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Review Article

Prevention of post operative complications following surgical treatment of equine colic: Current evidence

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Summary

Changes in management of the surgical colic patient over the last 30 years have resulted in considerable improvement in post operative survival rates. However, post operative complications remain common and these impact negatively on horse welfare, probability of survival, return to previous use and the costs of treatment. Multiple studies have investigated risk factors for post operative complications following surgical management of colic and interventions that might be effective in reducing the likelihood of these occurring. The findings from these studies are frequently contradictory and the evidence for many interventions is lacking or inconclusive. This review discusses the current available evidence and identifies areas where further studies are necessary and factors that should be taken into consideration in study design.

Keywords: horse; colic; post operative complications; surgical site infection; post operative colic; post operative ileus

Introduction

Colic is one of the most common causes of mortality in managed equine populations [1,2], accounting for 28% of reported horse deaths annually [3]. Most colic episodes that occur in the general equine population resolve spontaneously or following medical treatment but approximately 8% of episodes will require surgical treatment or euthanasia [4,5]. Surgical management of colic started to become more commonplace in the 1970s. Since that time, our knowledge of the pathophysiology and epidemiology of colic has improved significantly. Advancements in surgical techniques, anaesthetic management and post operative care have improved morbidity and mortality rates [6,7]. Current survival to discharge from hospital in horses that recover from anaesthesia is reported to be 74–85% [8–14] with 63–85% of those cases returning to athletic performance [15–18]. Post operative complications are common, have important welfare and economic consequences, and may impact negatively on horses' likelihood of survival or future athletic use [18,19]. Therefore, development of strategies and/or therapies to minimise development of these complications based on available evidence is important.

This review summarises the complications that can occur following surgical treatment of colic, the prevalence of these complications, and the predisposing factors leading to their occurrence. Particular focus has been placed on appraisal of study design, areas that require future research and factors that should be considered in the design of such studies. For the purpose of critical appraisal of relevant studies, a systematic electronic literature search of Medline Database, Web of Science and Cab Direct was performed and only papers with Level 4 or more of evidence (http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/) were considered for inclusion. Expert opinions, *in vitro* studies and studies where interventions were tested in clinically healthy horses or cadaver studies were excluded. In order to focus on studies relevant to current surgical management of colic, the search was also limited to those conducted from 1985 onwards.

Incisional complications

Prevalence

Incisional complications vary from mild, self-limiting conditions to those that increase duration and costs of hospitalisation, which are life-threatening or may prevent return to athletic function. These include oedema, dehiscence, drainage, infection and hernia formation (Supplementary Item 1). Surgical site infection (SSI)/drainage has been reported in 11–42% [20–24] of horses following laparotomy, which is greater than SSI rates reported following abdominal surgery in man (13.3%) [25], dogs and cats (5.5%) [26], and cattle (12.8%) [27]. Given that horses that developed an incisional hernia were 7–14 times less likely to return to athletic use [18,28], strategies to minimise the risk of SSI are therefore important.

The definition of, and variable use of, terms such as incisional infection/suppuration, drainage and SSI differ greatly between studies, making it difficult to make accurate comparisons. Frequently incisional drainage has been defined by its physical characteristics (haemorrhagic, serous/serosanguinous or purulent) [29–31]. Some studies have defined infection as purulent discharge only from the incision [21,32,33], whereas others have defined this as any type of incisional drainage [23,34–37] and irrespective of bacterial growth following swabbing of the surgical site. The definition of incisional oedema also varies between studies with some authors considering this to be a normal, physiological consequence of laparotomy rather than a surgical complication [38]. Incisional oedema is common in horses following laparotomy [29] with one study reporting a prevalence of 74.1% [31]. Incisional dehiscence has a relatively low prevalence of 1–4% [29,31,32] and may be limited to the skin and subcutaneous tissues (superficial) or include the *linea alba* (deep) resulting in potentially fatal visceral prolapse [29]. Incisional hernia formation has been reported in 6–17% of horses following laparotomy [18,29,32,39] and was most commonly identified 2–12 weeks post operatively [39,40]. Failure of studies to extend the follow-up period beyond the time of hospitalisation is likely to underestimate the prevalence of incisional complications as a proportion of SSI (13–100%) can still develop following hospital discharge [35,37]. The duration and quality of follow-up (owner vs. veterinary reports) is also highly variable between studies.

Risk factors and prevention

Multiple studies have reported on prevalence of incisional complications and risk factors for each and are summarised in Supplementary Item 1. Different pre-, intra- and post operative factors have been identified to alter the likelihood of incisional complications, and these vary between studies. Preoperative antimicrobial prophylaxis is standard practice prior to horses undergoing laparotomy [41,42]. However, some studies have demonstrated poor adherence to best practice in antimicrobial usage in terms of dosing and optimal timing before surgery [37,42]. In human medicine, guidelines for

preoperative antimicrobial prophylaxis comprise drug administration within 60 min of the surgical incision being performed and re-dosing when surgery time surpasses 2 half-lives of the drug [43]. However, evidence of similar best antimicrobial practice in equine colic surgery and any impact of this on the incidence of SSI is lacking, and is an area that requires future research. Post operatively, the type of antimicrobial administered has not been shown to be significantly associated with incisional SSI [44]. The duration of antimicrobial therapy following laparotomy is variable between studies and the optimal duration of therapy is also unknown. A recent study reported that the prevalence of SSI did not differ in horses that received antimicrobials for 72 h vs. 120 h post operatively [24]. These findings are consistent with human studies in which extended duration of antimicrobial prophylaxis failed to decrease the incidence of SSI after gastrectomy compared with single dose prophylaxis [45].

Clean contaminated surgeries have been associated with increased risk of SSI, suggesting a potential role of intestinal bacteria in the establishment of incisional infection [33,46]. However, many studies have reported no relationship between SSI and whether enterotomy was performed or not [22,30,32,36,39]. In addition, bacterial cultures taken from peritoneal fluid, enterotomy or resection and anastomosis sites intraoperatively and from the *linea alba* after its closure failed to predict the occurrence of SSI [34,47]. One study reported poor intraoperative drape adherence, high surgery room contamination and isolation of bacteria after anaesthetic recovery as significant risk factors for SSI [35]. These findings suggest that environmental contamination of the surgical site during and following anaesthetic recovery may play a major role in development of SSI, and that protection of the abdominal incision during recovery from anaesthesia and in the early post operative period may be beneficial [34]. A prospective, randomised controlled trial assessing the use of an abdominal bandage to protect the surgical incision placed immediately after recovery from general anaesthesia resulted in 45% absolute risk reduction of incisional complications [31]. Protection of the abdominal incision with a stent bandage during anaesthetic recovery followed by placement of an abdominal bandage following stent removal was reported to result in a significant reduction in the likelihood of SSI in a more recent study [23]. Further prospective, randomised controlled trials using well-defined outcomes and variables are required to evaluate the role of stent/abdominal bandages and other interventions in altering the prevalence of SSI in different hospital populations.

There is also no clear evidence about the optimal method for closing the abdominal incision and various suture materials, suture patterns and use of skin staples have been evaluated (Supplementary item 1). Three layer closure (*linea alba*, subcutaneous tissue and skin) of the laparotomy incision was reported in one study to decrease the risk of incisional drainage during hospitalisation [31]. In contrast, Coomer *et al.* [30] reported no significant difference in incisional suppuration between the 2 (*linea alba* and skin) vs. 3 layer closure techniques. Recently, a modified 2 layer closure technique was reported to decrease the risk of incisional drainage [20]. The timing and duration of follow-up may explain the differences between these studies as demonstrated by different risk factors identified by Smith *et al.* [31] at different time points post operatively. Abdominal bandages have been shown to achieve different sub-bandage pressures dependent on the type of bandage used [48] and this may have an impact on incisional healing. It is therefore important that studies appraising different methods of abdominal wall closure take into account the effect of whether abdominal bandaging was performed or not, the type of abdominal bandage used, frequency of bandage changes and duration of use.

Prolonged duration of general anaesthesia has been associated with greater risk of incisional complications [29,31,37] and a recent study also identified increased risk of incisional SSI with hypoxaemia (PaO_2<80 mmHg) [49]. Repeat laparotomy has been consistently identified to increase the risk of SSI with a reported prevalence of 44–84% [9,21,32] and to increase the risk of incisional hernia formation 12-fold [39]. Surgical site infection/incisional drainage and severe oedema are factors consistently identified to increase the risk of incisional herniation [31,34,39,44,50]. There is no current evidence that the time between initial and repeat laparotomy or location of the incision for repeat laparotomy (original midline vs. paramedian incision) has an effect on likelihood of hernia development. The use of a commercial hernia belt was reported to reduce the incidence of incisional hernia development in horses that developed other incisional complications [51]. However, the study was retrospective in nature and did not have a comparison group, making it difficult to assess the efficacy of this intervention fully.

Post operative pain/colic

Post operative pain/colic is a common complication following surgical management of colic, occurring in 11–35% of horses post operatively [19,21,50,52]. It is also the most common cause of post operative death or euthanasia [13,19,46,53,54] and post operative pain during hospitalisation has been significantly associated with reduced survival [55,56]. The prevalence of post operative colic varies depending on the location of the primary gastrointestinal lesion. Rates of up to 61% have been reported following small intestinal resection and anastomosis [10,57] and 41% in horses that had strangulating large colon lesions [58]. It is difficult to make accurate comparisons between studies as different definitions (e.g. 'pain', 'abdominal pain', 'colic/pain') are used and rarely are objective measures of pain used. It is therefore important that where post operative pain is investigated as an outcome or as a risk factor for development of other post operative complications, objective and validated measures specifically designed to measure equine visceral or post abdominal surgical pain are utilised [55,59,60].

In many cases, the definitive cause of post operative pain/colic is unknown as episodes may resolve spontaneously or following medical therapy. In addition, if euthanasia is performed on the basis of unrelenting pain/colic and a second surgery is not an option, it is impossible to be certain about the cause of colic recurrence unless *post mortem* examination is performed, which may be infrequent outside hospital facilities [61]. Post operative colic may be due to recurrence of the initial gastrointestinal lesion, intestinal obstruction related to adhesions or anastomotic complications, or the development of gastrointestinal lesions unrelated to the initial lesion [62]. Post operative pain may also be related to post operative ileus (POI) and nongastrointestinal causes including incisional infection and peritonitis [60]. Horses that undergo surgical correction of right dorsal displacement of the large colon have been shown to be more likely to develop post operative colic (prevalence 41.9%) compared with other forms of large intestinal displacement including left dorsal displacement (8.3%) and nonstrangulating volvulus (20.5%) [63]. Left dorsal displacement of the large colon was associated with a recurrence rate of 8.1–20% following surgical or nonsurgical correction in 2 other studies [64,65]. Post operative colic was also 3 times more likely to occur in horses that underwent correction of strangulating large colon torsion (volvulus) compared with other surgical lesions [44]. The type of surgical procedure performed has also been shown to alter the likelihood of post operative colic. Mechanical obstruction at the site of an intestinal anastomosis due to reduction in normal luminal diameter and functional obstruction due to altered motility of adjacent segments of gut are hypothesised as possible causes of post operative colic in horses that have undergone small intestinal resection and anastomosis [12,66]. Horses in which a side-to-side jejunocaecostomy was performed are reported to be at increased risk of developing colic post operatively compared with those horses where an end-to-end jejunojejunostomy was performed [67]. In addition, stapled side-to-side jejunocaecostomy has been associated with a greater prevalence of post operative colic (60%) compared with hand-sewn side-to-side jejunocaecostomy (9%) [66]. Jejunocaecostomy has also been associated with significantly reduced survival following hospital discharge compared with end-to-end jejunojejunostomy and jejunoileostomy [12]. In the latter study, a greater proportion of horses undergoing jejunoileostomy underwent repeat laparotomy during hospitalisation due to persistent post operative reflux compared with the other 2 anastomosis groups but this anastomosis had no significant effect on short- or long-term outcome. While the nature of the surgical lesion may limit the choice of small intestinal anastomosis, this knowledge enables post operative complications to be predicted more accurately.

Prevention

Prevention and management of post operative pain is usually based on administration of nonsteroidal anti-inflammatory drugs (NSAIDs) to provide analgesia and to reduce the inflammatory response. Due to

concerns about the detrimental effect of flunixin meglumine (a nonselective COX-1 and COX-2 inhibitor) on mucosal recovery of intestine, the use of other NSAIDs that are selective COX-2 inhibitors including firocoxib and meloxicam has been suggested based on the results of *in vitro* studies utilising equine jejunum [68,69]. However, other *in vitro* studies found that flunixin meglumine had no effect on recovery of equine colonic mucosa following ischaemic injury [70] and that administration of systemic lidocaine reduced the inhibitory effects of flunixin meglumine on recovery of the mucosal barrier [71]. A recent survey of European Equine Internal Medicine and Surgery Diplomates demonstrates that at present, flunixin meglumine remains the most frequently used NSAID following surgical treatment of colic in Europe [72]. Currently there is no evidence of improved outcome with alternative use of selective COX-2 inhibitors. In a randomised controlled trial comparing flunixin meglumine and meloxicam in horses following surgical management of strangulating small intestinal lesions [14], flunixin meglumine was significantly more effective than meloxicam in reducing pain scores but there was no difference in outcome between the 2 groups. Further randomised controlled trials using large numbers of horses in multicentre studies, providing sufficient study power, are warranted to determine the effect of COX-2 inhibitors such as firocoxib on outcome compared with flunixin meglumine. Continuous rate infusion (CRI) of lidocaine or butorphanol are also used by some clinicians. Rigorous appraisal of lidocaine CRI as a post operative analgesic has not been performed. In a study by Malone *et al.* [73], there was no significant difference in post operative pain between horses that did or did not receive lidocaine. However, pain was assessed subjectively, and because the study was relatively small in size, may have lacked power to detect a difference between the two groups. Butorphanol CRI has been shown to result in improved behavioural pain scores in a prospective randomised, controlled, blinded clinical trial [74]. However, the effects of butorphanol on gastrointestinal motility, particularly in horses at high risk of POI have not been fully investigated. Evidence suggests that the nature of the primary gastrointestinal lesion and requirement for certain surgical procedures to be performed (e.g. jejunocaecostomy) may place some horses at an inherent increased risk of post operative colic both in the short- and long-term, which therefore may be difficult to prevent. Laparoscopic ablation of the nephrosplenic space has been described as a technique to prevent recurrence of left dorsal displacement of large colon [64,75]. However, while this may physically prevent recurrence of nephrosplenic entrapment, there is no evidence that this reduces the likelihood of colic recurrence long-term. Colopexy may be indicated in some horses that have recurrent large colon displacement or torsion [76]. However, complications including post operative colic or colon rupture can occur making appropriate case selection important [77,78]. Closure of the epiploic foramen to prevent intestinal entrapment within the foramen is under current investigation [79,80]. The results of clinical trials will be needed before these can be appraised as methods to prevent epiploic foramen entrapment or its recurrence.

Post operative ileus and post operative reflux

Prevalence and risk factors

Post operative ileus has been demonstrated by multiple studies to have a negative effect on survival [10,21,36,81], to increase the likelihood of repeat laparotomy [44], development of laminitis and incisional drainage and to increase treatment costs significantly [82]. The reported prevalence of POI varies from 6.3% to 53% and was a reason for euthanasia or death of 9–43% of horses that had undergone surgical management of colic in these populations [19,36,46,81,83–86]. The criteria used to define POI differ, making it difficult to make accurate comparisons between some studies (Supplementary Item 2). While there is some variation in findings between studies, elevated heart rate and packed cell volume (PCV) on admission, small intestinal lesions, evidence of intestinal ischaemia and intestinal resection and anastomosis are factors that have consistently been identified to increase the likelihood of POI developing post operatively.

More recent studies have used an alternative term, 'post operative reflux' (POR), defined as >2 l reflux after nasogastric tube passage at any time during the post operative period [12,87]. The latter studies argued that without undertaking repeat laparotomy, in the majority of cases of horses with POR it is impossible to identify definitively the underlying pathophysiology resulting in nasogastric reflux. This highlights the need for common terminology, definitions and outcomes to be utilised by researchers. It would appear prudent to utilise the more generic term 'POR' in future studies but to also measure duration and quantity of reflux and to assign the diagnosis of POI as an additional variable/outcome measure where other causes of POR can be excluded.

Prevention

Early referral of horses for surgical management of colic, prior to development of cardiovascular derangements and progression of intestinal distention and compromise is therefore important in reducing the likelihood of POI developing. Evacuation of colonic contents via a pelvic flexure enterotomy reduced the risk of POI in one study [86]. However, a further study demonstrated that while pelvic flexure enterotomy was protective for large intestinal lesions it increased the risk of POI in horses with small intestinal lesions [82]. Therefore, in horses considered to be at high risk of POI that have small intestinal lesions, evacuation of colonic contents might best be reserved only for horses with large quantities of ingesta within the large colon.

A variety of medical therapies that are currently used to prevent and manage POI include flunixin meglumine, lidocaine, butorphanol, metoclopramide, erythromycin, morphine and neostigmine [72]. However, there have been relatively few clinical trials undertaken to determine the efficacy of these in preventing and managing POI. In a prospective, blinded, randomised clinical trial [88], significant differences in ultrasonographic measurements of jejunum, an intestinal function index and ultrasonographic identification of peritoneal fluid were demonstrated between lidocaine CRI (initiated intraoperatively) and placebo (saline) treated groups. There were no significant differences between time to first defaecation or the proportion of horses that survived to hospital discharge. This study included 18 horses with large colon lesions and 8 horses with small intestinal lesions (4 treatment and 4 placebo). A separate prospective, double-blinded, placebo-controlled trial conducted by Malone *et al.* [73] demonstrated that treatment with lidocaine for 24 h significantly reduced the proportion of horses refluxing at 30 h, the rate of reflux after initiation of treatment and days of hospitalisation compared with the placebo (saline) group. There was no difference in proportion of horses that survived to discharge home between the 2 groups. It is very important to note that the latter study has some key limitations including the fact that it was performed on a relatively small number of horses, with consequent low study power, and included horses with both proximal duodenitis-jejunitis treated medically and POI (8 proximal duodenitis-jejunitis and 24 POI horses), which are lesions with different pathobiology and relevance when considering post operative complications. In a retrospective study of 126 horses that recovered following small intestinal surgery, lidocaine therapy (initiated intraoperatively and continued post operatively) resulted in a 3-fold increase in likelihood of survival to hospital discharge in horses with POI and a 3-fold reduction in likelihood of POI developing [36]. In the latter study, some horses received concurrent metoclopramide but this had no significant effect on likelihood of POI developing. Continuous i.v. infusion of metoclopramide in POI was reported in another retrospective study to result in a significant decrease in the rate and volume of gastric reflux obtained and a shortened duration of hospitalisation compared with horses with POI where metoclopramide was administered as an intermittent infusion or was not administered [89]. They found no significant differences in the survival rate to hospital discharge among the treatment groups.

Therefore, there is a need for prospective, large (i.e. sufficient study power), and potentially multicentre randomised controlled clinical trials to be conducted on therapies and strategies to manage POI. It is important that there is a consensus on the criteria by which POI is defined and which is consistently used between studies, including rigorous differentiation of horses with true primary POI and ileus secondary to mechanical causes [90,91] and that study populations are well defined, e.g. only horses

undergoing small intestinal surgery. This is essential if multicentre studies are to be conducted effectively and in enabling accurate comparisons to be made between studies. Treatments for POI can be expensive, almost doubling the costs of treatment in one study [82]. The benefits of medical therapies for prevention and treatment of POI, including therapies being considered for future development [92] on outcome vs. economic costs also need to be considered.

Intra-abdominal adhesions

Prevalence and risk factors

Intra-abdominal adhesion formation that was considered to be pathological in nature has been reported in 9–27% of horses undergoing repeat laparotomy or *post mortem* examination following gastrointestinal surgery [61,93,94]. Given that adhesions may not result in clinical signs of pain or gastrointestinal obstruction and definitive diagnosis is only possible at repeat surgical exploration of the abdomen or necropsy, the prevalence of post operative adhesions is likely to be underestimated following surgical management of colic [61]. Confirmed formation of adhesions was reported in 6–22% of horses following small intestinal surgery [9,22,95], in 8–17% in foals and young horses (age <2 years) following laparotomy for any reason [15,96–98] and in 32% of horses undergoing repeat laparotomy [61]. Comparison of prevalence reported between studies is difficult due to differences in study design. For example, in the study by Gorvy *et al.* [61] only horses that underwent repeat laparotomy were included while in the other studies, the primary surgical colic case cohorts were used.

Factors that have been identified to increase the risk of adhesion formation include small intestinal surgery [22,94,99] and performing intestinal resection and anastomosis [22,50]. One study of 99 horses that underwent repeat laparotomy demonstrated that adhesions develop irrespective of the site of the primary lesion [61]. This and other studies concluded that resection and type of anastomosis were not associated with increased likelihood of intra-abdominal adhesion formation [61,95,99].

Preventive measures

Clinicopathological parameters measured on hospital admission have been shown to have no effect on likelihood of development of intra-abdominal adhesion formation after surgery for management of colic. This would suggest that adhesion formation is more likely to be related to surgical trauma rather than systemic inflammatory response syndrome (SIRS)/hypercoagulable systemic state [61,95]. Assessment of coagulation and coagulopathies is not commonly performed perioperatively in horses but is an area for further research [100] to determine whether this may assist more accurate prediction of complications such as adhesion formation and likelihood of post operative mortality and morbidity. Therapies that have been proposed to prevent adhesion formation based on laboratory animal models, some models utilising healthy horses and work performed in man [101–105] include peritoneal lavage, systemic administration of low-dose heparin, and chemical agents to physically separate serosal and peritoneal surfaces such as 1% high molecular sodium carboxymethylcellulose (SCMC), hyaluronate/SCMC spray and bioresorbable barriers such as hyaluronate/SCMC membrane.

Local therapies that have been investigated in colic cases include use of a hyaluronate/SCMC membrane covering a continuous Lembert suture pattern. This showed no superiority over an uncoated interrupted Lembert pattern for performing a one-layer jejunojejunostomy in terms of post operative survival rate and prevalence of post operative complications [106]. This might not be surprising if the findings of Gorvy *et al.* [61] are to be accepted, i.e. adhesions are not specifically related to the site of the primary lesion. Omentectomy has been proposed as a method to prevent adhesion formation but had no significant effect on colic related adhesions found at repeat laparotomy [99].

Abdomen-wide therapies have also been investigated in equine clinical studies. SCMC solution was shown in one retrospective study to have no effect on rates of short- and long-term survival and the incidence of post operative complications following exploratory laparotomy [107]. In contrast, another retrospective study by Fogle *et al.* [56] demonstrated a significant positive effect of SCMC solution on post operative survival. Due to the nonrandomised and retrospective nature of the latter 2 studies, both had some limitations due to bias. A prospective, randomised controlled trial to assess the use of SCMC is warranted. One study found a protective effect of use of intraperitoneal heparin therapy in reducing intra-abdominal adhesion formation [50]. However, as acknowledged by the study authors, the findings from this study should be viewed with caution as only univariable analysis was performed, preventing assessment of the effect of potential confounders.

Therefore, much of the evidence on how adhesions may be prevented is inconclusive, due to the relatively small number of studies and their largely retrospective nature, with resultant inherent biases. This demonstrates the need for prospective, randomised controlled trials to appraise fully the evidence for use of surgical strategies or therapies to prevent adhesion formation. Given that therapies used to prevent adhesions in human patients are designed to be used in a much smaller abdominal cavity, cost–benefit analysis of use of these products and effect on outcome would also be important. One of the greatest challenges is in correctly determining whether adhesions are present or not and proxy endpoints, e.g. post operative colic where surgical or *post mortem* examination cannot be performed may be the only current practical outcome measure. Biomarkers for adhesion formation would be a potentially important area for future investigation.

Post operative diarrhoea

Post operative diarrhoea increases costs of treatment, reduces survival and post operative performance, and increases the risk of nosocomial infection developing in other horses within the hospital environment [18,108]. Its prevalence varies widely depending on the location and pathology of the primary gastrointestinal lesion and on the geographical location of horses. Diarrhoea is usually defined as passage of unformed faeces for more than 24 h [21,109] or on 2 or more consecutive occasions [110] following surgical treatment of colic. However, in many studies, case definition is poorly described.

Horses diagnosed with large intestinal lesions were significantly more likely to develop diarrhoea post operatively compared with other intestinal lesions [111]. Diarrhoea has been reported to be a frequent complication following surgical correction of strangulating large colon volvulus (28–45%) [58,109], treatment of sand impaction of the large colon (46%) [112] and following removal of large colon enteroliths (20%) [110]. Horses treated surgically for small colon diseases were shown in one study to be 17 times more likely to develop diarrhoea post operatively compared with other surgical lesions [113], with the prevalence of diarrhoea ranging from 11% to 70% [113–115]. This complication was not as frequent following small intestinal resection and anastomosis with reported prevalences of 2.7–25% [9,10]. The prevalence of post operative diarrhoea would also appear to be higher in some studies based in the USA (varying from 1.3% to 53.2%) [18,82,84,111,116] compared with the UK (3.2–3.8%) [19,21]. This is interesting and could potentially reflect differences in gastrointestinal microbial ecosystems and environmental conditions (e.g. temperature, humidity) that vary geographically. This observation merits further investigation.

Despite the high prevalence of diarrhoea following surgical treatment of colic, it is usually self-limiting [109,114]. Infectious agents such as *Salmonella* spp. and *Clostridia* spp. are seldom isolated from affected horses [114,116]. Studies that have conducted active surveillance for faecal shedding of *Salmonella* spp. in horses admitted with clinical signs of gastrointestinal disorders demonstrated that *Salmonella* spp. were isolated from the faeces of a large proportion of horses that did not develop clinical salmonellosis post operatively (43–74%) [108,116,117]. Molecular studies of the horse's hind gut microbiota provides evidence to suggest that colitis arises as a result of imbalance among the different microbial species in the gut (dysbiosis) rather than a disease caused by a single bacterial species [118]. Development of diarrhoea in colic cases post operatively is likely to be due to a combination of factors including the nature of the primary gastrointestinal lesion and concurrent changes in gut motility, surgical manipulation of the gastrointestinal tract and administration of antimicrobials that may disrupt the normal microbial ecosystem

[108,119,120]. Characterisation of hindgut microbial communities using nonculture-dependent techniques in normal horses and those that have undergone surgical management of colic would assist in determining whether there is evidence for the use of interventions such as administration of probiotics or certain feeds to manipulate these ecosystems, enabling these to return quickly to a potentially 'normal, presurgical state'.

Prevention

Clinical trials evaluating the efficacy of probiotics administered following colic surgery to minimise shedding of *Salmonella* spp. and development of diarrhoea have not shown any significant effect on these outcomes [116,121]. A prospective, randomised controlled trial evaluated the efficacy of post operative administration of di-tri-octahedral smectite (vs. water placebo) for 3 consecutive days following surgery in 67 horses. These were horses that had undergone surgical treatment of a large colon disorder, including pelvic flexure enterotomy, and a faecal scoring system was used to objectively assess outcome. There was a significant reduction in the prevalence of post operative diarrhoea in the treatment group (10.8%) vs. the placebo group (41.4%) [122], which would support the use of this agent to reduce the likelihood of post operative diarrhoea in horses with surgical diseases of the large colon.

Systemic inflammatory response syndrome, endotoxaemia and related complications

The SIRS and presence of bacterial endotoxins in the circulation (endotoxaemia) are common in horses that present with colic. SIRS was evident in 28% of horses in a study by Epstein *et al.* [100] of which 37% had lesions requiring surgical intervention. Plasma endotoxin was also detected in 29% of horses presenting with colic in a study by Senior *et al.* [123]. Markers of endotoxaemia/SIRS including tachycardia, elevated PCV and altered mucous membrane colour have consistently been shown to be one of the most reliable determinants of post operative morbidity (and mortality) in many studies assessed in this review. Therefore, strategies to prevent or attenuate the effects of endotoxaemia/SIRS could theoretically reduce the prevalence of post operative complications. This is an area of current, active work in research models and is therefore beyond the scope of this review. An update on current findings has recently been summarised by Moore and Vandenplas [124]. In the studies appraised, standard post operative care following surgical management of colic includes use of NSAIDs, i.v. fluids and in some studies, use of polymixin B, in horses with evidence of or that are at high risk of endotoxaemia/SIRS. Of note, there is no current evidence to support the use of polymixin B once signs of SIRS are evident.

Endotoxaemia has been identified to increase the likelihood of thrombophlebitis [44,125,126] and laminitis [127]. The prevalence of thrombophlebitis in post operative colic patients varies from 1.3% to 18% [8,10,14,19,21,37,42,84,109,125]. Risk factors for catheter-associated thrombophlebitis identified in one study were endotoxaemia, salmonellosis, low systemic total protein and location in which they were hospitalised [126]. Other studies identified tachycardia and elevated PCV at admission [44], prolonged duration of catheterisation, post operative diarrhoea [125], colic and endotoxaemic shock (SIRS) [21,44,126] post operatively to increase the risk of this complication. These findings are consistent with horses that are likely to be in a hypercoagulable state, explaining the greater propensity for horses that have undergone surgical management of colic to develop catheter-associated complications compared with other groups of horses [128]. Heparin therapy has been suggested as a way in which the risk of thrombophlebitis might be reduced post operatively. However, at present there is a lack of evidence to support its use [129,130]. Frequent ultrasonographic examination of the catheter site in high-risk horses to monitor for increased thickness of the vessel wall and visible thrombus formation would be indications to remove the catheter prior to development of overt clinical signs of thrombophlebitis [131].

The frequency of post operative laminitis following surgical management of colic varies between studies, with prevalences of 0.4–12% reported [10,19,21,22]. Distal limb cryotherapy may be used to attenuate laminar damage [132]. There are no reports of its effectiveness specifically in horses following surgical management of colic but there is evidence to suggest that its use should be considered in horses with clinical evidence of SIRS/endotoxaemia that are at increased risk of developing this complication.

Other post operative complications and future interventions

The prevalence of other complications that may occur following surgical management of colic is generally low. These include septic peritonitis [10,14,21,57,84], haemoperitoneum [12], intraluminal haemorrhage [133], myopathies, gastric rupture [12], cardiac arrhythmias and derangements in electrolytes [134], clotting disorders and disseminated intravascular coagulation, pre- and post operative renal azotaemia and renal failure [10,84]. Treatment and preventive strategies for these are detailed elsewhere [135–138].

Nutrition of the post operative colic case is an area that has been investigated infrequently [139–141] and evidence about nutritional strategies to optimise patient survival and minimise post operative complications are lacking [142]. Intestinal microbiota and changes that may precede colic development or develop subsequent to surgical management of colic are areas of current research. Such studies may further our understanding of equine gut health and interventions to minimise post operative complications such as colic.

A study that measures 'disease burden' of surgical management of colic that considers that the prevalence, economic costs and welfare issues arising from post operative complications may be useful in order to prioritise future research in this area. It is important that future studies have suitable outcome measures to assess the effectiveness of new therapies or management strategies. Use of survival rates as sole measures of success should be avoided as euthanasia is a complex area and issues such as selection bias may occur [143].

Conclusions

Early surgical intervention, prior to the development of cardiovascular derangements and marked intestinal distention, remains key in preventing or reducing many post operative complications that may develop following surgical treatment of colic. There is a lack of current evidence of the efficacy of some interventions proposed to reduce the incidence of, or prevent, specific post operative complications. In addition, there is a need to better understand the pathobiology of post operative complications in order to develop better preventive strategies. The results between studies are often highly variable and sometimes contradictory due to inconsistent definitions and outcome measures used. Therefore, there is a need for clinical veterinary researchers to make concerted efforts to adopt common terminology, definitions and outcome measurements, and a continued need for well-designed and co-ordinated, prospective, large, suitably powered (multicentre, international) studies with common goals of research. New therapies and ways in which post operative colic cases are managed may improve mortality and morbidity rates in the future. However, these may add to the expense of treatment, which has important implications in keeping surgical treatment of colic affordable for horse-owners [144]. Appropriate and aggressive primary treatment of intestinal obstructions can be expensive but may provide a better outcome without the expense of treating post operative complications (both short- and long-term). It is essential that studies investigating new therapies and management strategies not only undertake rigorous prospective testing of their efficacy in a suitable number of relevant clinical cases and using appropriate outcome measures, but also that they report and consider the economic costs vs. benefits of these interventions before these are promoted for widespread clinical use.

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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: Summary of studies that have specifically investigated prevalence rates and risk factors for post operative incisional complications.

Supplementary Item 2: Summary of studies reporting prevalence of and risk factors for post operative ileus.