *et al*. 1997). Although raw linseed oil has greater laxative effects than mineral oil, these side effects may preclude its use, particularly in horses with compromised intestinal mucosa (Schumacher *et al*. 1997).

Mineral oil (liquid petrolatum) is a colourless, odourless mixture of a distillate of petroleum. It acts as an intestinal lubricant by coating the faecal contents and decreasing the absorption of intraluminal water. (Schumacher *et al*. 1997; Rakestraw and Hardy 2012). Unformed faeces were apparent 18–24 h after its administration in normal horses (Schumacher *et al*. 1997). Administration to normal horses decreased glucose absorption and intestinal transit time (Macoris and Gandolphi 1998; Rodrigues 1998). Administration of 5–10 mL/kg bwt is usually recommended. Because mineral oil is evident in faeces 12–24 h after its administration in normal horses, it can serve as a marker for intestinal transport of ingesta (Schumacher *et al*. 1997). Inadvertent administration of mineral oil into the lungs results in lipid pneumonitis, which is usually fatal (Scarratt *et al*. 1998; Bos *et al*. 2002).

Dioctyl sodium sulfosuccinate (DSS) is an anionic surface-active agent that facilitates the penetration of ingesta by water by lowering surface tension. Usually recommended doses of DSS range from 16.5 to 66 mg/kg bwt, with a maximal recommended dose of 200 mg/kg bwt (Rakestraw and Hardy 2012). Death because of circulatory shock can occur at dosages of 1 g/kg bwt (Moffat *et al*. 1975). This drug's advantage is that it is administered in low volume. However, the drug's low margin of safety and lack of efficacy at low dosages make its use questionable. When given with mineral oil, emulsification may result in the absorption of mineral oil from the gut to cause a foreign body reaction in mesenteric lymph nodes and the intestinal wall (Davis and Knight 1977). Because of this, concurrent administration of DSS and mineral oil is discouraged in people, but the significance of this drug combination in horses is unknown. Analgesics are administered to horses with colonic impactions. Flunixin meglumine is currently the NSAID most prescribed in the UK, USA and Canada for treatment of horses with colic (Duz 2019b; Duz *et al*. 2019a). Other NSAIDs administered to horses with abdominal pain include phenylbutazone and ketoprofen. Flunixin meglumine can be administered twice daily at a 1.1 mg/kg bwt i.v. or orally and will control pain for many horses with intraluminal obstruction. Side effects associated with NSAID administration in the horse include gastric glandular ulceration, renal papillary necrosis and right dorsal colitis (MacAllister *et al*. 1993). Excessive doses or combined administration of NSAIDs for the relief of colic pain may potentiate these detrimental effects (Reed *et al*. 2006). Administration of low-dose flunixin meglumine (0.25 mg/kg bwt) may help control pain without significantly affecting large colon motility (Hallowell 2008; Monreal *et al*. 2010). Combining phenylbutazone and flunixin meglumine or doubling the dose of flunixin meglumine was no more effective than use of the single drug at the recommended dose at alleviating foot pain (Foreman and Ruemmler 2011; Foreman *et al*. 2012). This information should be considered even though the effect of NSAID combinations and doses may be different for visceral pain. Ketaprofen is administered to horses at a dose of 2.2 mg/kg bwt i.v. once daily for treatment of abdominal pain. It has a wide margin of safety (MacAllister *et al*. 1993) but reports of its efficacy in comparison to flunixin meglumine are lacking except for general statements that it has similar efficacy for treatment of colic pain (Zimmel 2003a; Davis 2018).

Alpha-2 agonists such as xylazine or detomidine can also be used to control pain of horses with large colon obstructions, but their analgesic effect is short-lived and their effect on intestinal motility is longer than their sedative and analgesic effects (Zimmel 2003a). Chloral hydrate administered i.v., slowly over 5 min at 22 mg/kg bwt as a 12% solution in conjunction with a NSAID has been recommended specifically to treat horses with gas distention of the large colon and small colon impactions (Ball and Peek 1996). Chloral hydrate has minimal cardiovascular or gastrointestinal effects and can be re-administered at one-half of this dose in 30 min. A constant-rate infusion of lidocaine (1.3 mg/kg bwt slow i.v. bolus followed by a constant-rate infusion of 0.05 mg/kg bwt/min for up to 24–36 h) can be used to ameliorate pain although its effectiveness is a matter of debate (Southwood 2019).

Trocarisation of the large colon or caecum may relieve pain and improve motility of the large colon if these structures become markedly tympanic as a result of large colon feed impaction; however, tympany is likely to recur if the impaction remains unresolved. Site location for the caecal trocarisation is the right flank, lateral to epaxial musculature, caudal to the last rib, and cranial to the great trochanter. The left colon is trocarised through the left flank and the exact site selected is based on results of palpation per rectum. Trocarisation is contraindicated when there is possibility of trocarising the small intestine. Trocharisation of the caecum has been reported to cause subcutaneous abscess formation, septic peritonitis and haemorrhage following needle decompression which can be the cause of possibly life-threatening complications (Unger *et al*. 2014). Removal of the metal stylet from an i.v. catheter on entering the caecum may help to reduce the risk of lacerating soft tissues (Unger *et al*. 2014). Systemic antibiotics may be justified (Wintzer and Kraft 1999; Dallap Schaer and Orsini 2008; Weese *et al*. 2011; Edwards 2013) although some authors only recommend their use in cases showing signs of complications (Zimmel 2003b).

After aseptically preparing the site and injecting several mLs of local anaesthetic subcutaneously, a stab incision in the centre of the subcutaneous block is made with a No. 15 scalpel blade (Schaer and Orsini 2014). A subcutaneous abscess is less likely to develop if the trocar is inserted through a stab incision than a puncture. A 14-gauge, 5″ or 5 1/4″ i.v. catheter is inserted through the stab incision and advanced into tympanic caecum or colon. If the catheter is appropriately placed in the lumen of the gas-distended caecum, the aroma of methane may be evident. Alternatively, i.v. tubing can be attached to the catheter and its end placed in a cup of water to observe for formation of bubbles in the water by escaping gas. The stylet is removed and gas is allowed to escape until the colon or caecum falls from the catheter. A vacuum pump can be used to speed evacuation of gas. The flexible, soft texture of the i.v. catheter will not lacerate bowel as it falls from the trocar as it deflates (Schaer and Orsini 2014).

Sand impaction

Medical treatment of horses with sand impaction that have only mild signs of abdominal pain, that are passing faeces, that have no abdominal distention and a normal heart rate and borborygmi, involves administering i.v. or enteral fluids, administering laxatives, and preventing access to sand. Medical management successfully resolved sand impactions in 76% of affected horses in one retrospective study (Hart *et al*. 2013). A combination of psyllium (1 g/kg bwt) and MgSO4 (1 g/kg bwt) administered once daily for 4 days was more effective than either treatment alone for resolving sand accumulations in the large colon (Niinistö *et al*. 2014; Niinisto *et al*. 2018). Mineral oil alone is usually not effective for treatment of sand accumulation as it penetrates and breaks up sand poorly (Rakestraw and Hardy 2012). Psyllium with mineral oil administered via a nasogastric tube was better at clearing intestinal sand than mineral oil alone (Hotwagner and Iben 2008). However, psyllium did not have a significant effect on sand evacuation from the equine large intestine in an experiment, where 10 g/kg of sand was surgically placed into the caecum of ponies. The amount of sand passed by treated ponies was not significantly different from that of untreated ponies indicating that, if additional intake of sand is prevented, normal passage of ingesta can eliminate sand without treatment (Hammock *et al*. 1998). Resolution of a sand impaction can be monitored using ultrasonography or abdominal radiography, the latter of which is not highly recommended because of excessive radiation exposure. Because resolution of clinical signs can occur before complete radiographic clearance of sand, continuing treatment beyond clinical improvement is warranted (Ruohoniemi *et al*. 2001; Korolainen *et al*. 2003). Horses with sand impaction often develop abnormal motility patterns which can result in displacement of the large colon resulting in signs that prompt exploratory celiotomy.

Surgical treatment

Feed impaction

Surgical intervention for treatment of horses with feed impactions of the large colon is indicated when abdominal distention continues to increase, a displacement is suspected, when abdominal pain cannot be controlled, when cardiovascular parameters deteriorate, or when there is evidence of intestinal devitalisation (Specht and Colahan 1988; Ragle *et al*. 1989a).

Pelvic flexure enterotomy is performed for evacuation of ingesta, sand, enteroliths and foreign bodies from the pelvic flexure or right dorsal colon (Stewart *et al*. 2014). Emptying a majority of the contents of the large colon through a pelvic flexure enterotomy rather than injection of fluids to soften and disperse the impaction may prevent the development of post-operative ileus (Roussel *et al*. 2001; Cohen *et al*. 2004).

A 40–50 cm ventral midline incision is often necessary to exteriorise the heavy, distended, and possibly, poorly perfused impacted colon. Care must be exercised during exteriorisation of the large colon, because the weight of the contents predisposes the diaphragmatic flexure of the colon to tear or rupture, especially in long-standing cases. To facilitate exteriorisation of heavy impactions, the abdomen can be filled with an isotonic electrolyte solution to lighten the colon, so that it can be partially ‘floated’ from the abdomen. Alternatively, the horse can be tilted towards the left side of the abdomen to ease removal of the colon. Coating the surface of the colon with sterile sodium carboxymethylcellulose may facilitate safe colonic exteriorisation. When the colon is very heavy and prone to rupture, the minimal length of it should be exteriorised to safely perform a colotomy. As the colon is evacuated, more of its length can be safely exteriorised.

A ‘U’-shaped laparotomy drape surrounding the ventral midline celiotomy incision, the hindlimbs and the caudal portion of the abdomen is placed over the laparotomy drape to rest underneath the colon after exteriorisation. Alternatively, the large colon is placed on a colon tray (Kimsey Enterotomy Surgery Table) after exteriorisation from the abdomen either on the left side of the horse or caudally between and behind the hind legs. The tray contacts the edge of the horse with the laparotomy drape placed over the tray to maintain a sterile field. A separate enterotomy drape is placed over this drape before the colon is laid upon these drapes. The colon tray is angled about 20 degrees downward, away from the horse. A drape can be placed over the colon once it is positioned on the tray to serve as a barrier between the enterotomy site and the colon. While emptying the colon, its underside is periodically lavaged as this is a common site of residual accumulation of ingesta. It is preferable not to use an enterotomy table, but rather to place the colon between the hindlimbs to evacuate the colon (**Fig 6**). Using an enterotomy table is more time-consuming and less effective in clearing the colon, results in more contamination and occupies space that could be occupied by an assistant surgeon.

Before it is incised, the pelvic flexure is positioned over a digesta disposal system built into the surgery room. Alternatively, an ingesta sediment collection container or modified large container with an ingesta strainer and a liquid runoff outflow is used by some surgeons to collect and evacuate the contents of the colon (**Fig 7a,b**). Two garden hoses or one hose with a Y-connection is used for intraluminal lavage and evacuation of the colon and the other for lavage of the colonic serosa.

Although no intraperitoneal studies have been performed in horses, the application of 30,000 IU heparin diluted in saline solution is routinely used and has been informally described as effective to decrease fibrin formation on the serosal surface (Eggleston and Mueller 2003). Alternatively, sodium carboxymethylcellulose can be applied to the serosal surface of the exposed colon to reduce attachment of ingesta and expedite removal of gross debris prior to returning the colon to the abdomen (Southwood 2019).

An 8–12 cm full thickness incision is made on the most dependent portion of antimesenteric border of the pelvic flexure. The ventral and dorsal colons are emptied in turn. The surgeon at the ventral midline celiotomy site manipulates the hose through the colon wall as it is passed into the colon by the ingesta-contaminated, enterotomy surgeon (**Fig 7b**). With the hose in or against the impaction, the surgeon massages the impaction through the colon wall to soften it. The colon is emptied beginning with the section of the left colon closest to the enterotomy and moving sequentially towards the right dorsal or ventral colon.

If the abdominal cavity or bowel becomes grossly contaminated prior to closure, the abdominal cavity should be copiously lavaged with balanced electrolyte solution. The

***Fig 6:** Pelvic flexure enterotomy is performed after placing the large colon between the pelvic limbs. A 'U'-shaped laparotomy drape surrounding the ventral midline celiotomy incision, the hindlimbs and the caudal portion of the abdomen is placed over the laparotomy drape to rest underneath the colon after it is removed from the abdomen.*

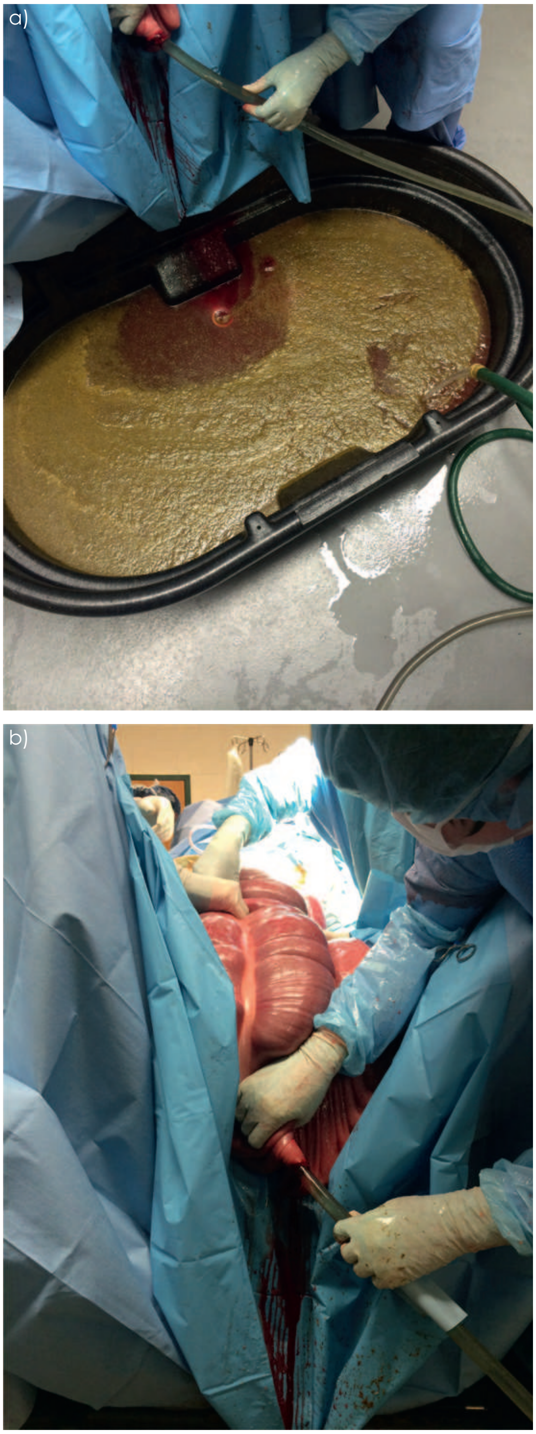

***Fig 7:** a) Ingesta from the pelvic flexure enterotomy is collected in a large container that allows the supernatant to escape in a floor drain. b) The colon is best emptied by flushing the section of the left colon closest to the enterotomy with water administered through a garden hose and then moving the hose towards the right dorsal or ventral colon as ingesta is evacuated.*

fluid is administered through a nasogastric tube placed deep into the dorsal part of the abdominal cavity (**Fig 8**), and then removed from the abdominal cavity using suction. A Poole suction tip directed to both the left and right side of the abdomen between the body wall and liver is effective in retrieving lavage fluid. Normally, 50–75% of the abdominal lavage fluid can be retrieved by suction during surgery. An abdominal drain (Jackson Pratt 15 French round drain) can be inserted 5 cm cranial to the ventral midline celiotomy prior to closure of the abdomen to allow remaining fluid to drain after the horse is standing (**Fig 9**). After escape of fluid, the drain is recapped. The purpose of the drain is to minimise leakage of lavage solution through the abdominal incision, thus decreasing the possibility of dehiscence of the celiotomy wound. Twelve hours after surgery, the drain is uncapped and a representative sample of peritoneal fluid is collected for cytological evaluation. If examination reveals nondegenerate neurophils, the drain is removed. Absolute nucleated cells counts can exceed 30 x 10^9/L as a normal response to intestinal surgery and are not indicative of peritoneal sepsis. Abdominal lavage or re-examination of the abdomen via laparotomy is considered if cytological examination reveals degenerate neutrophils with intra and extracellular bacteria (Hanson *et al*. 1992).

Sand impaction

The most common location for accumulation of sand is the right dorsal colon, but any location, from the ileocecal junction to the small colon, is a possible site of sand accumulation, and multiple sites of impaction are commonly encountered (Specht and Colahan 1988; Ragle *et al*. 1989a; Granot *et al*. 2008). Concurrent large colon displacements or volvulus were found in 25–54% of horses with sand impactions (Specht and Colahan 1988; Ragle *et al*. 1989a; Granot *et al*. 2008; Hart *et al*. 2013). Where a large colon displacement occurs concurrently, the indicators for surgical intervention are increasing gas distension of the large colon on rectal examination with an associated increase in abdominal pain.

Sand and gravel are difficult to remove from the dorsal and transverse colon due to the impossibility of exteriorising these segments of the large colon and the nature of sand and gravel to settle quickly on the lumen floor. Re-impaction can occur if sand evacuation is insufficient (Hart *et al*. 2013). A large bore tube with an outside diameter of 1.5 inches and an inside diameter of 1 inch and 10 feet long (Kingman tube) can be inserted through a pelvic flexure enterotomy to be placed in the dorsal and transverse colon to siphon a majority of the sand and gravel that is too heavy to allow the colon to be exteriorised. Digesta and sand or gravel in the aboral right dorsal and transverse colon unable to be flushed from the dorsal and transverse site can be lavaged aborally into the small colon.

Enteroliths

For large enteroliths that cannot be manipulated from the right dorsal colon to the pelvic flexure because of the decrease in lumen size, a second enterotomy can be made in the diaphragmatic flexure to remove the enterolith. The enterotomy at these sites is performed in the same way as a pelvic flexure enterotomy except that drapes should be added to prevent contamination of the peritoneal cavity as

***Fig 8:** If the abdominal cavity or bowel becomes grossly contaminated prior to closure, the abdominal cavity should be copiously lavaged with balanced electrolyte solution. The fluid is administered through a nasogastric tube placed deep into the dorsal part of the abdominal cavity.*

***Fig 9:** After abdominal lavage, an abdominal drain (15 French round multifenestrated) can be inserted 5 cm cranial to the ventral midline celiotomy prior to closure of the abdomen to allow remaining fluid to drain after the horse is standing. The purpose of the drain is to minimise leakage of lavage solution through the abdominal incision, thus decreasing the possibility of dehiscence of the celiotomy wound. Twelve hours after surgery, the drain is uncapped and a sample of peritoneal fluid is collected for cytological evaluation.*

well as carefully covering exposed serosal surfaces of the colon that cannot be lavaged during the procedure. Several layers of moistened laparotomy sponges placed under the proposed enterotomy site may be useful as individual sponges can be removed as they become contaminated. Enterotomies in the ventral colon are performed between the tenia because the fibrous nature of the teniae prevents inversion during suturing. If the enterolith is lodged in the transverse colon, retrograde flushing by enema may facilitate its movement back to the dorsal colon for removal. If the enterolith cannot be moved from the transverse colon, it can be removed by reaching with a hand and arm directly into the lumen of the right dorsal colon to grab and retract it. Retraction of edges of the intestinal wound with four Babcock forceps will decrease contamination as the hand and arm displace ingesta from the colon as the enterolith is retrieved. The main complication of performing an enterotomy at a site other than the pelvic flexure is increased risk of infection of the celiotomy site due to its close proximity to the enterotomy site (Darnaud *et al*. 2016). Once the colon is sufficiently emptied, care should be taken to remove all gross debris contaminating the serosal surface of the colon. The serosal surface is cleaned using sterile gauze sponges moistened with saline. Closure of the pelvic flexure enterotomy is performed by placing 2-0 absorbable suture material in two layers: a Connell or a simple continuous seromuscular layer is followed by a Lembert or Cushing pattern (Young *et al*. 1991; Doyle *et al*. 2003; Rakestraw and Hardy 2012). This two-layer closure results in the best tissue alignment, haemostasis, and improved healing as well as higher bursting pressure compared to other techniques (Young *et al*. 1991; Gandini *et al*. 2013). The serosal surface of the colon is thoroughly cleaned and lavaged prior to returning the colon to the abdominal cavity.

A Thoracoabdominal (TA-90) Premium stapling device has been described for use in closure of pelvic flexure enterotomies (Gandini *et al*. 2013). The expense of stapling equipment, the length of the enterotomy, bowel thickness and viability warrant consideration prior to using the TA-90 for enterotomy closure (Southwood 2019).

Horses are treated perioperatively with antimicrobial drugs for approximately 24–36 h as well as flunixin meglumine and, possibly, i.v. fluids (Southwood 2019). Feed is gradually reintroduced over 48–72 h or longer depending on the appearance of the intestine at surgery (Southwood 2019). Diarrhoea is the most common post-operative complication (12–23%) (Hassel *et al*. 1999; Pierce *et al*. 2010).

Prognosis

Feed impaction

The prognosis for horses undergoing pelvic flexure enterotomy is dependent on the extent and type of impaction, but is generally excellent (Rosser *et al*. 2012). Long-term positive outcome for horses treated medically for feed impactions was 95.1%, compared with 57.8% for horses treated surgically in one study. The poorer surgical outcome was due to tears in the large colon created during exteriorisation of the colon (Dabareiner and White 1995). The most common complication of surgical treatment of large colon impaction in one study was jugular vein thrombophlebitis (Rakestraw and Hardy 2012). Other, less common complications of surgery include post-operative diarrhoea, incisional drainage, and rarely, clinically significant septic peritonitis (Dabareiner and White 1995). It is important to avoid risk factors that predispose to impactions. Horses are at risk for re-impaction if the same initiating conditions remain. A decrease in the density of gastrointestinal pacemaker cells, the cells of Cajal, were found in horses with large colon disorders which might explain why some horses experience repeated bouts of impaction (Hillyer and Mair 1997; Fintl *et al*. 2004). The cause for the decrease in density of these cells is not known. Some horses require permanent dietary modifications to prevent re-impaction. Providing salt for the diet has been suggested to increase hydration of ingesta (Byars 1993); however, when as much as 5% of the diet was fed as salt to ponies, water consumption did not increase (Schryver *et al*. 1987). For routine feeding of concentrate, provision of more frequent (3 times/day), smaller meals (each <0.4% of bodyweight) throughout the day is recommended to minimise delivery of undigested hydrolysable carbohydrate to the hindgut (Geor and Harris 2007). Ultimately, a well-established target for healthy adult horses is consumption of approximately 2–2.5% of their body weight daily, with at least 1.5% of body weight as good quality hay or pasture (Geor and Harris 2007; NRC 2007).

Sand impaction

Reports of surgical treatment of horses with sand impaction indicate long-term survival (Granot *et al*. 2008). The most common complication is post-operative diarrhoea, but this complication is commonly observed after surgical evacuation of the large colon for any reason (Granot *et al*. 2008). Other complications of surgically resolved sand impaction include recurrence of colic, peritonitis associated with intestinal devitalisation from pressure necrosis, incisional infection and dehiscence and laminitis of unspecified causes (Granot *et al*. 2008). The prognosis for horses with sand impaction is good with 85–100% of horses recovering from surgery surviving to hospital discharge (Specht and Colahan 1988; Ragle *et al*. 1989a; Granot *et al*. 2008).

Prevention of sand impaction includes providing adequate roughage, feeding off the ground, and providing additional roughage when pastures are insufficient. If possible, horses should not be pastured on sandy soil. Ingestion of sand is more likely when horses are maintained in pastures with grass having shallow roots that are easily pulled from the ground as the horses graze. Feeding of psyllium has been advocated at different dosages (once a day for 3 weeks, then 1 week off, to twice a day for 2 weeks, then 1 week off), but the efficacy of these different dosing regimens to prevent further sand accumulation has not been evaluated (Rakestraw and Hardy 2012). The rationale behind periodic rather than constant administration of psyllium is that long-term use of psyllium alters the colonic microflora with subsequent bacterial digestion of the psyllium and decreased efficacy (Borquin *et al*. 1993; Campbell and Fahey 1997).

Enteroliths

Horses surgically treated for enterolithiasis have an excellent long-term prognoses (Hassel *et al*. 1999; Cohen *et al*. 2000; Pierce *et al*. 2010). Local necrosis of the intestine in an area that cannot be exteriorised, such as the transverse colon, is associated with a grave prognosis. Where enterolithiasis is endemic, the recurrence rate was 8%, and up to 18% of horses had undiagnosed colic episodes following hospital discharge (Hassel *et al*. 1999; Pierce *et al*. 2010).

The recurrence rate of enteroliths is unknown, but dietary modifications such as avoidance of legume hay are usually recommended (Rakestraw and Hardy 2012). Other recommendations include offering feed free from debris (which can serve as a nidus) and adding psyllium to the diet (Rakestraw and Hardy 2012). Because the colonic pH of horses with enterolithiasis is more basic than that of normal horses, adding cider vinegar (one cup twice daily) to the diet has been suggested as a preventative (Rakestraw and Hardy 2012). In geographic areas where the water has a high mineral concentration, providing an alternative source of water might be useful (Hassel *et al*. 1999). Wheat bran should not be fed because of its high phosphorous content. Control of the dietary cation–anion balance has been suggested, but the benefits are unproven (Rakestraw and Hardy 2012).

Conclusion

Enteral administration of a large volume of an isotonic electrolyte solution should be considered as an alternative to more traditional medical treatments of large colon impactions. Enteral fluid therapy is well tolerated by almost all horses, does not produce deleterious systemic effects, and could restore electrolyte deficits. Although it has been experimentally demonstrated that enteral fluid therapy is very effective to soften colon contents, it appears effective and safe to resolve large colon obstructions (Monreal *et al*. 2010). Medical management can result in resolution of uncomplicated sand enteropathy in mature horses, and is associated with a good prognosis. However, the increased likelihood of nonsurvival and of another concurrent intestinal lesion in horses that did eventually undergo exploratory laparotomy suggests that prompt surgical intervention should be recommended for horses that show persistent colic signs despite medical management of sand enteropathy (Hart *et al*. 2013). Surgical intervention is indicated when moderate to marked abdominal distention is evident, a displacement is suspected, when abdominal pain cannot be controlled, when cardiovascular parameters deteriorate, or when there is evidence of intestinal devitalisation. Pelvic flexure enterotomy is performed for evacuation of ingesta, sand, enteroliths and foreign bodies from the pelvic flexure or right dorsal colon. A large bore rumenotomy tube can be placed through a pelvic flexure enterotomy into the dorsal and transverse colon to actively siphon a majority of the sand and gravel from colon that is too heavy to be exteriorised. Reports of surgical treatment of horses with sand impaction indicate that long-term survival can be expected.

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Review Article

White line disease: A review (1998–2018)

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Summary

White line disease (WLD) is a significant pathological condition that affects the equine hoof. White line disease continues to frustrate veterinarians and farriers due to the diversity regarding the aetiology, diagnosis and especially treatment. Furthermore, WLD lacks a definitive definition as the disease becomes apparent only when the hoof wall is compromised with an extensive separation, a hoof capsule distortion is present or when lameness exists. Clinical signs can range from a minor hoof wall separation to an extensive disruption of the external laminar bond resulting in displacement of the distal phalanx within the hoof capsule. There has been a myriad of treatments and topical preparations proposed for treating WLD, but most remain controversial with few having any scientific documentation or evidence of efficacy. This review of WLD is based on the sparse information available in the veterinary literature, the large number of WLD cases treated successfully in the authors' combined practices using conventional farriery and the relevant questions that hopefully can be answered in the future.

Introduction

White line disease (WLD) is a pathological condition localised to the equine hoof. The problem is widespread, the aetiology and mechanism of the disease are poorly understood and the treatment is often controversial. White line disease is the term used to describe a keratinolytic process that originates on the solar surface of the hoof characterised by a progressive separation of the inner zone of the hoof wall (Turner 1998; O'Grady 2002; Moyer 2003; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011; Redding and O'Grady 2012). The separation occurs in the inner nonpigmented section of the *stratum medium* and the junction with the *stratum internum* (**Fig 1**). The destruction that occurs within the separation as a consequence of WLD remains superficial to the stratum internum and does not invade the dermis. White line disease always occurs secondary to a hoof wall separation (Turner 1998; O'Grady 2002; Moyer 2003; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011; Redding and O'Grady 2012). The disease has been termed seedy toe, hoof wall disease, hollow hoof, yeast infection, Candida and Onychomycosis. Seedy toe is a focal separation that occurs in the centre toe dorsal to the crena marginalis of the distal phalanx. The separation may extend dorsally in the hoof wall directly above the origin but does not deviate laterally or medially. This hoof wall defect appears to be associated with the crena marginalis (T. D. Burns, unpublished data 2016). Onychomycosis denotes a mycotic disease that originates in the nail bed of the human and the dog. By contrast, in WLD the infection originates at the solar surface of the hoof and migrates proximally, approaching the coronet but never invading this structure. Keratinophilic fungi are often isolated from separated areas of the hoof wall (Kuwano 1998; Turner 1998; Ball 2000); however, in many cases of WLD, the pathogens cultured initially are purely bacterial or a mixed population of bacterial and fungal organisms (Turner 1998; O'Grady 2006). Therefore, onychomycosis may not be the appropriate term when referring to white line disease in the horse (O'Grady 2006). Furthermore, since the term 'white line disease' lacks a definitive definition, perhaps it should be considered a syndrome leading to a disease. The syndrome being symptoms such as a hoof wall separation, combined with a hoof capsule distortion leading to disease which is a pathophysiological response. Finally, the term white line disease that is commonly used to describe this hoof issue is a misnomer, as the disease process does not affect the white line or zona alba' of the horse's hoof capsule (**Fig 1**).

Anatomy of the hoof wall

A closer look at the hoof wall is necessary to appreciate the anatomical location where WLD occurs.

The hoof wall consists of three layers:

- the *stratum externum* (external layer);
- the *stratum medium* (the middle layer)
- the *stratum internum* (the inner layer).

The *stratum externum* arises from the perioplic epidermis and forms the thin outer layer of keratinised cells that give the wall its smooth, glossy appearance. The *stratum medium,* arising from the coronary epidermis, forms the bulk of the hoof wall and is the densest part of the horny wall. It consists of cornified epidermal cells arranged in parallel horny tubules surrounded by intertubular horn, which grow distally from the coronary groove to the basal border. In all hooves the *stratum medium* is always nonpigmented (white) in the deepest inner layer. The *stratum internum* arises from the lamellar epidermis, is nonpigmented, and when combined with the dermal lamellae, is responsible for attaching the hoof wall to the distal phalanx. The distal end of each dermal lamellae is a set of papillae known as the terminal papillae. Proliferation of basal cells from the keratinised epidermal lamellae and tubular horn formed from the epidermis overlying the terminal papillae form the terminal horn that fills

Fig 1:** Classic example of white line disease with separation at junction of **stratum medium** and **stratum internum.

the space between the inner layer of the wall (stratum internum) and the sole as they grow distally towards the ground surface (Bragulla *et al.* 1998; Pollitt 2010). This structure forms the bond between the hoof wall and the sole known as the white line or zona alba. When observed from the solar surface, this white line or *zona albicans* is always yellow in colour, resembles frog horn with a striated appearance and has a plastic consistency when compared to the adjacent dorsal hoof wall or horny sole (**Fig 2a–c**).

Aetiology

The aetiology of WLD remains elusive and is currently undetermined. The problem has been diagnosed in horses worldwide. The incidence of WLD in the United States is unknown and would be hard to determine without a working definition; however, our ability to recognise and treat this hoof issue appears to be increasing. A recent study in a small European country showed the incidence of WLD to be 17.8%; however, the authors did not state how they arrived at this diagnosis (Holzhauer *et al.* 2017). White line disease can affect a horse of any age, sex or breed. One or multiple hooves may be involved, and the affected hooves can be barefoot or shod. One or multiple horses on the same farm may be affected. It is generally agreed that WLD is a

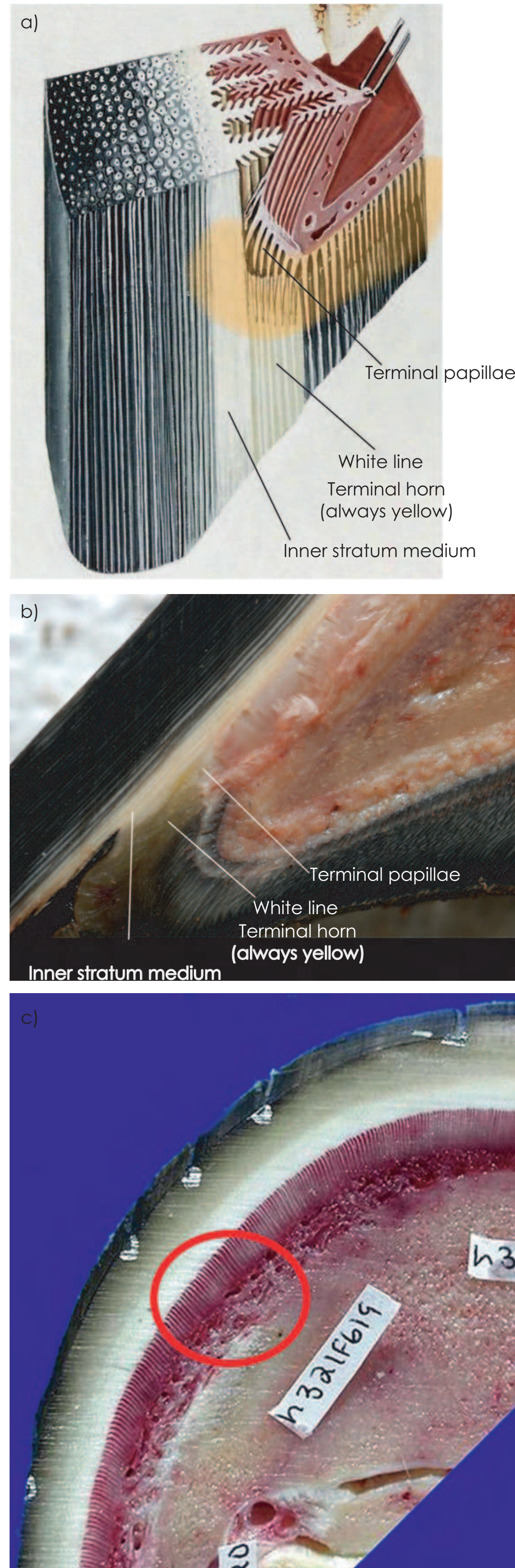

***Fig 2:** Arrangement of the anatomical structures on the distal hoof. Orange highlights the growth zones in the distal hoof in (a). (b) shows separation present in the Inner section of the **stratum medium** that is nonpigmented and the **stratum internum** and (c) shows the striations (red circle) in the white line (Zona Alba) (a and b Courtesy of Dr Chris Pollitt; c Courtesy of Dr Jeff Thomason).*

multifactorial condition that develops secondary to an initial hoof wall separation or hoof wall defect (Turner 1998; O'Grady 2002; Moyer 2003; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011; Redding and O'Grady 2012). The presence of hoof wall separations encountered during the practice of farriery could be considered routine. These separations can be located in the toe, quarter or heel or any combination of the above. They generally vary in depth from 0.5 to 2 cm and when these separations are explored with a probe; the clinician will readily reach solid hoof wall. The unanswered question is why, in a small percentage of cases, a small insignificant hoof wall separation will progress proximally under the hoof wall to become a large significant clinical entity. There is a large population of horses that have hoof wall separations yet do not develop WLD; therefore, there may be some type of genetic propensity or cell-mediated immunity responsible for horses to develop this condition. A recent study correlated a genetic variant associated with a hoof wall separation in a certain breed of ponies (Finno *et al.* 2015).

Multiple other causes for WLD have been proposed, but none have been scientifically proven. Moisture may play a role as WLD is seen more in wet humid areas but it is also seen in hot arid conditions. Excessive moisture over time may soften the foot, allowing a separation to progress or allowing easier entry of dirt and debris into an existing separation. Continual bathing of competition horses, especially during the warmer months, appears to soften the horn and may contribute to the incidence of WLD in this population of horses. Excessively dry hooves, on the other hand, may form cracks or separations in the inner hoof wall, allowing pathogens to invade the horn.

If hoof wall separations are left unattended, dirt and debris become packed into the hoof wall defect and often result in progressive mechanical separation. Keratinopathogenic bacteria and fungi are commonly isolated from hoof wall separations of horses with WLD, particularly those with more extensive lesions (Turner 1998; O'Grady 2011; Redding and O'Grady 2012). However, it is generally believed that these microorganisms are opportunistic, secondary invaders found in the environment that enter the hoof wall through an existing separation or hoof wall defect and then exacerbate the hoof wall separation by the production of proteases that degrade keratin. The fact that WLD occurs in the avascular hoof wall and can be resolved with debridement alone further detracts from this being a predominately infectious process or the primary cause (Turner 1998; O'Grady 2002; Moyer 2003; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011; Redding and O'Grady 2012).

Mechanical stress or increased biomechanical forces placed on the inner hoof wall of horses with less than ideal hoof conformation appears to encourage a separation. The horn tubules of the stratum medium are arranged in a pattern of density going from a high density at the outer hoof wall to a low density at the inner hoof wall. The gradient of tubular density mirrors the moisture across the hoof wall and appears to be responsible for the smooth energy transfer across the hoof wall from the force of impact with the ground to the bone (Thomason *et al.* 1992; Pollitt 2010). As a result of the low tubular density, the inner section of the stratum medium is less rigid, softer and susceptible to compromise or failure. Therefore, it would seem logical that excessive force or stress on this part of the hoof wall created by leverage, or the various hoof capsule distortions would play a major role in the formation of hoof wall separations. Abnormal hoof conformation such as long toe and/or low heel, clubfoot (flexural deformities) and sheared heels are commonly seen in cases of WLD (O'Grady 2018).

Clinical signs

White line disease offers minimal threat to the soundness of the horse until damage to the attachment between the external lamellae, and the inner hoof wall is sufficient to allow movement and/ or a change in position of the distal phalanx within the hoof capsule. Most cases of WLD are first identified by the farrier during routine hoof care. In the early stages of WLD, a hoof wall separation is noted somewhere along the junction of the hoof wall and the sole (**Fig 3**). The area of wall separation can vary in length and is typically filled with foreign material. Exploration of the separated area with a small thin loop knife or a probe reveals an undermined area of hoof wall of varying proportions. In the early stages of the disease, the foreign debris can be removed from the separated horn down to a solid connection between the inner hoof wall and the white line. This area may remain localised or it may progress to involve a larger area of the hoof wall. If the extent of the separation goes deeper, it will classically be filled with a grey-white powdery horn material. Other early warning signs of WLD, depending on the extent of the separation, may be tender soles as noted with hoof testers, occasional heat in the feet, and the sole may become increasingly flatter in the affected area. The hoof wall overlying the defect usually has a normal appearance, but the hoof capsule may have a flare or bulge outward in horses with an extensive separation. Furthermore, there may be some full-thickness hoof cracks originating at the distal border of the hoof capsule and extending proximally which encroach on the inner hoof wall (**Fig 4**). There may be slow hoof wall growth, poor consistency of hoof wall and a hollow sound will be detected when the hoof wall overlying the defect is percussed with a hammer (O'Grady 2006; O'Grady 2011; Redding and O'Grady 2012). Often the disease goes undetected unless there is a change in hoof wall conformation, or the horse begins to show discomfort. When the separation becomes more extensive and involves the toe and a quarter, a concavity ('dish') may be seen forming along one side of the hoof and a bulge will be present on the contralateral side directly above the affected area above the coronary band (**Fig 5**). To explain the mechanism of this distortion – the distal phalanx is suspended within the hoof capsule by the circumferential lamellae when in the state of equilibrium. When a substantial separation affecting the epidermal lamellae attachment is present in the toe and either the medial or lateral quarter, the equilibrium is disrupted and the distal phalanx will shift towards the side of the foot with the separation, causing a concavity in the hoof wall on the contralateral side of the foot side of the foot.

Diagnosis

Lameness or hoof capsule abnormalities may not be observed in the early stages of the disease. Hoof tester examination does not always elicit a response. On the solar

***Fig 3:** Illustration in (a) shows a separation (arrow) in the inner hoof wall. (b) shows a separation in the hoof wall with the white line intact and (c) shows a separation that is more advanced.*

surface of the hoof, the sole/wall junction (white line) will be wider, softer and have a waxy texture. Exploring the inner hoof wall, which lies dorsal to the sole/wall junction, will generally reveal a separation filled with white/grey powdery horn material or there may be a black serous drainage from the separation. Further exploration with a blunt probe will reveal the depth and extent of the cavitation. The extent of the separation can be outlined by tapping the outer hoof wall with a hammer and then confirmed with radiographs. If the separation is extensive, hoof testers applied over this area will move the sole relative to the detached hoof wall leading to a 'pinching' effect in the tissue located at the proximal extent of the defect. The movement of the sole against the wall will generate a painful response. If lameness is present, a thorough lameness examination should be performed including local diagnostic analgesia to localise and confirm the suspected area of discomfort and then followed by radiographs.

Radiographs

Radiography can be very informative and should be considered essential if the separation is extensive. Good quality radiographs show the extent of the hoof wall separation, and whether the distal phalanx has displaced within the hoof capsule. A podiatry study consisting of a lateral and horizontal dorsopalmar 0-degree views along with any lateral oblique views necessary to visualise the extent of the separation should be acquired to evaluate the foot

***Fig 4:** Full-thickness hoof cracks in the distal one-third of the hoof capsule. Not the degenerating horn of the inner hoof wall that can be observed within the defect. Also, note the excessive hoof wall flares present on either side of the cracks.*

***Fig 5:** Hoof capsule distortion as a result of WLD. Extensive separation causing the distal phalanx to shift towards the side where the wall is undermined. Picture on the right shows same foot after trimming and the extent of the undermined horn.*

(**Fig 6**). The images allow the clinician to differentiate between WLD and laminitis. Radiographically, the separation or lucency in the lamellae will originate at the ground surface of the foot in WLD whereas the lucency will originate at the junction of the inner hoof wall and the terminal papillae of the dermal lamellae in laminitis. The radiographs can also be used as a guideline when applying the appropriate farriery to the horse (**Fig 7**).

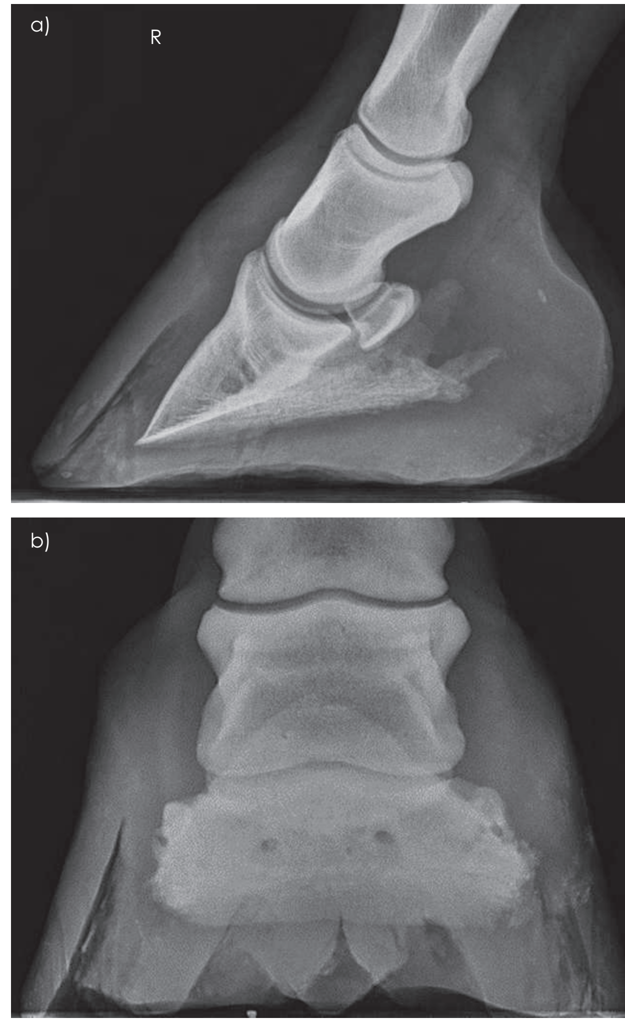

***Fig 6:** Lateral and horizontal 0-degree DP radiographic views that show marked separations within the hoof wall.*

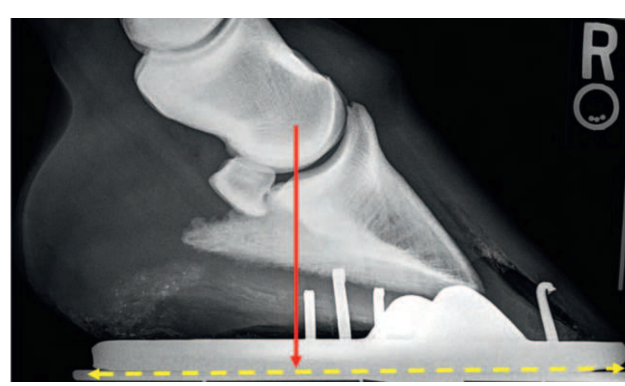

***Fig 7:** Radiograph shows a marked separation in the dorsal hoof wall, displacement of the distal phalanx and a mild flexural deformity. Red arrow is the centre of rotation COR and the yellow dotted line is the proportions of the solar surface on either side of the COR. These guidelines can be used to decrease the leverage on the dorsal foot.*

Laboratory

Laboratory findings have been unrewarding with regards to managing this disease.

Cultures may be of little value since the samples taken from the separations are contaminated with dirt and opportunistic organisms. Aerobic cultures usually reveal a mixed bacteria flora while anaerobic cultures are negative. Fungal cultures require a special media and time. The most common fungal species cultured are *Pseudallescheria*, *Scopulariopsis* and *Aspergillus* (Turner 1998; O'Grady 2006). A biopsy taken at the juncture between the normal and affected hoof wall shows a mixed population of microorganisms. These will generally include *coccobacilli*, yeast organisms and fungal spores. Inflammation in the laminar dermis will be seen deep to the affected area (Turner 1998).

A technique has been described for aseptic culture of the stratum medium, which involves creating a burr hole through the outer hoof wall at the proximal extent of a significant separated area (Ball 2000). In five horses with WLD that underwent this procedure, bacterial culture was negative but fungal culture yielded *Trichoderma* sp., *Mucor* sp., *Aspergillus* sp. or *Gliocladium* sp. None of these fungi is known to have the primary ability to cause disease. These fungi are environmental inhabitants and probably are merely contaminants of a compromised area of the hoof wall. However, none of these organisms could be considered a causative agent nor could this study justify using the term Onychomycosis when defining WLD. Onychomycosis should be limited to the human literature as the pathophysiology, and organisms are different from WLD. While this trephine technique has proven useful for microbiological investigation of hooves with WLD, it is likely to be of limited diagnostic value to the clinician in a practice setting.

Treatment

Cases of WLD referred to the authors' respective practices were generally in the advanced stage of the disease. They were referred due to veterinarian or farrier concerns, unfamiliarity with the disease, abnormal hoof shape or distortion, various stages of lameness and for a second opinion when the current therapy did not appear to be effective. In most cases, the hoof wall separation extended proximally from a halfway point determined when the length of the hoof wall was measured from the bearing border of the hoof to the coronet. Most, but not all, involved the dorsal hoof wall and extended a variable distance into either the lateral or medial side of the hoof.

Farriery

Farriery will form the basis for treating WLD. The spectrum of WLD can range from a subtle hoof wall separation to an extensive separation which may cause substantial disruption of the stratum internum. Disruption of the laminar bond allows the distal phalanx to become unstable or to displace within the hoof capsule which would be consistent with mechanical laminitis. The treatment and farriery for chronic laminitis are beyond the scope of this review paper and will not be considered here.

Improving hoof conformation and correcting any hoof capsule distortion that may have contributed to the hoof wall separation is the initial step in treating WLD. In order to prevent small separations from progressing, the clinician should examine each foot carefully during routine trimming. Separations involving the inner hoof wall should be explored and debrided down to solid horn whenever possible and any cavity that is left after debridement should be removed. If there are solid hoof structures on either side of the separation, the separated area is removed by using the rasp at steep angle and trimming the outer wall down to a solid sole-wall junction (**Fig 8**). If the separation is considered too deep or extensive, it should be debrided as much as possible and then filled with a mixture of oakum, venice turpentine[1] and copper sulphate or a medicated hoof putty[2] before the solar surface of the foot is covered with a shoe. Filling the defect with copper sulphate may have some form of antimicrobial effect and filling the void under the shoe appears to allow the separation to grow down without further deterioration of the hoof.

Treatment of WLD must include protecting and unloading the damaged section of the foot with the appropriate farriery combined with resection of the detached hoof capsule overlying the affected area. A hoof wall resection will disrupt the continuity of the weight-bearing surface of the hoof capsule. Therefore, the authors feel that some type of shoe or device should be applied to restore the continuity of the weight bearing surface, to stabilise the hoof capsule and protect the resected area. Furthermore, the application of a shoe will prevent the horse from utilising the sole for weight-bearing.

If the separated area of the hoof is determined to be extensive, it is important to initiate a farriery plan and then apply the appropriate farriery prior to resecting the outer hoof wall overlying the separation. Abnormal hoof conformation such as a long toe and or low heel, clubfoot and sheared heels is thought to contribute to the formation of WLD and should be addressed in the overall farriery plan. The farriery principles used to treat the hoof wall separations are to redistribute the load away from the defect, to unload the affected area and remove any leverage on the separated area.

The farriery always begins with the appropriate trim. As most separations occur in the dorsal hoof wall and extend to either the lateral or medial quarter, the weight-bearing is redistributed to the palmar/plantar foot. This can be accomplished by drawing a line across the widest part of the foot and trimming the hoof wall from this line palmarly/plantarly until the hoof wall and the frog are on the same horizontal plane. The trim increases the surface area in the palmar/plantar section of the foot recruiting it into 'load sharing' and generally creates two planes on the solar surface of the foot which will marginally unload the dorsal section to the foot (O'Grady and Poupard 2003). Excessive toe length, flares or leverage is reduced by trimming (rasping) the outer dorsal section of the hoof wall (**Fig 5**).

The type of shoe used and the method of attachment depend on the extent of the damaged hoof wall. If the defect is small, the hoof can be shod with an open shoe paying strict attention to any abnormal hoof conformation. If the defect is large and the overlying segment of detached hoof wall needs to be resected, some type of bar shoe is indicated to stabilise the hoof capsule. Often the shoe will need to be modified due to the loss of healthy hoof wall necessary for attachment. This can be accomplished by reshaping the shoe, punching additional nail holes in the shoe that approximate areas of solid horn and by adding clips to help secure the shoe. The shoe is fitted such that the branches of the shoe extend beyond the bearing border of the foot to provide additional weight-bearing surface in the palmar section of the foot. Breakover is placed palmar to the margin of the trimmed dorsal hoof wall to remove any leverage at the toe. This will also stop the 'pinching' effect that often occurs at the junction of normal hoof wall and detached horn at the proximal extent of the separation during breakover.

If the resection is to be extensive and/or if there is displacement of the distal phalanx, some type of supportive shoe or a wooden shoe should be used. Some form of supportive shoe allows some of the weight-bearing function to be transferred from the hoof wall to the frog (heart bar shoe) or to the frog, sole and bars (heel plate shoe) or the entire solar surface of the foot (wooden shoe) (**Fig 9**). Alternatively, the foot may be shod with an open shoe as described above and the solar surface of the foot between the branches of the shoe is filled with some type of silastic material (**Fig 10**).

If the clinician is not comfortable using a traditional shoe, if there is limited hoof wall available in which to place nails or shoes cannot be nailed on safely, glue-on shoes may be another option (O'Grady and Watson 1999). Direct or indirect gluing can be utilised. Direct gluing attaches the shoe directly to the solar surface of the foot whereas indirect gluing attaches the shoe to the outer surface of the hoof wall using some type of cuff or plate. With either direct or indirect glue-on shoes, the resected area can be left exposed for treatment (**Fig 11**).

Recently, the first author has been using a wooden shoe on WLD cases with extensive hoof wall separations. The wooden shoe redistributes the load (weight of the horse) or reduces the forces on a section of the ground surface of the foot. This is accomplished by placing one flat solid surface against the solar surface of the foot. Breakover can be created in the shoe at any point around the perimeter to reduce leverage on the wall. The shoe is attached with small thin screws placed specifically in healthy wall, and the resected area can be left exposed for treatment (O'Grady and Steward 2009; O'Grady 2020) (**Fig 12**).

If no rotation or displacement of the distal phalanx is present, a good 'rule of thumb' is that if greater than 1/3 of the overall surface area of the hoof wall is resected proximally, use palmar/plantar support. Foot casts and various types of boots have become popular in treating WLD especially after a resection has been performed; however, in the authors' opinion, casts should be avoided as they tend to cover the affected section of the foot and boots create a continuous moist environment.

Resection

Complete hoof wall resection and debridement of all tracts and fissures in the affected area is necessary. This can be readily accomplished using a motorised Dremel[3] tool with a tungsten carbide bit, a loop hoof knife and half-round hoof nippers. The debridement should be continued proximally and marginally until there is a solid attachment between the hoof wall and external lamellae (**Fig 13**). The clinician should not generally reach blood during debridement.

***Fig 8:** Note the separations between the toe and heel quarters (red arrows). Separations removed using a rasp at a steep angle; trimming to a solid sole-wall junction.*

Topical disinfectants and medications in any form are of no value without resection of the affected hoof wall. A plethora of topical medications have been described for

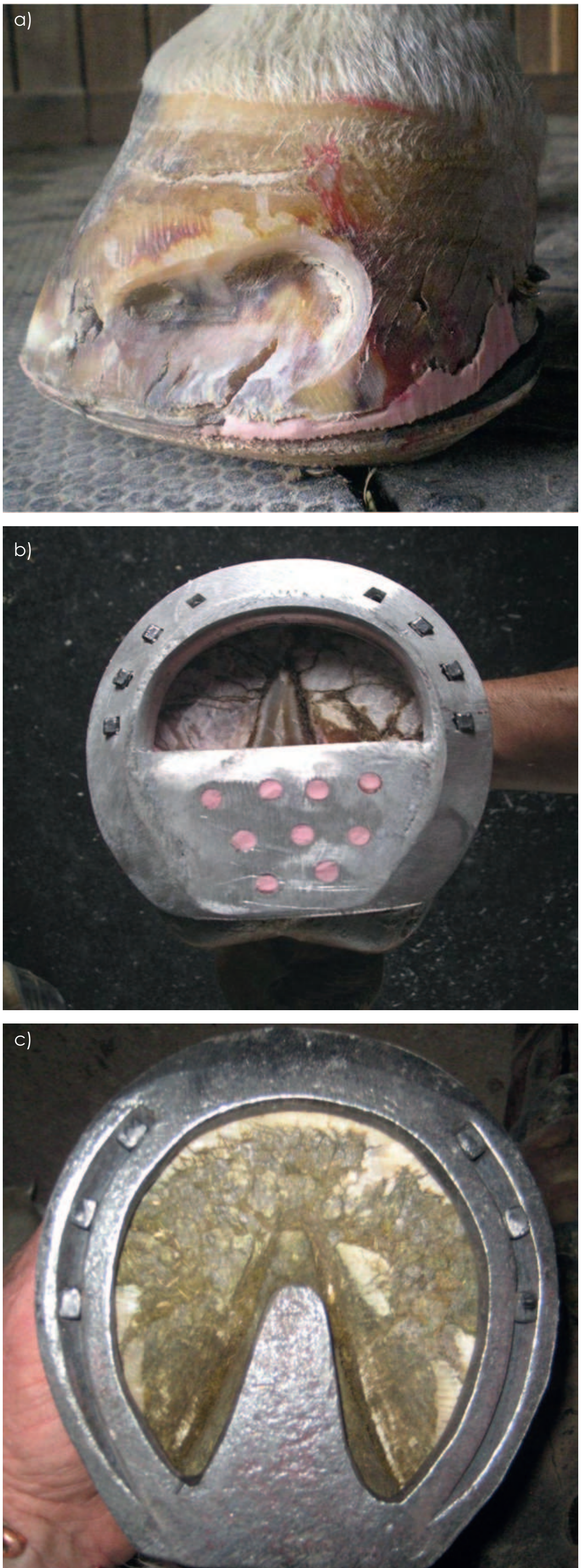

***Fig 9:** Support shoes used to redistribute the weight away from the hoof wall. Wooden shoe (a), heel plate shoe (b) and heart bar shoe (c).*

treatment following hoof wall resection but there have been no controlled studies on any product, and none have any proof of efficacy. Antiseptics/astringents such as Merthiolate or 2% iodine are commonly used; however, their most beneficial effect may be as a dye marker to outline any remaining tracts (**Fig 13**). The dye marker will serve as an aid in making the remaining tracts more visible at subsequent examinations and as a guideline during subsequent debridement. After thorough hoof wall resection, the affected area can be left open to grow out with debridement at frequent intervals. The authors use a wire brush daily to keep the resected area clean (O'Grady 2002; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011). Following the initial debridement, thorough exploration and debridement of any remaining tracts should take place at 2-week intervals by the veterinarian or farrier. When the resection has grown out, a thorough examination of the sole/wall junction is imperative at re-shoeing intervals of 4–5 weeks.

Complications

The authors feel that if an extensive hoof wall resection is performed in one or multiple feet, the horse should be taken out of work. A composite (acrylic or urethane) repair of the resected area is often requested by the client to keep the horse in work but this practice should be discouraged. An acrylic (poly methyl-methacrylate) material[4] with or without an antibiotic is still commonly used to repair a hoof wall

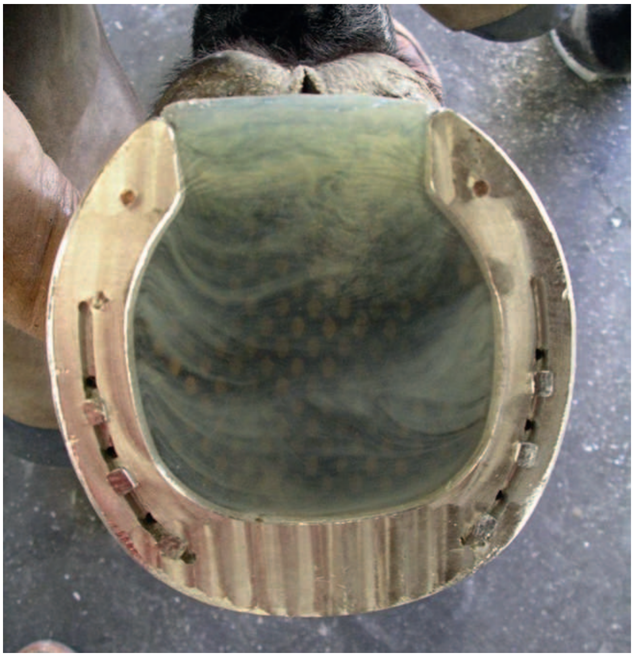

***Fig 10:** Aluminum shoe with silastic material inserted between the branches to redistribute the weight-bearing on the solar surface of the foot.*

***Fig 11:** Glue-on shoe using the indirect method of attachment. Using a cuff, the adhesive is only in contact with solid/healthy outer hoof wall, which eliminates the necessity for nails and there is no adhesive on the solar surface of the hoof. Note the exposure of the hoof wall resection for continued treatment and observation. Also, note the solid borders created around the periphery of the resection.*

***Fig 12:** Wooden shoe attached with screws. Note the dorsal section of the foot unloaded and the breakover moved palmarly (red arrow). After applying 2-in casting tape, the resected area will still be exposed for treatment.*

resection associated with WLD (Turner and Anderson 1996). When an acrylic hoof repair material impregnated with a powdered antibiotic is used, it requires moisture against the composite for the antibiotic to exude from the acrylic. Furthermore, the acrylic composite cures with marked hyperthermia which can create moisture under the repair.

***Fig 13:** Hoof wall resections. It is important to create and maintain around the perimeter of the resections solid margins noted on both feet in this illustration. Maintaining a solid junction prevents the separation from continuing proximally. Dye marker (2% tincture of iodine) being applied to the resection to show up the tracts in stratum internum. These tracts will generally require further debridement at the next recheck.*

Finally, any organisms on the surface of the *stratum internum* will be sealed under the repair and the heat generated when the acrylic cures make the underlying tissue softer, more permeable and may allow organisms entry into the dermis. Therefore, using an acrylic repair is counterintuitive to the accepted practice of creating a dry cornified surface of the *stratum internum* and allowing it to grow out. A repair should only be considered in selected cases where the client is unable to treat the resected area and where cosmetics are a necessity such as when a horse is competing in a nonperformance class. In this case, if a repair is applied, there should be a significant interface (silastic material or clay) placed between the composite and the *stratum internum*. In all cases, composites may hide and/or foster infection and tend to weaken the surrounding solid hoof wall, all of which can encourage continued propagation of a hoof wall separation or re-infection (O'Grady 2002; O'Grady 2006; Pleasant and O'Grady 2008; O'Grady 2011; Redding and O'Grady 2012).

Burr holes

The use of creating a burr hole through the hoof wall at the proximal extent of the separation has been described in farrier and lay publications. The rational behind this procedure is to attempt to treat the separated area by flushing with some type of medication without removing the overlying hoof wall. It is further thought that by treating WLD in this manner and not resecting the detached hoof wall, the horse can stay in work. However, the authors feel that if the separation is that extensive to warrant this type of treatment, the foot is compromised, the distal phalanx is unstable and has the potential for further damage. Furthermore, flushing does not remove the degenerating horn present within the separation and maintains a moist environment under the hoof wall.

Aftercare

A change in environment is important. The feet should be kept as dry as possible throughout the recovery period. Sawdust or wood shavings appear to dehydrate the feet making them the bedding of choice; the bedding should always be kept clean and dry. Limited turnout in rain or wet weather is helpful. Turnout can be delayed in the morning until the sun has dried the dew from the pasture.

A commitment from the owner with regards to a continuous treatment schedule is essential until all signs of disease have been eliminated, and the hoof wall is replaced with new growth. Equally important is maintaining a consistent schedule with the farrier who will continue the appropriate farriery and monitor the resection as it grows out. The extent of the damage will determine the approximate amount of time required to complete the treatment process.

Results

There are many contributing factors to consider when assessing the results of treating WLD. These factors would include an early and accurate diagnosis, the extent of the hoof wall defect, understanding the abnormal forces placed on the foot, the application of the appropriate farriery and the importance of owner compliance. Early recognition and treatment of WLD along with the use of frog and sole support materials is essential in order to prevent displacement of the distal phalanx. Obviously, the results would be further complicated if a case of WLD is associated with a marked displacement of the distal phalanx within the hoof capsule. The success of the authors' treating of WLD may be somewhat biased as both their practices are referral practices limited to the equine foot. The records from the authors' combined practices on greater than 100 cases presented with extensive WLD were reviewed. The treatment protocol was similar in both authors' practices: consisted of application of the appropriate farriery, resection of the devitalised hoof wall and owner using a wire brush on the resected area daily. In some cases, a dye marker was used to aid in recognising tracts in the epidermal lamellae on subsequent debridements. Follow-up on 70% of the cases showed complete resolution of the disease process. The other 30% of the cases were lost to follow-up or lack of compliance from the caretaker with regards to continuing treatment/ farriery.

Prevention

Prevention of WLD is difficult because the exact aetiology is unknown. Discussing the potential problem with the farrier and having them examine each foot when the horse is shod is extremely important and leads to early recognition. Any small abnormal separation or defect involving the inner hoof wall adjacent to the sole-wall junction should be noted, explored and debrided down to solid horn. Good basic farriery is essential for creating and maintaining a strong sole/ wall junction that may prevent separations and offer protection (O'Grady and Poupard 2003). Equally important is the necessity to carefully monitor horses that have previously had WLD as they tend to reoccur. A year or two after WLD has been successively treated and resolved, it can suddenly reappear in some horses with strong hoof walls that have shown no previous signs of a hoof wall separation.

Discussion

White line disease involves the inner, nonpigmented section of the *stratum medium* of the hoof wall, not the sole-wall junction (*zona alba*, or 'white line'). Thus, 'white line disease' is somewhat of a misnomer; however, it has become the accepted term used by most farriers and veterinarians. Certainly, it is a more useful term than onychomycosis, which implies a human disease and limits the primary aetiological organism to a fungal agent.

Treating WLD is often a dilemma for owners, veterinarians and farriers. Owners have been deluged with many proposed causes and a variety of treatment protocols. Numerous commercially available preparations have been marketed for treating WLD, all claiming success. The internet and social media describe a multitude of products and methods guaranteed to provide miraculous improvement. However, presently, there is no convincing scientific evidence as to the efficacy of any given product on the market. Veterinarians are often unaware of the magnitude of this problem or potential consequences of WLD as they only see the severe cases that present with a marked hoof capsule distortion, for lameness evaluation or when radiographic changes become apparent. However, WLD may be a subtle contributor to hoof capsule disorders such as a change in shape, full-thickness hoof wall cracks or abscessation; additionally, it may lead to other causes of lameness within the foot such as laminitis. Farriers generally see horses on a routine basis and need to be in the forefront regarding treatment and especially prevention of WLD. They need to be aware of hoof wall separations encountered during routine farriery (trimming and shoeing) and realise these separations have the potential to advance and extend proximally and marginally in the hoof wall. Abnormal hoof capsule conformation associated with hoof wall separations such as a long toe, clubfoot or sheared heels should be recognised and addressed. Farriers are aware of this disease as they are often confronted with nailing a shoe on to a limited or compromised hoof wall and keeping the shoe on between resets. Farriers often resort to using topical treatments since owners are reluctant to have resections performed; many farriers are reluctant to recommend resections – a procedure that can be daunting and that takes the horse out of work. Research, continued veterinarian/farrier awareness of WLD along with owner education appear to be the most promising direction for the future. There is ample evidence in this paper and other work that traditional farriery is effective in treating and resolving WLD. Research should look at the pathophysiological mechanism where a minor hoof wall separation advances to a marked pathological disease process. Understanding this pathway would provide additional information as to how WLD could be prevented. Quality continuing education (CE) would alert both veterinarians and farriers to the significance of hoof wall separations and their potential to progress to WLD. Furthermore, it appears that abnormal hoof capsule conformation or distortions are risk factors for WLD; therefore, educating both veterinarians and farriers to recognise and address these distortions with appropriate farriery would be useful. The successful management of WLD demonstrates the importance of maintaining and promoting a functional veterinarian–farrier relationship.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Authorship

S. E. O'Grady did the literature search. S. E. O'Grady and T. D. Burns used their combined clinical cases for reviewing the consistent, successful treatment of a large number of white line disease cases. S. E. O'Grady and T. D. Burns revised the manuscript.

Manufacturers' addresses

[1]Hawthorne Products, Inc., N. Dunkirk, Indiana, USA.
[2]Keratex, Brookeville, Maryland, USA.
[3]Dremel, Mount Prospect, Illinois, USA.
[4]Equilox Int'l, Pine Island, Michigan, USA.

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