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Article

Incidence of incisional complications after exploratory celiotomy in equids affected with enterolithiasis

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Abstract — This study reports the prevalence of and risk factors for incisional complications in equids after ventral midline celiotomy for enterolithiasis. This study covered the years 2008 to 2015 and included 72 equids. Enteroliths were removed from the ascending or descending colon through 1 or more enterotomies. Complications were defined as surgical site infection and/or incisional hernia formation. Follow-up by telephone questionnaire or medical records determined that 10/72 (13.9%) equids experienced complications, with 6/72 (8.3%) developing a surgical site infection and 5/72 (6.9%) a hernia. Seven of ten were presented for chronic abdominal discomfort (> 24 hours), and 8/10 had right dorsal colon and pelvic flexure enterotomies. All equids that developed an incisional hernia and 4 with surgical site infection had enteroliths > 15 cm diameter removed from the right dorsal colon. Antimicrobial powder applied to the ventral midline incision during closure significantly reduced incisional complications. Removal of > 15 cm diameter enteroliths from the right dorsal colon may predispose to postoperative incisional complications.

Résumé — Incidence des complications incisionnelles après une céliotomie exploratoire chez des équidés atteints d'entérolithiase. Cette étude rapporte la prévalence et les facteurs de risque des complications incisionnelles chez les équidés opérés pour l'entérolithiase en utilisant une celiotomie médiane ventrale de 2008 à 2015. Soixante-douze équidés ont été inclus. Les entérolithes ont été retirés du côlon ascendant ou descendant par ≥ 1 entérotomies. Les complications étaient définies comme une infection du site opératoire et/ou la formation d'une hernie incisionnelle. Le suivi a été obtenu par questionnaire téléphonique ou par dossiers médicaux. Dix des 72 (13,9 %) des équidés ont eu des complications, dont 6/72 (8,3 %) ont développé une infection du site opératoire et 5/72 (6,9 %) une hernie. Sept sur 10 ont été présentés pour un malaise abdominal chronique (> 24 heures) et 8/10 avaient des entérotomies du côlon dorsal droit et de la flexion pelvienne. Tous les équidés ayant développé une hernie incisionnelle et quatre avec une infection du site opératoire avaient des entérolithes > 15 cm de diamètre prélevés du côlon dorsal droit. La poudre antimicrobienne appliquée sur l'incision médiane ventrale lors de la fermeture réduisait significativement les complications incisionnelles. Le retrait d'entolithes de > 15 cm de diamètre du côlon dorsal droit peut prédisposer aux complications incisionnelles postopératoires.

(Traduit par les auteurs)

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Introduction

Enterolithiasis is a significant cause of abdominal pain in equids, with abdominal pain developing secondary to partial or complete obstruction of the ascending colon (AC) descending colon (DC), or transverse colon (TC). Prevalence of enterolithiasis has been reported to range from 1.7% to 15.1% in certain geographical regions of the United States, particularly in California, Florida, and Texas, and occurs sporadically in other parts of the world (1–4). Most often, horses are presented for mild to moderate intermittent abdominal discomfort (5–7) or a history of recurrent colic (4), but others are presented with signs of acute, severe abdominal pain (8). Surgical removal

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through ventral midline incision with subsequent enterotomy is the treatment of choice, and successful removal was reported as early as 1877 (8,9).

Success rates following surgical removal of enteroliths are good to excellent (2,10), with short-term survival ranging from 94% to 96.2% (4,11), and long-term survival from 85% to 92.5% (4,10,11). Nevertheless, exploratory celiotomy in equids is not without risk for potential complications, with incisional complications being one of the most commonly reported problems following ventral midline celiotomy (12).

Several studies have reported incisional infection as a complication following exploratory celiotomy, with an incidence ranging from 2.7% to 42% (13,14). Pre- and peri-operative factors identified as predisposing factors for postoperative incisional complications include anamnesis, signalment, and several pre-, intra-, and postoperative variables (12,13, 15–30). Incisional infection, dehiscence, and hernia formation have been reported to be of particular concern following enterotomy (12). However, other studies did not support the finding that enterotomy influenced the development of incisional complications (11,15,17,18,31).

Several studies reported that ventral abdominal hernia formation was most common in equids that had developed postoperative incision drainage or infection (18,22,32). In 1 study, equids that experienced an incisional infection were 17.8 times more likely to develop a hernia compared to equids that did not develop infection (18). In another study, purulent incisional drainage preceded development of a hernia in 48% of cases (33). Furthermore, the odds of incisional hernia formation were 62.5 times greater for horses that had incisional drainage after surgery, and incisional drainage and herniation negatively influenced survival (34).

Regarding enterolithiasis, incisional complications following exploratory celiotomy have been reported, with a prevalence between 12.9% and 44.1% (4,35). However, investigating specific risk factors associated with incisional complications was not the focus of these studies. One study found no statistical significance between location of enteroliths (AC or DC) and incidence of incisional complications, although more complications developed when enteroliths were removed from the DC (11).

To our knowledge, specific pre-, intra-, and postoperative factors contributing to incisional complications following enterolith removal have not been investigated. The objectives of this study were to report the prevalence of incisional complications following enterolith removal through ventral midline celiotomy, determine if there is increased risk for incisional complications following AC enterotomy compared to DC enterotomy performed for enterolith removal, determine whether the risk for incisional complications increased with increased number of enterotomies, and determine if enterolith size and location of enterotomy influenced the incidence of incisional complications in equids following enterolith removal. We hypothesized that the overall rate of incisional complications would be low for horses with enteroliths removed *via* ventral midline celiotomy, that the incidence of incisional complications would be similar when enteroliths were removed from either the AC or DC, and that increasing the size and number of enterotomies necessary for removal of enteroliths would be associated with an increased rate of incisional complications.

Materials and methods

Case selection

Medical records from the William R. Pritchard Veterinary Medical Teaching Hospital at the University of California-Davis were reviewed to identify equids that underwent exploratory celiotomy for enterolithiasis affecting the AC, DC, and/or TC between January 1, 2008, and June 30, 2015. A tentative diagnosis of enterolithiasis was made if 1 or more radiopaque spherical structures were identified on a complete abdominal radiographic study, with definitive diagnosis made following identification of 1 or more enteroliths during exploratory celiotomy.

Equids were included in the study if they recovered from anesthesia, survived $>$ 4 mo after surgery, and follow-up information was available.

Medical records review

Pre-operative data collected included signalment, body weight, physical examination findings, results of complete blood cell count, serum biochemistry and peritoneal fluid analysis, and results of abdominal radiography. Duration of colic signs was recorded and considered acute for equids displaying signs of abdominal discomfort of $<$ 24 h and chronic for cases displaying signs for $>$ 24 h.

Intra-operative data collected included duration of surgery, length of ventral midline incision, location of enteroliths (AC, DC, and/or TC), additional lesions discovered at surgery, hypoxemia (PaO_2 $<$ 65 mmHg), or hypotension during anesthesia (MAP $<$ 65 mmHg for $>$ 15 min), and quality of recovery. Additional intra-operative data collected included suture material used for subcutaneous closure, topical administration of an antimicrobial following closure of the linea alba and type of incisional protection applied for recovery from anesthesia.

Postoperative data collected included duration of hospitalization and administration of systemic antimicrobial and anti-inflammatory medications, development of colic, fever, and results of hematologic evaluation when available. Incisional complications were defined as persistent incisional drainage with or without positive bacterial culture which was considered indicative of surgical site infection, and hernia formation.

Surgical technique

Prior to surgery, an IV catheter was inserted into the left jugular vein using aseptic technique. All equids were administered parenteral broad-spectrum antimicrobials and tetanus prophylaxis 30 min before induction of general anesthesia. Flunixin meglumine (Intervet, Madison, New Jersey, USA), 1.1 mg/kg body weight (BW) IV, was administered unless the horse had already received an NSAID 6 to 8 h before surgery.

Following induction of anesthesia and orotracheal intubation, equids were mechanically ventilated, and anesthesia was maintained using isoflurane in 100% oxygen. Equids were placed in dorsal recumbency and hair was removed from the ventral abdomen using electric clippers. For intact males and geldings, the prepuce was cleaned, packed with gauze and sutured closed

or closed with towel clamps. Preparation of the skin for each member of the surgical team consisted of a 5-minute scrub of the hands and forearms with a scrub brush using 4% chlorhexidine gluconate (BD E-Z Scrub 107; Becton, Dickinson and Company, Franklin Lakes, New Jersey, USA) followed by application of an 85% ethyl alcohol-based rub (Sterillium Rub; Medline Industries, Northfield, Illinois, USA).

Following aseptic preparation of the ventral abdomen, an iodine impregnated adhesive drape (Ioban; 3M Health Care, St. Paul, Minnesota, USA) was applied and the surgical site draped routinely. A ventral midline incision was created using a #10 scalpel blade, beginning at the umbilicus and extending cranially. The incision was carried through the subcutaneous tissues and was lavaged with sterile 0.9% irrigation saline. A new #10 scalpel blade was used to incise the linea alba.

The large colon was exteriorized and placed on a colon tray (Colon Tray; Kimsey Welding Works, Woodland, California, USA). An enterotomy was created at the pelvic flexure (PF) and contents of the AC were evacuated. When size permitted, enteroliths within the TC or right dorsal colon (RDC) were mobilized to the PF enterotomy and removed. Larger enteroliths located in either the RDC or TC were mobilized as far orad as possible and removed through a second enterotomy created at the antimesenteric border of either the RDC or left dorsal colon (LDC). Enteroliths located within the DC were removed through an enterotomy created through the antimesenteric band. All enterotomies were closed in 2 layers using #2-0 USP polydioxanone (PDS; Ethicon, Somerville, New Jersey, USA). A full thickness simple continuous pattern was placed and oversewn in a Cushing pattern. The colon was replaced in the abdomen and intra-abdominal lavage performed using sterile 0.9% irrigation saline prior to abdominal closure. The linea alba was closed in a simple continuous pattern using #3 USP polyglactin 910 (Vicryl; Ethicon) followed by lavage with 0.9% irrigation saline. In most cases, 1 g of cefazolin (Cefazolin; Apotex, Weston, Florida, USA) powder was applied topically to the incision before closure of the subcutaneous tissue and skin based on surgeon preference. The subcutaneous tissues were closed in a simple continuous pattern using #2-0 USP polydioxanone (Ethicon) or #2-0 USP poliglecaprone acid (Ethicon). The skin was closed with nonabsorbable stainless steel staples (Vet One, MWI Animal Health, Boise, Idaho, USA). The incisions were measured using the metric measurement markings on the scalpel blade handle at the end of surgery. A sterile bandage was placed over the incision and consisted of either a 50 × 30 cm rolled cotton sterile disposable surgical towel (Medline) or antimicrobial impregnated roll gauze (AMD Kerlix, Covidien, Plymouth, Minnesota, USA) secured with #2 USP polypropylene (Ethicon) or gauze placed over the incision and secured using an iodine impregnated adhesive drape (Ioban; 3M Health Care). Recovery from anesthesia was assisted using a head and tail rope in all but 2 cases.

Postoperative care

Following recovery from anesthesia, equids were admitted to the intensive care unit for monitoring and treatment. Equids were immediately allowed free access to water, with food withheld for 6 to 12 h. Crystalloids (2 to 4 mL/kg BW per hour) were administered IV for a minimum of 8 h. At the discretion of the attending clinician, some equids received a constant rate infusion (CRI) of 2% lidocaine (VetOne), 0.05 mg/kg BW per min IV, for 12 to 24 h. Parenteral administration of broad-spectrum antimicrobials was continued for 1 to 5 d after surgery based on the clinical case progression of each individual equid. Flunixin meglumine (Intervet), 0.75 mg/kg BW, IV, q8h was initially administered for 3 d, followed by transition to oral flunixin meglumine (Intervet), 0.5 mg/kg BW, q12h with this dose gradually reduced.

Feed was gradually reintroduced, with frequent feedings of small amounts of grass hay starting 6 to 12 h after surgery. The amount of feed was then gradually increased, and frequency of feeding was decreased during the postoperative hospitalization period.

The surgical site was monitored daily. Incisional bandages placed at the completion of surgery were removed immediately after recovery from anesthesia or within the first 24 h after surgery. During the hospitalization period, incisions were cleaned twice daily using gauze soaked in isopropyl alcohol or dilute chlorhexidine solution to remove any debris from the surgical incision and identify any abnormalities indicative of developing incisional complications such as tenderness or discharge from the surgical site.

Restricted exercise was recommended for 12 wk, with confinement to a box stall (3.7 × 3.7 m) for the first 4 wk followed by small paddock (6.1 × 6.1 m) turnout for 4 wk and finally unrestricted turnout for the final 4 wk. Daily monitoring of the surgical site was recommended, with follow-up examination performed by the referring veterinarian at 2 wk after surgery for skin staple removal, and at each monthly increase in exercise during this initial 12-week period.

Postoperative incisional complications were defined as the presence of surgical site infection (SSI), and/or development of hernia formation. Surgical site infection was defined as development of spontaneous serosanguinous or purulent incisional drainage persisting for > 24 h, and/or positive bacterial culture of incisional drainage. Improved drainage was facilitated by selective removal of staples in these cases. Incisional complications that developed during hospitalization were identified from the medical record. Incisional complications that developed following discharge from the hospital were identified by telephone questionnaire with owners or referring veterinarians.

Statistical analysis

Data were divided into continuous (age, body weight, preoperative physical examination and clinicopathological findings, enterolith size and number, incision length, duration of surgery, days of hospitalization) and categorical variables [colic duration (acute, chronic) year and month of presentation, breed, gender, number of enterotomies, location of enterotomies, application of topical antibiotics in the incision during closure, recovery quality, type of suture material used for subcutaneous incisional closure, type of postoperative incision protection, signs of postoperative colic, presence of postoperative fever]. Continuous variables were evaluated for normality using Q-Q plots and comparisons between equids with and without incisional complication were made using Student's *t*-tests,

if the data were normally distributed, and Wilcoxon rank-sum test, if the data were not normally distributed. Similarly, categorical variables were compared between equids with and without incisional complications using χ^2 test or a Fisher's exact test, as appropriate. Significance was set at $P \leq 0.05$ for all tests. Statistical analyses were performed using commercially available statistical analysis software (SAS 9.4, SAS Institute, Cary, North Carolina, USA). Descriptive statistics are reported as range [mean ± standard deviation (SD)].

Results

Seventy-two equids met the inclusion criteria. There were 29 Quarter Horses, 12 Arabians, 10 American Paint Horses, 4 Appaloosas, 4 Thoroughbreds, 2 each of Aztecas, Morgans, Tennessee Walking Horses, Friesians, and 1 each of Warmblood, Peruvian Paso, National Show Horse, American Miniature Horse, and miniature donkey. Ages ranged from 4 to 33 y old (mean: 13.89 ± 7.5 y). There were 32 geldings (44%), 30 mares (42%), and 10 intact males (14%). Body weight ranged from 87 to 658 kg (mean: 486.2 ± 90.6 kg).

Thirty (41.7%) equids were presented for evaluation of acute abdominal pain and 37 (51.4%) for chronic abdominal pain. Five equids (6.9%) were presented for elective abdominal radiographs and were not exhibiting signs of abdominal discomfort on admission but were presented with a history suggestive of enterolithiasis including episodic abdominal discomfort, anorexia, passage of soft feces, or passage of small enteroliths in manure.

Seventy equids had a complete digital radiographic study of the abdomen performed at hospital admission and 1 horse was presented with abdominal radiographs taken by the referring veterinarian. The other equid was not radiographed and exploratory celiotomy was performed immediately following initial evaluation due to intractable abdominal pain. In this case, enterolithiasis was diagnosed during abdominal exploration.

A single or multiple enteroliths were identified radiographically in 65 equids (65/71, 91.6%). Radiography failed to identify enteroliths in the remaining 6. For the 64 equids that had evidence of enterolithiasis on radiographs obtained at our institution, the approximate diameters of enteroliths were measured in 61 using dedicated medical imaging software (SAS 9.4; SAS Institute). The diameters of enteroliths ranged from 4.5 to 27.8 cm (mean: 17.2 ± 4.7 cm). The diameter of enteroliths could not be measured in the remaining 3 equids due to indistinct margins.

Length of the ventral midline incision was recorded for 68 equids, and ranged from 15 to 40 cm (mean: 28.1 ± 5.9 cm). Nine equids were hypotensive during general anesthesia (MAP < 65 mmHg) for > 15 min. Two of these equids developed incisional complications. Total surgery time was recorded in 71 cases and ranged from 70 to 200 min (mean: 127.6 ± 30.5 min). Surgical time was > 120 min in 38 of these cases and included 8 equids that developed 1 or more incisional complication. Forty-four equids had a single enterolith located in either the RDC (n = 19), TC (n = 12), or DC (n = 13). Fourteen equids had multiple enteroliths located in the RDC and 1 had 3 enteroliths located in the TC. In 11 equids the enteroliths were identified in multiple locations throughout the AC, TC, and DC including RDC and DC (n = 5), RDC and TC (n = 3), LDC and RDC (n = 2), and LDC, RDC, and DC (n = 1). The location of enteroliths was not recorded in 2 equids. Nine equids were presented with a concurrent right dorsal displacement of the large colon and 1 with a concurrent large colon sand impaction. No ischemic lesions were observed in any of the equids included in this study.

Among 72 equids, 71 had PF enterotomy performed to empty the colon and facilitate mobilization of enteroliths to a portion of the colon safer for removal. Specifics regarding enterotomies performed for enterolith removal were recorded in 69 cases. In 9 equids, a solitary enterolith was removed through a single enterotomy. In 8 of these cases the enterolith was manipulated from the RDC to the PF enterotomy. In 1 equid PF enterotomy was not performed and the enterolith was removed through an enterotomy performed in the DC. A second enterotomy was created for enterolith removal in 57 equids following PF enterotomy. Of these, 38 enterotomies were performed in the RDC, 15 were performed in the DC, and 4 were performed in the LDC. Three equids with multiple enteroliths required a total of 3 enterotomies. Two had enterotomies performed in the PF, RDC, and DC, and 1 had enterotomies performed in the PF, LDC, and DC. The number of enterotomies was not reported for 3 equids.

The duration of postoperative hospitalization ranged from 2 to 13 d (mean: 4.7 ± 1.9 d). Ten equids (13.9%) developed 1 or more incisional complication and all weighed > 400 kg. Seven of ten were presented for evaluation of chronic abdominal pain. Postoperative incisional complications occurred in 6 equids (8.3%) diagnosed with SSI and 5 equids (6.9%) that developed incisional hernias. One equid with confirmed SSI also had an incisional hernia. Three equids had SSI definitively diagnosed on microbial culture performed during postoperative hospitalization and in the remaining 3 a presumptive diagnosis of SSI was based on persistent serosanguinous or purulent incisional drainage which began after hospital discharge. For the 3 horses that had microbial culture performed, bacterial isolates included colonies of *Staphylococcus* sp., *Enterococcus faecium, Escherichia coli,* and *Bacteroides fragilis.* In each of these cases treatment included establishment of adequate incisional drainage, continued local wound care, and administration of systemic antimicrobials until incisional drainage resolved. For the 3 cases with presumed SSI diagnosed after hospital discharge, administration of systemic antimicrobials prescribed by referring veterinarians and local wound care resulted in resolution of clinical signs.

For the 5 equids that developed incisional hernias, the defect in the body wall was detected between 1 and 5 mo following hospital discharge. More Quarter Horses (n = 3) developed an incisional hernia than did other breeds, but Quarter Horses were initially overrepresented in this population and this finding was not statistically significant. In 2 equids, hernias were managed successfully using an abdominal support bandage, and no treatment was deemed necessary in 2 equids. For the remaining equid, surgical repair was recommended due to the size of the hernia.

Eight of ten equids with incisional complications had an enterotomy performed in the RDC following PF enterotomy for removal of an enterolith measuring > 15 cm in diameter. Of these, 4 developed an incisional hernia as a sole complication, 3 developed an SSI as a sole complication (2 confirmed,

1 presumptive) and 1 developed a hernia following SSI (confirmed). The remaining 2 with SSI (presumptive) had enteroliths removed through DC enterotomy following PF enterotomy.

Cefazolin powder (Cefazolin; Apotex, Weston, Florida, USA) was applied topically to the incision following closure of the linea alba in 39 of 72 cases. Eight of ten equids that developed incisional complications did not have a topical antibiotic applied during closure of the ventral midline incision. Topical application of an antimicrobial powder (Cefazolin; Apotex) to the incision following closure of the linea alba was significantly associated ($P = 0.02$) with a reduced occurrence of incisional complications. A statistically significant association was not found for any other pre-, intra-, or postoperative continuous or categorical variables evaluated in the study.

Thirty-one equids recovered with the incision protected using a stent bandage. Twenty-three had a sterile blue towel sutured over the incision, 5 had an antibiotic impregnated dressing sutured over the incision, and in 3 the type of stent bandage was not recorded. Thirty-one equids recovered with the incision protected using sterile gauze and an iodine impregnated adhesive drape placed over the incision. Type of incisional protection employed for recovery from anesthesia was not recorded in the remaining 10 equids.

Discussion

In the current study, horses undergoing exploratory celiotomy for removal of enteroliths had an overall incisional complication rate of 13.9%, with 8.3% SSI and 6.9% hernia formation rates respectively. Pre-operative reported factors that have been associated with increased risk of SSI include body weight $>$ 300 kg (12); longer duration of colic signs ($>$ 8 to 24 h) before presentation at a referral center (24); and the nature of the emergency surgical procedure (12). Intra-operative variables such as hypovolemia, hypoxemia, poor tissue perfusion (12,27), increased duration of surgery (19) and anesthesia (24,25), creation of an enterotomy and draping technique to isolate the enterotomy site (23), contamination of the abdominal cavity during surgery (12,15), length of the incision (29), quality of recovery from general anesthesia (17), and administration of a topical antibiotic during closure of the abdominal incision (23) have all been shown to influence the occurrence of incisional complications.

In the current study, no statistically significant increase in incisional complications was identified when comparing the different locations or number of enterotomies (AC compared to DC) created for enterolith removal. Furthermore, size of enteroliths was not significantly associated with an increased risk for incisional complications. However, 8 of the equids that developed incisional complications had an enterolith $>$ 15 cm removed through an enterotomy performed in the RDC.

All equids that developed incisional complications weighed $>$ 400 kg, in 8/10 surgical time was $>$ 2 h, in 8/10 a topical antimicrobial was not applied to the incision during wound closure and 7/10 were presented for a chronic episode of abdominal discomfort ($>$ 24 h).

At our institution, it is standard for surgeons to prepare the skin with a 5-minute scrub using 4% chlorhexidine gluconate followed by application of an 85% ethyl alcohol-based rub before exploratory celiotomy. A recent study evaluated pre-operative hand preparation using chlorhexidine applied using either the scrub side or sponge side of a disposable sponge/scrub brush, a chlorhexidine/alcohol based rub, or an alcohol based rub alone (36). The authors of that study concluded that while all 4 preparations adequately reduced bacterial counts on the skin, an alcohol based rub alone was less effective than products containing chlorhexidine. Furthermore, given the residual effects of chlorhexidine, these findings may be of further significance when performing exploratory celiotomy and extended surgical times may be encountered.

In the current study, the only factor significantly associated with a reduced occurrence of incisional complications was the topical application of an antimicrobial to the incision following closure of the linea alba and before closure of the subcutis and skin ($P = 0.02$). Cefazolin is a broad-spectrum first-generation cephalosporin with activity against Gram-positive and Gram-negative bacteria that have been commonly isolated from ventral midline incisional infections in horses, including *Staphylococcus* spp., *Streptococcus* spp. and *E. coli* (34). Thirty-nine equids had cefazolin powder applied topically following closure of the linea alba and 33 did not. Eight of the 33 cases that did not have cefazolin powder applied subsequently developed 1 or more incisional complication. Based on these results, the authors recommend application of cefazolin powder during closure of ventral midline celiotomy incisions.

A recent study reported that the development of SSI does not appear to be solely related to bacterial contamination of the incision peri-operatively, and that various bacterial isolates will be cultured pre-, intra-, and post-surgery without the development of an SSI (37). Also, the authors of that report state that the development of an SSI is multifactorial and influenced by other factors including hematogenous spread of bacteria. In the current study, ventral midline incisions were only cultured if evidence of SSI was present which is standard practice at our institution. This is because development of SSI is not necessarily related to bacterial isolates present without concurrent signs of an SSI. Based on this recent study (36), a positive bacterial culture obtained during or after surgery should be interpreted cautiously if no overt signs of SSI are present.

In the current study, the rate of SSI was low and incisional hernia formation was similar to previous reports (4,11,18,35). It is difficult to make comparisons between the current study and previous reports on SSI and hernia formation, due to temporal and spatial differences, pre-, intra-, and postoperative variables, and indications for exploratory celiotomy. This study specifically evaluated a relatively systemically healthy subset of equids requiring exploratory celiotomy for correction of a non-strangulating gastrointestinal lesion.

A recent study reported that a 3-layer closure of a ventral midline incision was protective compared to a 2-layer closure (28). Closure of the skin incision with staples was associated with increased incisional complications in 1 study (25), whereas other authors were unable to demonstrate a significant effect of the use of skin staples on the incidence of incisional drainage (31). In the current study, all ventral midline incisions were closed in

3 layers (linea alba, subcutaneous tissues, and skin). The linea alba was closed with #3 USP polyglactin 910[e], and in the 67 cases for which it was reported, the subcutaneous tissues were closed with either #2-0 USP poliglecaprone acid (n = 46) or #2-0 USP polydioxanone (n = 21) and skin with nonabsorbable stainless steel staples. No association was identified between incisional complications and suture material used for closure of the subcutis.

An additional risk factor associated with the development of incisional complications following exploratory celiotomy is trauma to the incisional edges while manipulating the gastrointestinal tract (15,16,20). Manipulation and mobilization of enteroliths from the point of obstruction to a suitable location for removal may cause iatrogenic trauma to the edges of the incision.

Incisional infection and subsequent hernia formation are of concern after enterotomy (12,15), in particular when enteroliths cannot be mobilized to a location distant from the ventral midline incision before enterotomy (7). This can be due to the size of the enterolith exceeding the diameter of the colon through which mobilization is being attempted, and can be compounded by anatomic restrictions limiting mobility of certain segments of colon. One study found an association between enterotomy and an increased risk of incisional infection (20), and another study reported a 20% occurrence of incisional hernia formation after ventral midline celiotomy with enterotomy (12). However, other studies did not find any association between incisional complications and enterotomy performed as part of the procedure (11,15,17,18,31,34).

In the current study, only 1 of the 5 equids that developed an incisional hernia experienced incisional infection before hernia formation, suggesting that risk factors for incisional hernia following enterolith removal may not be associated with earlier signs of incisional complications. It has also been reported that incisional herniation may be attributed to factors such as uncontrolled early postoperative exercise, suture material failure, inadequate anatomic reconstruction, or violent postoperative recovery (17). However, none of these factors were reported in any of the cases reported here that developed hernias.

In a previous report, location of enteroliths (AC or DC) did not significantly affect the number of postoperative complications (11). In that report, incisional complications were among the most frequent short-term postoperative complications encountered, with an increased frequency for enteroliths located within the DC compared with the AC. In the current study, 8/10 equids that developed incisional complications had an enterotomy performed in the AC and only 2 had enterotomy performed in the DC, which contrasts with the aforementioned report. This finding may have been due to the large diameter of enteroliths (> 15 cm) in the 8/10 equids that developed incisional complications. Larger enteroliths are more difficult to mobilize to an intraluminal location distant from the primary surgical field and thus enterotomy is more likely to contaminate the celiotomy incision.

Contamination of unprotected ventral midline incisions during anesthetic recovery was found to be an important risk factor for the development of incisional drainage following colic surgery (21). In our experience, a sutured stent bandage is more reliable than an adhesive incise drape in maintaining a protective barrier against incisional contamination during recovery from anesthesia. In the current study the type of incisional protection applied was not found to be significantly associated with the development of incisional complications.

Limitations of the current study include its retrospective nature, the limited total number of equids that met the inclusion criteria with even fewer of those that went on to develop incisional complications, and that follow-up was dependent on owner information in most of the cases. While application of a topical antimicrobial during closure of ventral midline celiotomy was the only factor found to be statistically significant regarding a reduced risk for incisional complications in the current study, the specific reason for application in each case was not investigated. Therefore, factors which may have contributed to the decision to apply a topical antimicrobial such as surgical time, length of incision, number and location of enterotomies and surgeon preference, among others, may have been confounders as they were not included in analysis.

Additional limitations include lack of standardization (i.e., different suture materials used to close the subcutaneous tissues and different methods used to protect the incisions for recovery related to surgeon preference), presence of multiple surgeons, lack of a control group, or that the distance between the enterotomy performed for enterolith removal and the ventral midline incision was not recorded.

In conclusion, the overall prevalence of incisional complications following removal of enteroliths was low (13.9%), and the application of antimicrobial cefazolin powder in the incision following closure of the linea alba had a statistically significant effect in reducing the rate of incisional complications. Furthermore, proper surgical technique with an emphasis on meticulous draping of the enterotomy site is critical, especially when dealing with large enteroliths, which may increase the risk for incisional complications following exploratory celiotomy. Owners should be aware of an increased risk of incisional complications when large size enteroliths are observed in preoperative radiographs. CVJ

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