**Epidemiology of colic: Current knowledge and future directions**

Author name: Alexandra Gillen

Degree: MA MS VetMB

Affiliation: University of Liverpool

Email: Alexandra.Gillen@liverpool.ac.uk

**Mailing address:** Department of Equine Clinical Science, Leahurst Campus, University of Liverpool, Leahurst, Neston, Wirral, CH64 7TE UK

**Author name:** Debra Catherine Archer

**Degree:** BVMS PhD

**Affiliation:** University of Liverpool

**Email:** darcher@liverpool.ac.uk

**Mailing address:** Department of Equine Clinical Science, Leahurst Campus, University of Liverpool, Leahurst, Neston, Wirral, CH64 7TE UK

**Corresponding author:** Debra Archer

**Disclosure statement:** Neither author has any commercial or financial conflicts of interests or funding sources related to writing of this article.

**Synopsis:**

Epidemiological studies are essential for generation of evidence-based, preventive healthcare strategies. This includes ways to minimise colic risk and assist informed decision-making around diagnosis, treatment and likely outcomes. It is important to consider that colic is not a simple ’disease’ but is a syndrome of abdominal pain that encompasses multiple different disease processes, and which is multi-factorial in nature. This review focuses on prevention and diagnosis of colic, including specific forms of colic, communications with owners /carers around colic risk and management, and areas of future research focus.

**Key words:** colic; epidemiology; preventive strategies; risk factors; microbiome; biomarkers

**Key points:** (3-5)

* Colic continues to be a key health and welfare issue in horses, remaining a common concern for horse owners and a frequent reason for veterinary attendance with potential for death or euthanasia despite medical and / or surgical treatment.
* Education around colic prevention remains critical, taking into account the different perspectives that exist across different types of horse owners, including those with differing levels of education and with different perceptions and previous experiences around colic.
* Veterinary treatments, whether medical or surgical, should consider evidence of benefit, cost and owner affordability.
* Use of ‘big data’ through generation of large patient medical databases, surveillance data and research datasets across different equine populations and technological advances facilitating real-time clinic and stall-side data collection have great potential to add to our evidence-base from farm / clinic level to international studies, facilitating more accurate monitoring of colic prevalence, rapid assessment of the efficacy of new interventions and generation of specific predictive models.

**INTRODUCTION**

Epidemiological studies investigating colic provide important information that can be used to devise evidence-based preventive healthcare strategies to minimise the risk of colic and assist informed decision-making around diagnosis, treatment options and likely outcomes. Identification of risk-factors for colic also provides further clues about aetiology, including potential pathophysiological mechanisms that warrant further laboratory-based, fundamental research. Epidemiological studies in this area are complicated by the fact that colic is not a simple ’disease’ but is a syndrome of abdominal pain that encompasses multiple different disease processes, and which is multi-factorial in nature. Appraisal of such studies should consider study design, including the population being investigated and definition of colic used, and data analysis including use of multivariable techniques. This is not an exhaustive review of the epidemiology of colic, which is beyond the scope of this article, but will focus on key aspects in relation to colic prevalence and impact, prevention, diagnosis, communications between veterinarians and owners /carers around colic risk and management, and areas of future research focus.

**POPULATION STUDIES AND ‘BIG DATA’**

Multiple epidemiological studies conducted in the 1990’s, mainly in the USA, demonstrated

that colic has a significant impact on equine health and welfare, with a case fatality rate of 6.7-11%, accounting for upto 28% of equine deaths depending on the population studied.1–3 In the US 2015 National Animal Health Monitoring System (NAHMS) report, 4 colic continues to be one of the most common causes of morbidity, affecting 1.2 – 4.2% of horses based on age group. Colic was the most common cause of mortality in horses aged between 1 – 20 years of age, accounting for 31.2% of deaths in this age category, and was the second most common cause of death in geriatric horses (13.4% of deaths in horses >20 years of age). These figures are consistent with morbidity and mortality data from other countries, based on equine insurance datasets.5–8

Colic is one of the most commonly cited equine medical concerns for veterinarians9 and horse owners / carers 10,11, including owners of working equids in developing countries. 12,13 Severe forms of colic, requiring surgery or euthanasia, have previously been considered to represent <10% of colic cases assessed by veterinarians in ambulatory practice.2,14,15 However, a recent study reported that 23.5% of colic cases seen by veterinary practitioners in two UK ambulatory practices were classified as ‘critical’ in nature (defined as cases that required intensive medical or surgical management, were euthanased or died)16. Colic is a common cause of out-of-hours (OOH) veterinary visits in equine ambulatory practice, being the most common equine emergency requiring veterinary attendance accounting for 35% of OOH visits in two UK ambulatory equine practices17, and one of the most common causes of emergency admissions to large animal referral hospitals.18 Colic therefore continues to be a key health issue for veterinarians and horse owners globally and remains an important focus for ongoing research.

By identifying modifiable risk-factors, epidemiological studies have enabled evidence-based strategies to be devised to reduce the risk of colic. 19,20 However, the degree to which colic incidence overall has changed since these risk-factors started to be identified and quantified is difficult to determine. Very few studies have investigated the effect of interventions on the incidence of colic21 and is an area for future research focus. Within managed equid populations, the incidence of colic has been estimated at between 4-26 episodes per 100-horse-years-at-risk15. Most studies have investigated colic incidence in specific equine populations and have been used to extrapolate likely incidence in the wider equid population. However, the true incidence of colic in the general equid population is unknown. These studies have traditionally been expensive and time consuming to perform. However, technological advances may offer opportunities for more cost effective, rapid collection and reporting of data obtained from horse owners and veterinarians in field and hospital settings. These include data collection via mobile devices such as phones and tablets, use of text-mining software to interrogate data records and design of bespoke computer programmes to facilitate real-time data collection and reporting.

Use of ‘big data’ approaches is not a new concept for epidemiological investigations of colic, utilising national survey data and insurance datasets as already outlined. Within the field of companion animal epidemiology, this is an area that has expanded rapidly including development of large medical record datasets by veterinary corporate companies, 22 collaborations between epidemiologists, private and university-based veterinary practices and hospitals (e.g. SAVSNET 23, VetCompass 24), and development of research datasets (e.g. Dogslife Project25 ). Whilst there are challenges around privacy, data security and technical vulnerabilities, these large-scale datasets provide many opportunities for research and improvements in pet health26. Text-mining of large datasets to investigate the prevalence and survival of horses with chronic diseases 27 and antimicrobial prescribing practices in equine practice 28, expansion of medical recording systems and surveillance datasets to include collection of equine data (e.g. EVSNET 29) and creation of colic audit and research datasets (INCISE30) all provide opportunities to enhance epidemiological investigations into equine colic, including real-time reporting of data. However, it is important that such data is accurate and can be reliably collected and analysed, including data collected outside clinic facilities e.g. ambulatory practice. For studies investigating colic, specific potential barriers to data collection such as time constraints, concerns around confidentiality and use of data have already been identified 31. Around a quarter of colic episodes may resolve spontaneously with no veterinary intervention 15, so use of veterinary treatment records or direct veterinary reporting of colic episodes is likely to underestimate the true prevalence. Other limitations include biases in data collection such as reporting bias due to veterinarians only inputting data for selected cases (e.g. more memorable cases or severe forms of colic) or observer bias e.g. veterinarian or horse owner misreporting of colic cases 32. Overall, whilst there are limitations and challenges, big-data approaches provide exciting new opportunities in colic epidemiological research.

**ECONOMICS AND AFFORDABILITY OF CARE**

The current economic cost of colic to the global equine industry is unknown. In the 1990’s the economic impact of colic to the US equine industry was estimated at $115.3 million, 66% of these costs associated with horse mortality1. These costs will now invariably be substantially greater given that colic remains a common cause of equine morbidity and mortality. The total world equid population has previously been estimated at 112 million, comprising of 58.5 million horses and 53.5 million donkeys and mules, with working equids in low income, net food-importing countries representing >1/3 of all equids and >50% of all donkeys33. In addition to direct economic costs of colic related treatment and mortality, diseases such as colic have wider socio-economic impacts in the latter populations34.

Economics also impact on owner decision-making and options for treatment. During periods of global economic recession, data from a US and a UK referral hospital population demonstrated reduction in the proportion of horses presented for assessment of colic undergoing surgical treatment and increased proportion of horses being euthanased 35. Increases in the cost of veterinary care due to inflation and new therapies are not always associated with parallel increases in the cover provided by insurance companies36 and there are concerns that colic surgery may become unaffordable for some horse owners37. Therefore, the economics of treatment of colic and affordability for individual owners have to be considered. Similar to human health care, the costs of veterinary medical care have been increasing faster than inflation over the last 20 years38. The principle of value-based care has been utilised within human healthcare, where care is based around the principle of achieving the best patient-based outcomes for the lowest cost39. Development of a value-based veterinary care (VBVC) framework based around this principle has been proposed38. Epidemiological studies demonstrating efficacy of different treatments on colic outcomes, including well designed interventional, multi-centre studies and cost-benefit analyses of these are key areas for ongoing research. Such studies would assist veterinarians and owners in making informed decisions around treatment, particularly where economics are limited and may constrain options, keeping treatment of colic (and in particular surgery) as affordable as possible for horse owners.

**THE HUMAN ELEMENT**

In addition to using an evidence-based approach to guide management of our patients, as veterinary professionals, we also have to consider how we convey information from epidemiological studies about preventive healthcare to animal owners. Horse owners / carers play a critical role in decisions about routine management of horses, which may impact on colic risk. These include recognition of signs of colic, decisions around seeking veterinary advice and choice of treatment options, including potential surgical management. Social science approaches are widely used in the medical field to better understand the behaviour of people, including barriers and motivators to improving human health, which can be used to develop tailored, educational strategies40. A UK study showed that multiple different owner typologies exist with variations not only between but within professional and non-professional (lay) horse owner groups in how they recognise and manage colic41. The motivation to contact a veterinarian and make decisions around treatment is related to the owner’s primary attitude towards colic (for example, some owners choose to wait and see, some use lay treatments, and some choose to contact a veterinarian initially), as well as financial aspects. Owner’s attitudes were also shown to be based around their previous experience of colic and the experiences of their friends and other horse owners. In a separate study, owners’ knowledge was also shown to have an impact on the speed of recognition of colic, as well as an estimation of severity42. Due to the variations in owner’s attitudes towards colic and the disparity in knowledge between some owners, there is no ‘one size fits all’ approach and veterinarians must tailor their approach to communication and education around colic prevention and care based on individual client’s knowledge and perceptions. This approach can help to develop educational campaigns around colic such as the UK’s British Horse Society ‘REACT now to beat colic’ campaign43. For working equid populations, in addition to conventional epidemiological approaches44, use of participatory methods provides valuable and complementary information that can be used to inform interventions12,34. These approaches can be used to explore horse owners understanding of colic and gaps in knowledge around colic13 and subsequent development of interventional strategies to minimise colic risk.

Epidemiological studies have also challenged some common perceptions held by horse owners and some veterinarians. One such example is surgical treatment of colic in geriatric horses and ponies. Epidemiological studies have shown that horses and ponies over 16 years of age are more likely to be euthanased prior to surgical intervention, compared to younger age groups45. However, there is no evidence of increased risk of postoperative mortality in geriatric patients treated for small intestinal strangulating disease.46 Horse owners commonly cite perceived poor success rates of surgical treatment and concerns about horses inability to return to athletic function (authors observations). However in horses undergoing surgical treatment of colic that recover following anaesthesia, whilst prognosis can vary dependent on a number of identified risk factors for non-survival, studies have demonstrated that overall 74-85% of horses survive to hospital discharge with 63-85% returning to athletic performance.47 Therefore it is important that veterinarians can present available evidence enabling horse owners to make informed decisions around colic management, including surgical treatment.

**COLIC PREVENTION**

Epidemiological studies have demonstrated that there are various horse- and management-level risk factors for colic in general, and for specific forms of colic, which are often multiple and overlapping. 19,20,48 Factors such as age, sex and breed cannot be modified but can assist identification of horses at higher risk of specific forms of colic, assisting decision-making around likely diagnosis and treatment options (see next section). Where identified risk factors can be modified, this evidence can be used to devise preventive strategies to reduce the likelihood of colic developing, particularly in horses who have already had a colic episode. A longitudinal study performed in the UK demonstrated that of horses that required medical treatment for colic, 36.5% of horses had recurrence of colic in the following 12 months with a recurrence rate of 50 colic events per 100-horse-years-at-risk, which is much higher than the risk of colic in the general population49. Therefore even when attending a horse that presents with colic for the first time and which resolves following medical treatment, veterinarians should provide advice around colic prevention. Most important in terms of identified modifiable risk factors are diet, time spent at pasture or stalled, parasite control and dental prophylaxis as outlined in the following sections.

Geography and season are known to play a role in colic risk, which likely reflect an interplay between various environmental and management related factors. Epidemiological studies conducted at a more regional level can alert veterinary surgeons and owners to increased risk of specific forms of colic in particular geographic regions such as those caused by enteroliths50,51, duodenitis-proximal jejunitis (DPJ)52 or more unusual forms of colic such as idiopathic focal eosinophilic enteritis (IFEE).53 Anecdotal evidence of possible variation in colic incidence at specific times of the year (seasonality) has been suggested in various studies but this is difficult to prove using conventional statistical methods. In the UK, this has been investigated using more complex mathematical models.53,54 In a UK hospital population, consistent seasonal patterns for colic admissions of any type and specific forms of colic were identified and for others (pedunculated lipoma obstruction) where there was no evidence of seasonality (Figure 1)54. Cyclical patterns for all colic admissions, medical and surgical colic admissions, large colon displacements/volvulus coincided with spring and autumn (fall) months, coinciding with times of the year when horses are likely to undergo changes in diet, turnout and other management-related factors such as exercise. Other patterns such as large colon impaction and epiploic foramen entrapment admissions demonstrated a consistent cyclical increase in frequency over the winter months, times of the year when horses are more likely to be stalled and where sudden changes in pasture turnout and feeding may occur.

**Stalling, pasture turnout and exercise**

These factors all have a degree of interplay, as a horse that is stalled for long periods of the day will also have reduced opportunity to graze at pasture and more limited ability for exercise. Epidemiological studies demonstrate that in general, colic risk is reduced by avoiding sudden changes in turnout and stalling, avoiding long periods of time spent stalled and by providing consistent pasture turnout55–57. Increasing time spent at pasture also reduced the likelihood of colic recurrence in horses subsequent to an episode of medical colic, making this an important intervention to consider in individual colic cases. For some groups of horses such as those that display cribbing behaviour, increased likelihood of colic has also been shown to be directly correlated with increased hours spent stalled per day and decreased hours of pasture turnout58. This is also an important risk factor for specific forms of colic such as simple colonic obstruction distention(SCOD) where risk is greatest in horses stalled for 24 hours per day59 and where recent decrease in exercise and transport <24 hours previously were also identified to increase SCOD risk, all factors which contribute to reduced gastrointestinal motility. Other examples of specific groups of horses where increased pasture turnout is protective include horses at irisk of enterolithiasis51.

**Diet**

Epidemiological studies have demonstrated that diet is a key element in colic risk and has been a focus of multiple investigations. Overall, colic risk in general is reduced by avoiding sudden (<2 weeks duration) changes in forage type and batch and changes in concentrate type and quantity55–57,60,61. For horses in specific regions such as those where enterolithiasis is more likely to occur or where specific feed types such as Coastal Bermuda hay are more likely to be fed, dietary interventions are important in reducing risk of enterolith associated colic50,51,62 or development of ileal impactions63. Diet is complex to assess and in epidemiological studies, it can be difficult to obtain detailed and reliable dietary data, even in prospective studies, and particularly on premises where multiple people may be involved in a horses daily care. It is not currently clear why some certain forage types or sugar beet pulp have been associated with increased risk of colic in specific groups of horses58 or specific forms of colic64. Diet type, quantity and dietary alterations may all be factors associated with changes at a more molecular level within the horses gastrointestinal system65.

Technological developments have led to major advances in molecular gastrointestinal research, and increased availability and affordability have made these technologies accessible for equine intestinal research. A vast amount of research conducted in laboratory animals and people has demonstrated that the intestinal microbiome has significant effects on a range of host systems including metabolism, immune system and brain function66,67. Investigation of the equine microbiome in health and disease is an important and active area of current research68. In future epidemiological studies, specific features of the equine microbiome may be important variables to include in multivariable models investigating colic risk. Studies have demonstrated that the microbiome of healthy horses varies with season, age, subsequent to parturition and according to management related factors including changes in diet, access to pasture, gastrointestinal parasite status and following administration of medications69–74. Microbiome alterations have been demonstrated in horses with colic 75–77 but more studies are required to gain a greater understanding of specific features of the equine microbiome and association with colic risk across a range of different equine populations and different forms of colic. There is huge potential to conduct interventional studies to manipulate the microbiome through dietary supplementation such as administration of probiotics78, particularly in horses that develop recurrent episodes of colic where there is no identifiable cause. Fungi are also key components of the microbial gut population79 and mycobiome studies are in their relative infancy in current equine gastrointestinal research. One recent study identified mycobiome alterations in the gastrointestinal tract of horses with grass sickness (equine dysautonomia)80 providing important, new insights into this disease. It is important that such studies, including the effects of interventions to manipulate microbial populations of the equine gut, are well designed and utilise statistical models that take into account the normal differences between individual horses and effects of other potentially confounding factors such as pasture turnout and concurrent administration of medications.

**Parasite prophylaxis**

Epidemiological studies provide evidence that minimising gastrointestinal parasite burdens through administration of anthelmintics is associated with reduced risk of colic 44,55,59,81 and that high gastrointestinal burdens of the equine tapeworm, *Anoplocephala perfoliata*, is an important risk factor for spasmodic colic and ileal impaction, accounting for 81% of ileal impactions in one study82. However, frequent administration of anthelmintics increases selection pressure for anthelmintic resistance (AHR) and failure to be able to effectively minimise equine gastrointestinal parasite burdens due to development of AHR could increase colic risk. There is evidence of AHR in strongyle populations in different geographic regions to different classes of anthelmintics used in horses83,84 and evidence that effects of climate change may also accelerate AHR85. Lack of development of any new classes of anthelmintics means that judicious, best-practice in parasite control is critical. 84 Educational strategies in this area will become increasingly important including use of targeted worming strategies and avoidance of anthelmintic administration as a sole means of parasite prophylaxis.

**Dental prophylaxis**

Severe orodental disease is a risk factor for colic44 and known dental issues have been identified to increase the risk of colic recurrence86 and impaction colic in donkeys87. Dental prophylaxis has also been shown to be associated with reduced risk of SCOD colic59 and identification of quidding behaviour, frequently associated with orodental pathology, increases the risk of large colon volvulus64. Therefore horse owners should be aware of the importance of regular (6-12 monthly), thorough dental assessment and appropriate treatment as a way to reduce colic risk.

**Stereotypic behaviour**

Horses that display oral stereotypic behaviours including cribbing have been shown to be at increased risk of colic44, recurrent colic86 and specific forms of colic including SCOD59 and epiploic foramen entrapment88,89. Once established, cribbing behaviour is difficult to stop making it important to try to prevent this behaviour from developing during a horses early life90 as interventions to physically prevent horses from cribbing are likely to severely compromise welfare91 and there is no evidence that such interventions reduce the risk of colic in these horses. Severity of cribbing behaviour has also been shown to be associated with increased likelihood of a history of previous colic92. This is area that requires more research to better understand the relationship between the gut-brain axis in horses that display oral stereotypic behaviours. Current evidence suggests that avoiding feeding of haylage and maximising pasture turnout in the autumn (fall) months may help to reduce the likelihood of colic in these horses.58

**Surgical interventions to prevent colic**

Specific forms of colic including left and right dorsal displacement of the large (ascending) colon, large colon volvulus, epiploic foramen entrapment and inguinal hernias are more likely to recur compared to other forms of colic. This has resulted in development of several surgical procedures to reduce the risk of recurrence of these specific forms of colic including laparoscopic methods to close or ablate the nephrosplenic space93,94, epiploic foramen 95,96 and inguinal rings97–99 and colopexy or resection of the large colon.100 From an epidemiological point of view, the optimal way to demonstrate efficacy of an intervention is to assign these randomly. However, in practical terms this is unlikely to be achievable as these procedures are more likely to be biased towards horses who are considered good candidates for a specific surgical procedure, or horse owners who have the financial means / emotional investment in that horse. Demonstrating efficacy of any surgical intervention is essential but when appraising studies where interventions are not randomly assigned, it is important to consider the potential for selection bias. Assessment of outcome following such procedures is important and whilst it is important to consider the potential for bias, there is evidence to support their use in reducing recurrence of these specific forms of colic.94,101,102

**DECISION-MAKING AROUND LIKELY DIAGNOSIS AND TREATMENT**

Early identification and surgical intervention for those forms of colic that cannot be managed medically is critical for optimal survival and reduction in postoperative morbidities. Multiple studies have demonstrated that reduced survival and increased incidence of postoperative complications are more likely in horses with severe cardiovascular derangements prior to surgery including elevations in heart rate, systemic packed cell volume, plasma and peritoneal lactate103–105. However, in the early stages, many different pathological lesions that cause abdominal pain, and which may or may not require surgery, present with similar signs. This makes the veterinarian’s task challenging, particularly in the early stages of colic and where use of additional tests may not be feasible to perform outside of clinic facilities.

Epidemiological studies have shown that different risk factors exist for specific forms of colic, some of which may overlap with other forms of colic. These studies also quantify the increase or decrease in risk associated with these different colic types (Table 1). Veterinarians can utilise a risk-based approach to consider how likely a horse is to have a particular form of colic (or not) by using information about horse signalment, prior colic history, current management and knowledge of local geographic information about colic risk, in conjunction with the results of clinical examination and response to analgesia. An exact diagnosis is not essential prior to referral to a suitable facility for potential surgical intervention. Increasing certainty of a specific diagnosis by waiting for additional or worsening clinical signs to develop risks deteriorations in the horse’s systemic status and potential requirement for intestinal resection, with consequent reduction in the chance of an optimal postoperative outcome. However, for horses that are at high risk for specific forms of colic that require surgical intervention, the decision for early referral and surgical intervention may be facilitated through application of epidemiological information and use of this in discussions with horse owners.

Identification of other risk factors that could increase the certainty of the need for surgical intervention at the earliest possible stages, particularly if this information can be utilized stall side, is a key area of ongoing research and could have major potential benefits for equine health and welfare. In recent years, research has focused on identification of biomarkers in blood or peritoneal fluid that can be detected in the earliest stages of the disease process. Alterations in lactate, serum amyloid A, haptoglobin and creatinine kinase in peripheral blood and peritoneal fluid have all been identified as biomarkers for more severe forms of gastrointestinal disease106–109. However, there is a current lack of evidence around their ability to reliably detect surgical lesions using multivariable models and, apart from use of portable lactate meters, many of these biomarkers can only be measured in suitably equipped clinics.

Metabolomic and proteomic approaches have been widely used in the human medical field to assist identification and prognostication of human patients with a variety of disease conditions. Biomarkers including L-histidine, pyruvic acid and stearic acid have been demonstrated to have clinical application in improving prediction of patient survival, as well as the likelihood of morbidities110,111. Nuclear magnetic resonance (NMR) and mass spectroscopy are screening tools that can be used to assess large numbers of biomarkers in both tissues and biofluids. Although at a relatively early stage in equine colic research, this approach has been applied to analysis of blood and peritoneal fluid samples of horses with different forms of colic107–109,112. If one or more novel biomarkers that can be easily assessed at one point or sequentially are identified, these will require testing in multivariable models to determine if this information improves our ability to better predict which horses may need surgical intervention and likely operative outcomes.

Mutiple epidemiological studies have been undertaken to determine factors that are associated with postoperative survival and likelihood of development of postoperative complications47. Evidence from these studies is important in assisting informed decision-making in the primary care and referral hospital setting and can aid discussions with owners prior to, during and following surgery regarding likely outcome and associated costs. A recent study demonstrated that previously developed single and multivariable predictive models113–117 were poor predictors of patient survival in populations different to the population used to develop a specific model118. This highlights the importance of generating and maintaining large patient datasets, including pooling of data from multiple clinics. This would assist generation of additional multivariable models, some of which are based on more localised data, and updating of models ulitizing data obtained from larger populations of horses with colic.

**CONCLUSIONS**

Colic continues to be a key health and welfare issue in horses, remaining a common concern for horse owners and a frequent reason for veterinary attendance with potential for death or euthanasia despite medical and / or surgical treatment. Education around colic prevention remains critical, taking into account the different perspectives that exist across different types of horse owners, including those with differing levels of education and with different perceptions and previous experiences around colic. Veterinary treatments, whether medical or surgical, should consider evidence of benefit, cost and owner affordability. Development of large computer datasets across different equine populations and technological advances facilitating real-time clinic and stall-side data collection have great potential to add to our evidence-base from farm / clinic level to international studies, facilitating more accurate monitoring of colic prevalence, rapid assessment of the efficacy of new interventions and generation of specific predictive models. Concurrently, ongoing and future equine gastrointestinal research utilising metabolomics, proteomics, and further studies of the equine gut microbiome and mycobiome are key in helping us to better understand the pathophysiology of different forms of colic, improved methods of prevention, earlier detection of cases requiring potential surgical intervention and more accurate prognostication.

**Figure 1.** Seasonal patterns of colic in cases presented to a UK referral hospital over a 10 year period, using estimates from a Bayesian regression model (reproduced with permission Archer et al. BMC Veterinary Research 200654)

|  |  |  |
| --- | --- | --- |
| **Specific colic type** |  | **References** |
| Epiploic foramen entrapment | ↑ Risk: Cribbing behavior, history of colic in the prior 12 months, increased stabling in the prior 28 days, increased height, person responsible for daily care, winter months  ↓ Risk: Access to mineral / salt lick, behavioural features, not fed at the same time as other horses | 54,88,89 |
| Pedunculated lipoma obstruction | ↑ Risk: Increasing age, geldings and breed (Arabians, Quarter Horses, Saddlebred, Pony breeds) | 119–121 |
| Ileal impaction | ↑ Risk: *Anoplocephala perfoliata* infection, feeding Coastal Bermuda hay, failure to administer a pyrantel salt in prior 3 months | 63,122123 |
| Idiopathic focal eosinophilic enteritis | ↑ Risk: Younger age, geographic location, months between July - November | 53 |
| Large colon volvulus | ↑ Risk: Increasing height, multiple colic episodes in the previous 12 months, mares, mares that had previously foaled, quidding behaviour, receiving medication (other than anthelmintics), in the previous 7 days, increase in the hours of stabling in the previous 14 days, greater number of horses on the premises, 3 or more people involved in horse’s daily care, feeding of hay, feeding of sugar beet, a change in pasture in the previous 28 days, an alteration in amount of forage in the previous 7 days | 64 |
| Simple colonic obstruction and distention | ↑ Risk: Cribbing behavior, increased hours stabled, recent reduction in exercise, transport in the previous 24 hours, absence of administration of ivermectin or moxidectin in prior 12 months, resident on premises <6 months, history of previous colic, reduced frequency of dental prophylaxis | 59 |
| Impaction colic in donkeys | ↑ Risk: Increasing age, receiving extra feed rations, previous history of colic, paper bedding, feeding of concentrates, limited pasture access, increasing number of carers, recent weight loss, recent vaccination, dental pathology | 87,124 |
| Enterolithiasis | ↑ Risk: Feeding Alfalfa hay, feeding ≥ of diet as alfalfa, feeding <50% of diet as oat hay or grass hay, lack of daily access to pasture grazing, ≤ 50% time spent outdoors, Arabian / Arabian x, Miniature, Morgan, American Saddlebreds horse breeds, donkeys  Dry climates, magnesium, ammonium phosphorus in diet  ↓ Risk: Thoroughbred, Standardbred and Warmblood breeds, stallions | 50,51,62 |

**Table 1.** Horse and management level risk factors for specific forms of colic identified from epidemiological studies selected on the basis of a suitable control population.

**REFERENCES**

1. Traub-Dargatz JL, Kopral CA, Seitzinger AH, Garber LP, Forde K, White NA. Estimate of the national incidence of and operation-level risk factors for colic among horses in the United States, spring 1998 to spring 1999. *J Am Vet Med Assoc*. 2001;219(1):67-71. doi:10.2460/javma.2001.219.67

2. Tinker MK, White NA, Lessard P, et al. Prospective study of equine colic incidence and mortality. *Equine Vet J*. 1997;29(6):448-453. doi:10.1111/j.2042-3306.1997.tb03157.x

3. Cohen ND. The John Hickman memorial lecture: Colic by numbers. *Equine Vet J*. 2003;35(4):343-349. doi:10.2746/042516403776014244

4. USDA. Equine 2015. 2016;(December).

5. Leblond A, Villard I, Leblond L, Sabatier P, Sasco AJ. A Retrospective Evaluation of the Causes of Death of 448 Insured French Horses in 1995. *Vet Res Commun*. 2000;24(2):85-102. doi:10.1023/A:1006408522233

6. Penell JC, Egenvall A, Bonnett BN, Olson P, Pringle J. Specific causes of morbidity among Swedish horses insured for veterinary care between 1997 and 2000. *Vet Rec*. 2005;157(16):470-477. doi:10.1136/vr.157.16.470

7. Egenvall A, Penell J, Bonnett BN, Blix J, Pringle J. Demographics and costs of colic in Swedish horses. *J Vet Intern Med*. 2008;22(4):1029-1037. doi:10.1111/j.1939-1676.2008.0136.x

8. Higuchi T. A retrospective survey of equine acute abdomen in a breeding region of Japan based on agricultural mutual relief insurance data. *J Equine Sci*. 2006;17(1):17-22. doi:10.1294/jes.17.17

9. Traub-Dargatz JL, Salman MD, Voss JL. Medical problems of adult horses, as ranked by equine practitioners. *J Am Vet Med Assoc*. 1991;198(10):1745-1747.

10. Mellor DJ, Love S, Walker R, Gettinby G, Reid SWJ. Sentinel practice-based survey of the management and health of horses in northern Britain. *Vet Rec*. 2001;149(14):417-423. doi:10.1136/vr.149.14.417

11. Buckley P, Dunn T, More SJ. Owners’ perceptions of the health and performance of Pony Club horses in Australia. *Prev Vet Med*. 2004;63(1-2):121-133. doi:10.1016/j.prevetmed.2004.01.013

12. Upjohn MM, Attwood GA, Lerotholi T, Pfeiffer DU, Verheyen KLP. Quantitative versus qualitative approaches: A comparison of two research methods applied to identification of key health issues for working horses in Lesotho. *Prev Vet Med*. 2013;108(4):313-320. doi:10.1016/j.prevetmed.2012.11.008

13. Wild I, Freeman S, Robles D, et al. Owners’ knowledge and approaches to colic in working equids in honduras. *Animals*. 2021;11(7). doi:10.3390/ani11072087

14. PROUDMAN CJ. A two year, prospective survey of equine colic in general practice. *Equine Vet J*. 1992;24(2):90-93. doi:10.1111/j.2042-3306.1992.tb02789.x

15. Hillyer MH, Taylor FGR, French NP. A cross-sectional study of colic in horses on Thoroughbred training premises in the British Isles in 1997. *Equine Vet J*. 2001;33(4):380-385. doi:10.2746/042516401776249499

16. Bowden A, England GCW, Brennan ML, et al. Indicators of critical’ outcomes in 941 horses seen out-of-hours’ for colic. *Vet Rec*. 2020;187(12):492. doi:10.1136/vr.105881

17. Bowden A, Boynova P, Brennan ML, et al. Retrospective case series to identify the most common conditions seen a € out-of-hours’ by first-opinion equine veterinary practitioners. *Vet Rec*. 2020;187(10):404. doi:10.1136/vr.105880

18. Dolente BA, Lindborg S, Russell G, Southwood LL. Emergency case admissions at a large animal tertiary university referral hospital during a 12-month period. *J Vet Emerg Crit Care*. 2008;18(3):298-305. doi:10.1111/j.1476-4431.2008.00305.x

19. Cohen ND. Epidemiology of colic. *Vet Clin North Am Equine Pract*. 1997;13(2):191-201. doi:10.1016/S0749-0739(17)30236-5

20. Archer DC, Proudman CJ. Epidemiological clues to preventing colic. *Vet J*. 2006;172(1):29-39. doi:10.1016/j.tvjl.2005.04.002

21. UHLINGER C. Effects of three anthelmintic schedules on the incidence of colic in horses. *Equine Vet J*. 1990;22(4):251-254. doi:10.1111/j.2042-3306.1990.tb04263.x

22. Banfield Pet Hospital S of PH. No Title.

23. Surveillance S (Small AV. No Title. Accessed October 24, 2022. https://www.liverpool.ac.uk/savsnet/

24. VetCompass. Vet Compass. Accessed October 24, 2022. https://www.vetcompass.org

25. Dogslife Project. No Title. Accessed October 24, 2022. https://www.ed.ac.uk/roslin/eeragroup/research/dogslife

26. Paynter AN, Dunbar MD, Creevy KE, Ruple A. Veterinary big data: When data goes to the dogs. *Animals*. 2021;11(7). doi:10.3390/ani11071872

27. Welsh CE, Duz M, Parkin TDH, Marshall JF. Prevalence, survival analysis and multimorbidity of chronic diseases in the general veterinarian-attended horse population of the UK. *Prev Vet Med*. 2016;131:137-145. doi:10.1016/j.prevetmed.2016.07.011

28. Welsh CE, Parkin TDH, Marshall JF. Use of large-scale veterinary data for the investigation of antimicrobial prescribing practices in equine medicine. *Equine Vet J*. 2017;49(4):425-432. doi:10.1111/evj.12638

29. EVSNET. Equine Veterinary Surveillance Network. Accessed October 24, 2022. https://www.liverpool.ac.uk/evsnet/

30. INCISE. International Colic Surgery Audit. https://www.internationalcolicaudit.com

31. Mair TS, White II NA. The creation of an international audit and database of equine colic surgery: Survey of attitudes of surgeons. *Equine Vet J*. 2008;40(4):400-404. doi:10.2746/042516408X284655

32. Curtis L, Burford JH, Thomas JSM, et al. Prospective study of the primary evaluation of 1016 horses with clinical signs of abdominal pain by veterinary practitioners, and the differentiation of critical and non-critical cases. *Acta Vet Scand*. 2015;57(1):1-12. doi:10.1186/s13028-015-0160-9

33. Stringer AP. Infectious diseases of working equids. *Vet Clin North Am - Equine Pract*. 2014;30(3):695-718. doi:10.1016/j.cveq.2014.09.001

34. Stringer AP, Christley RM, Bell CE, et al. Owner reported diseases of working equids in central Ethiopia. *Equine Vet J*. 2017;49(4):501-506. doi:10.1111/evj.12633

35. Blikslager AT, Mair TS. Trends in the management of horses referred for evaluation of colic: 2004–2017. *Equine Vet Educ*. 2021;33(4):192-197. doi:10.1111/eve.13244

36. Barker I, Freeman SL. Assessment of costs and insurance policies for referral treatment of equine colic. *Vet Rec*. 2019;185(16):508. doi:10.1136/vr.105415

37. Archer DC. Colic surgery: Keeping it affordable for horse owners. *Vet Rec*. 2019;185(16):505-507. doi:10.1136/vr.l6062

38. Pantaleon L. Why measuring outcomes is important in health care. *J Vet Intern Med*. 2019;33(2):356-362. doi:10.1111/jvim.15458

39. Erstad BL. Value-Based Medicine: Dollars and Sense. *Crit Care Med*. 2016;44(2):375-380. doi:10.1097/CCM.0000000000001559

40. Davis E. Donkey and Mule Welfare. *Vet Clin North Am - Equine Pract*. 2019;35(3):481-491. doi:10.1016/j.cveq.2019.08.005

41. Scantlebury CE, Perkins E, Pinchbeck GL, Archer DC, Christley RM. Could it be colic? Horse-owner decision making and practices in response to equine colic. *BMC Vet Res*. 2014;10(Suppl 1):1-14. doi:10.1186/1746-6148-10-S1-S1

42. Bowden A, Burford JH, Brennan ML, England GCW, Freeman SL. Horse owners’ knowledge, and opinions on recognising colic in the horse. *Equine Vet J*. 2020;52(2):262-267. doi:10.1111/evj.13173

43. The British Horse Society REACT Now to Beat Colic. REACT.

44. Salem SE, Scantlebury CE, Ezzat E, Abdelaal AM, Archer DC. Colic in a working horse population in Egypt: Prevalence and risk factors. *Equine Vet J*. 2017;49(2):201-206. doi:10.1111/evj.12573

45. Southwood LL, Dolente BA, Lindborg S, Russell G, Boston R. Short-term outcome of equine emergency admissions at a university referral hospital. *Equine Vet J*. 2009;41(5):459-464. doi:10.2746/042516409X385823

46. Southwood LL, Gassert T, Lindborg S. Colic in geriatric compared to mature nongeriatric horses. Part 2: Treatment, diagnosis and short-term survival. *Equine Vet J*. 2010;42(7):628-635. doi:10.1111/j.2042-3306.2010.00085.x

47. Salem SE, Proudman CJ, Archer DC. Prevention of post operative complications following surgical treatment of equine colic: Current evidence. *Equine Vet J*. 2016;48(2):143-151. doi:10.1111/evj.12517

48. Curtis L, Burford JH, England GCW, Freeman SL. Risk factors for acute abdominal pain (colic) in the adult horse: A scoping review of risk factors, and a systematic review of the effect of management-related changes. *PLoS One*. 2019;14(7). doi:10.1371/journal.pone.0219307

49. Scantlebury CE, Archer DC, Proudman CJ, Pinchbeck GL. Recurrent colic in the horse: Incidence and risk factors for recurrence in the general practice population. *Equine Vet J*. 2011;43(SUPPL.39):81-88. doi:10.1111/j.2042-3306.2011.00383.x

50. Cohen ND, Vontur CA, Rakestraw PC. Risk factors for enterolithiasis among horses in Texas. *J Am Vet Med Assoc*. 2000;216(11):1787-1794. doi:10.2460/javma.2000.216.1787

51. Hassel DM, Aldridge BM, Drake CM, Snyder JR. Evaluation of dietary and management risk factors for enterolithiasis among horses in California. *Res Vet Sci*. 2008;85(3):476-480. doi:10.1016/j.rvsc.2008.03.001

52. Steward SKT, Hassel DM, Martin H, et al. Geographic Disparities in Clinical Characteristics of Duodenitis–Proximal Jejunitis in Horses in the United States. *J Equine Vet Sci*. 2020;93. doi:10.1016/j.jevs.2020.103192

53. Archer DC, Costain DA, Sherlock C. Idiopathic Focal Eosinophilic Enteritis (IFEE), An emerging cause of abdominal pain in horses: The effect of age, time and geographical location on risk. *PLoS One*. 2014;9(12):1-19. doi:10.1371/journal.pone.0112072

54. Archer DC, Pinchbeck GL, Proudman CJ, Clough HE. Is equine colic seasonal? Novel application of a model based approach. *BMC Vet Res*. 2006;2. doi:10.1186/1746-6148-2-27

55. Cohen ND, Gibbs PG, Woods AM. Dietary and other management factors associated with colic in horses. *J Am Vet Med Assoc*. 1999;215(1):53-60.

56. Cohen ND, Peloso JG. Risk factors for history of previous colic and for chronic, intermittent colic in a population of horses. *J Am Vet Med Assoc*. 1996;208(5):697-703.

57. Hudson JM, Cohen ND, Gibbs PG, Thompson JA. Feeding practices associated with colic in horses. *J Am Vet Med Assoc*. 2001;219(10):1419-1425. doi:10.2460/javma.2001.219.1419

58. Escalona EE, Okell CN, Archer DC. Prevalence of and risk factors for colic in horses that display crib-biting behaviour. *BMC Vet Res*. 2014;10. doi:10.1186/1746-6148-10-S1-S3

59. Hillyer MH, Taylor FGR, Proudman CJ, Edwards GB, Smith JE, French NP. Case control study to identify risk factors for simple colonic obstruction and distension colic in horses. *Equine Vet J*. 2002;34(5):455-463. doi:10.2746/042516402776117746

60. Reeves MJ, Salman MD, Smith G. Risk factors for equine acute abdominal disease (colic) : Results from a multi-center case-control study. *Prev Vet Med*. 1996;26(3-4):285-301. doi:10.1016/0167-5877(95)00551-X

61. Cohen ND, Matejka PL, Honnas CM, Hooper RN. Case-control study of the association between various management factors and development of colic in horses. Texas Equine Colic Study Group. *J Am Vet Med Assoc*. 1995;206(5):667-673.

62. Hassel DM, Rakestraw PC, Gardner IA, Spier SJ, Snyder JR. Dietary risk factors and colonic pH and mineral concentrations in horses with enterolithiasis. *J Vet Intern Med*. 2004;18(3):346-349. doi:10.1892/0891-6640(2004)18<346:DRFACP>2.0.CO;2

63. Little D, Blikslager AT. Factors associated with development of ileal impaction in horses with surgical colic: 78 Cases (1986-2000). *Equine Vet J*. 2002;34(5):464-468. doi:10.2746/042516402776117773

64. Suthers JM, Pinchbeck GL, Proudman CJ, Archer DC. Risk factors for large colon volvulus in the UK. *Equine Vet J*. 2013;45(5):558-563. doi:10.1111/evj.12039

65. Shirazi-Beechey SP. Molecular insights into dietary induced colic in the horse. *Equine Vet J*. 2008;40(4):414-421. doi:10.2746/042516408X314075

66. Fan Y, Pedersen O. Gut microbiota in human metabolic health and disease. *Nat Rev Microbiol*. 2021;19(1):55-71. doi:10.1038/s41579-020-0433-9

67. Morais LH, Schreiber HL, Mazmanian SK. The gut microbiota–brain axis in behaviour and brain disorders. *Nat Rev Microbiol*. 2021;19(4):241-255. doi:10.1038/s41579-020-00460-0

68. Sanz MG. Science-in-brief: Equine microbiomics makes its way into equine veterinary medicine. *Equine Vet J*. 2022;54(2):453-454. doi:10.1111/evj.13548

69. Costa MC, Arroyo LG, Allen-Vercoe E, et al. Comparison of the fecal microbiota of healthy horses and horses with colitis by high throughput sequencing of the V3-V5 region of the 16s rRNA gene. *PLoS One*. 2012;7(7). doi:10.1371/journal.pone.0041484

70. Costa MC, Stämpfli HR, Arroyo LG, Allen-Vercoe E, Gomes RG, Weese JS. Changes in the equine fecal microbiota associated with the use of systemic antimicrobial drugs. *BMC Vet Res*. 2015;11(1):1-12. doi:10.1186/s12917-015-0335-7

71. Peachey LE, Molena RA, Jenkins TP, et al. The relationships between faecal egg counts and gut microbial composition in UK Thoroughbreds infected by cyathostomins. *Int J Parasitol*. 2018;48(6):403-412. doi:10.1016/j.ijpara.2017.11.003

72. Slater R, Frau A, Hodgkinson J, Archer D, Probert C. A comparison of the colonic microbiome and volatile organic compound metabolome of anoplocephala perfoliata infected and non‐infected horses: A pilot study. *Animals*. 2021;11(3):1-22. doi:10.3390/ani11030755

73. Salem SE, Maddox TW, Berg A, et al. Variation in faecal microbiota in a group of horses managed at pasture over a 12-month period. *Sci Rep*. 2018;8(1):1-10. doi:10.1038/s41598-018-26930-3

74. Salem SE, Hough R, Probert C, et al. A longitudinal study of the faecal microbiome and metabolome of periparturient mares. *PeerJ*. 2019;7:e6687. doi:10.7717/peerj.6687

75. Weese JS, Holcombe SJ, Embertson RM, et al. Changes in the faecal microbiota of mares precede the development of post partum colic. *Equine Vet J*. 2015;47(6):641-649. doi:10.1111/evj.12361

76. Stewart HL, Southwood LL, Indugu N, Vecchiarelli B, Engiles JB, Pitta D. Differences in the equine faecal microbiota between horses presenting to a tertiary referral hospital for colic compared with an elective surgical procedure. *Equine Vet J*. 2019;51(3):336-342. doi:10.1111/evj.13010

77. Stewart HL, Pitta D, Indugu N, et al. Changes in the faecal bacterial microbiota during hospitalisation of horses with colic and the effect of different causes of colic. *Equine Vet J*. 2021;53(6):1119-1131. doi:10.1111/evj.13389

78. Schoster A. Probiotic Use in Equine Gastrointestinal Disease. *Vet Clin North Am - Equine Pract*. 2018;34(1):13-24. doi:10.1016/j.cveq.2017.11.004

79. Cui L, Morris A, Ghedin E. The human mycobiome in health and disease. *Genome Med*. 2013;5(7). doi:10.1186/gm467

80. McGorum BC, Chen Z, Glendinning L, et al. Equine grass sickness (a multiple systems neuropathy) is associated with alterations in the gastrointestinal mycobiome. *Anim Microbiome*. 2021;3(1). doi:10.1186/s42523-021-00131-2

81. Kaneene JB, Miller R, Ross WA, Gallagher K, Marteniuk J, Rook J. Risk factors for colic in the Michigan (USA) equine population. *Prev Vet Med*. 1997;30(1):23-36. doi:10.1016/S0167-5877(96)01102-6

82. Proudman CJ, French NP, Trees AJ. Tapeworm infection is a significant risk factor for spasmodic colic and ileal impaction colic in the horse. *Equine Vet J*. 1998;30(3):194-199. doi:10.1111/j.2042-3306.1998.tb04487.x

83. Peregrine AS, Molento MB, Kaplan RM, Nielsen MK. Anthelmintic resistance in important parasites of horses: Does it really matter? *Vet Parasitol*. 2014;201(1-2):1-8. doi:10.1016/j.vetpar.2014.01.004

84. Rendle D, Austin C, Bowen M, et al. Equine de-worming: a consensus on current best practice. *UK-Vet Equine*. 2019;3(Sup1):1-14. doi:10.12968/ukve.2019.3.s.3

85. Sauermann CW, Leathwick DM, Lieffering M, Nielsen MK. Climate change is likely to increase the development rate of anthelmintic resistance in equine cyathostomins in New Zealand. *Int J Parasitol Drugs Drug Resist*. 2020;14:73-79. doi:10.1016/j.ijpddr.2020.09.001

86. Scantlebury CE, Archer DC, Proudman CJ, Pinchbeck GL. Management and horse-level risk factors for recurrent colic in the UK general equine practice population. *Equine Vet J*. 2015;47(2):202-206. doi:10.1111/evj.12276

87. Cox R, Burden F, Gosden L, Proudman C, Trawford A, Pinchbeck G. Case control study to investigate risk factors for impaction colic in donkeys in the UK. *Prev Vet Med*. 2009;92(3):179-187. doi:10.1016/j.prevetmed.2009.08.012

88. Archer DC, Pinchbeck GL, French NP, Proudman CJ. Risk factors for epiploic foramen entrapment colic in a UK horse population: A prospective case-control study. *Equine Vet J*. 2008;40(4):405-410. doi:10.2746/042516408X312149

89. Archer DC, Pinchbeck GL, French NP, Proudman CJ. Risk factors for epiploic foramen entrapment colic: An international study. *Equine Vet J*. 2008;40(3):224-230. doi:10.2746/042516408X266079

90. Waters AJ, Nicol CJ, French NP. Factors influencing the development of stereotypic and redirected behaviours in young horses: Findings of a four year prospective epidemiological study. *Equine Vet J*. 2002;34(6):572-579. doi:10.2746/042516402776180241

91. Wickens CL, Heleski CR. Crib-biting behavior in horses: A review. *Appl Anim Behav Sci*. 2010;128(1-4):1-9. doi:10.1016/j.applanim.2010.07.002

92. Escalona EE, Okell CN, Archer DC. Prevalence of and risk factors for colic in horses that display crib-biting behaviour. *BMC Vet Res*. 2014;10(Suppl 1):1-8. doi:10.1186/1746-6148-10-S1-S3

93. Röcken M, Schubert C, Mosel G, Litzke LF. Indications, surgical technique, and long-term experience with laparoscopic closure of the nephrosplenic space in standing horses. *Vet Surg*. 2005;34(6):637-641. doi:10.1111/j.1532-950X.2005.00098.x

94. Nelson BB, Ruple-Czerniak AA, Hendrickson DA, Hackett ES. Laparoscopic Closure of the Nephrosplenic Space in Horses with Nephrosplenic Colonic Entrapment: Factors Associated with Survival and Colic Recurrence. *Vet Surg*. 2016;45:O60-O69. doi:10.1111/vsu.12549

95. Munsterman AS, Hanson RR, Cattley RC, Barrett EJ, Albanese V. Surgical Technique and Short-Term Outcome for Experimental Laparoscopic Closure of the Epiploic Foramen in 6 Horses. *Vet Surg*. 2014;43(2):105-113. doi:10.1111/j.1532-950X.2013.12116.x

96. van Bergen T, Wiemer P, Bosseler L, Ugahary F, Martens A. Development of a new laparoscopic Foramen Epiploicum Mesh Closure (FEMC) technique in 6 horses. *Equine Vet J*. 2016;48(3):331-337. doi:10.1111/evj.12427

97. Ragle CA, Yiannikouris S, Tibary AA, Fransson BA. Use of a barbed suture for laparoscopic closure of the internal inguinal rings in a horse. *J Am Vet Med Assoc*. 2013;242(2):249-253. doi:10.2460/javma.242.2.249

98. Rossignol F, Mespoulhes-Rivière C, Vitte A, Lechartier A, Boening KJ. Standing laparoscopic inguinal hernioplasty using cyanoacrylate for preventing recurrence of acquired strangulated inguinal herniation in 10 stallions. *Vet Surg*. 2014;43(1):6-11. doi:10.1111/j.1532-950X.2013.12083.x

99. Wilderjans H, Meulyzer M. Laparoscopic closure of the vaginal rings in the standing horse using a tacked intraperitoneal slitted mesh (TISM) technique. *Equine Vet J*. 2022;54(2):359-367. doi:10.1111/evj.13454

100. Pezzanite LM, Hackett ES. Technique-associated outcomes in horses following large colon resection. *Vet Surg*. 2017;46(8):1061-1067. doi:10.1111/vsu.12725

101. van Bergen T, Wiemer P, Bosseler L, Ugahary F, Martens A. Development of a new laparoscopic Foramen Epiploicum Mesh Closure (FEMC) technique in 6 horses. *Equine Vet J*. 2016;48(3):331-337. doi:10.1111/evj.12427

102. Arévalo Rodríguez JM, Grulke S, Salciccia A, De La Rebière De Pouyade G. Nephrosplenic space closure significantly decreases recurrent colic in horses: A retrospective analysis. *Vet Rec*. 2019;185(21):657. doi:10.1136/vr.105458

103. Proudman CJ, Smith JE, Edwards GB, French NP. Long-term survival of equine surgical colic cases. Part 2: Modelling postoperative survival. *Equine Vet J*. 2002;34(5):438-443. doi:10.2746/042516402776117881

104. Tennent-Brown BS, Wilkins PA, Lindborg S, Russell G, Boston RC. Sequential plasma lactate concentrations as prognostic indicators in adult equine emergencies. *J Vet Intern Med*. 2010;24(1):198-205. doi:10.1111/j.1939-1676.2009.0419.x

105. Hackett ES, Embertson RM, Hopper SA, Woodie JB, Ruggles AJ. Duration of disease influences survival to discharge of Thoroughbred mares with surgically treated large colon volvulus. *Equine Vet J*. 2015;47(6):650-654. doi:10.1111/evj.12358

106. Peloso JG, Cohen ND. Use of serial measurements of peritoneal fluid lactate concentration to identify strangulating intestinal lesions in referred horses with signs of colic. *J Am Vet Med Assoc*. 2012;240(10):1208-1217. doi:10.2460/javma.240.10.1208

107. Henderson ISF. Diagnostic and prognostic use of L-lactate measurement in equine practice. *Equine Vet Educ*. 2013;25(9):468-475. doi:10.1111/eve.12033

108. Dondi F, Lukacs RM, Gentilini F, Rinnovati R, Spadari A, Romagnoli N. Serum amyloid A, haptoglobin, and ferritin in horses with colic: Association with common clinicopathological variables and short-term outcome. *Vet J*. 2015;205(1):50-55. doi:10.1016/j.tvjl.2015.03.015

109. Kilcoyne I, Nieto JE, Dechant JE. Predictive value of plasma and peritoneal creatine kinase in horses with strangulating intestinal lesions. *Vet Surg*. 2019;48(2):152-158. doi:10.1111/vsu.13147

110. Cambiaghi A, Pinto BB, Brunelli L, et al. Characterization of a metabolomic profile associated with responsiveness to therapy in the acute phase of septic shock. *Sci Rep*. 2017;7(1). doi:10.1038/s41598-017-09619-x

111. Wang J, Sun Y, Teng S, Li K. Prediction of sepsis mortality using metabolite biomarkers in the blood: a meta-analysis of death-related pathways and prospective validation. *BMC Med*. 2020;18(1). doi:10.1186/s12916-020-01546-5

112. Bardell D, Milner PI, Goljanek-Whysall K, Peffers MJ. Differences in plasma and peritoneal fluid proteomes identifies potential biomarkers associated with survival following strangulating small intestinal disease. *Equine Vet J*. 2019;51(6):727-732. doi:10.1111/evj.13094

113. Pascoe PJ, Ducharme NG, Ducharme GR, Lumsden JH. A computer-derived protocol using recursive partitioning to aid in estimating prognosis of horses with abdominal pain in referral hospitals. *Can J Vet Res*. 1990;54(3):373-378.

114. Reeves MJ, Curtis CR, Salman MD, Hilbert BJ. Prognosis in equine colic patients using multivariable analysis. *Can J Vet Res*. 1989;53(1):87-94.

115. Reeves MJ, Curtis CR, Salman MD, Stashak TS, Reif JS. Multivariable prediction model for the need for surgery in horses with colic. *Am J Vet Res*. 1991;52(11):1903-1907.

116. FURR MO, LESSARD P, II NAW. Development of a Colic Severity Score for Predicting the Outcome of Equine Colic. *Vet Surg*. 1995;24(2):97-101. doi:10.1111/j.1532-950X.1995.tb01302.x

117. Farrell A, Kersh K, Liepman R, Dembek KA. Development of a Colic Scoring System to Predict Outcome in Horses. *Front Vet Sci*. 2021;8. doi:10.3389/fvets.2021.697589

118. Bishop RC, Gutierrez-Nibeyro SD, Stewart MC, McCoy AM. Performance of predictive models of survival in horses undergoing emergency exploratory laparotomy for colic. *Vet Surg*. 2022;51(6):891-902. doi:10.1111/vsu.13839

119. Blikslager AT, Bowman KF, Haven ML, Tate LPJ, Bristol DG. Pedunculated lipomas as a cause of intestinal obstruction in horses: 17 cases (1983-1990). *J Am Vet Med Assoc*. 1992;201(8):1249-1252.

120. EDWARDS GB, PROUDMAN CJ. An analysis of 75 cases of intestinal obstruction caused by pedunculated lipomas. *Equine Vet J*. 1994;26(1):18-21. doi:10.1111/j.2042-3306.1994.tb04324.x

121. Garcia-Seco E, Wilson DA, Kramer J, et al. Prevalence and risk factors associated with outcome of surgical removal of pedunculated lipomas in horses: 102 Cases (1987-2002). *J Am Vet Med Assoc*. 2005;226(9):1529-1537. doi:10.2460/javma.2005.226.1529

122. Proudman CJ, French NP, Trees AJ. Tapeworm infection is a significant risk factor for spasmodic colic and ileal impaction colic in the horse. *Equine Vet J*. 1998;30(3):194-199. doi:10.1111/j.2042-3306.1998.tb04487.x

123. PROUDMAN CJ, SMITH JE, EDWARDS GB, FRENCH NP. Long-term survival of equine surgical colic cases. Part 2: Modelling postoperative survival. *Equine Vet J*. 2010;34(5):438-443. doi:10.2746/042516402776117881

124. Cox R, Proudman CJ, Trawford AF, Burden F, Pinchbeck GL. Epidemiology of impaction colic in donkeys in the UK. *BMC Vet Res*. 2007;3. doi:10.1186/1746-6148-3-1