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Are horse age and incision length associated with surgical site infection following equine colic surgery?

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ABSTRACT

It is our clinical impression that age and incision length are more strongly associated with surgical site infection (SSI) following colic surgery than skin closure or wound protection method. Therefore, the objective of this observational clinical cohort study was to identify the risks for SSI in horses undergoing colic surgery. Data collection included pre-, intra-, and postoperative variables. Variables with $P < 0.2$ following univariable analysis were used in a logistic regression multivariable model. Variables with $P < 0.05$ were included in the final model. Odds ratios (OR; 95% confidence intervals, 95% CI) were determined. The area under the curve (AUC) for the receiver-operator characteristic was calculated.

The final multivariable model included breed ($P = 0.008$), incision length ($P = 0.004$), surgical procedure classification ($P < 0.001$), and postoperative (PO) colic ($P = 0.037$; overall model $P < 0.001$, and AUC was 0.81 [excellent discrimination between SSI vs. no SSI]). Warmbloods (OR 12.0; 95% CI 2.7–74.8), American breeds (OR 6.4; 95% CI 1.2–43.0), and Thoroughbreds (4.5; 95% CI 1.1–25.5) more commonly had SSI than other breeds (ponies/miniature horses, Draft breeds, Standardbreds, Arabians, and Crossbreeds [referent]). A higher SSI rate was associated with incision lengths >27 cm (3.7; 95% CI 1.5–9.9), heavily contaminated procedures (12.0; 95% CI 3.3–49.9), and horses with PO colic (2.7; 95% CI 1.1–6.8). SSI appeared to be more common after heavily contaminated procedures and in horses with PO colic, which probably resulted in more incisional contamination and trauma. Some breeds appeared to have higher odds of SSI. Age was not associated with SSI. The risk of developing SSI was higher for horses with an incision >27 cm; therefore, surgeons are encouraged to use the minimum incision length required to accomplish the necessary abdominal exploration and bowel manipulation in the safest manner possible.

Introduction

Incisional surgical site infection (SSI) following colic surgery is typically reported in 15–25% of horses (Ingle-Fehr et al., 1997; Mair and Smith, 2005a; Coomer et al., 2007; Torfs et al., 2010; Anderson et al., 2014; Colbath et al., 2014; Isgren et al., 2015); however, reports vary from as low as 3% (Tnibar et al., 2013) to >40% (Wilson et al., 1995; Durward-Akhurst et al., 2013; Costa-Farré et al., 2014). The frequent occurrence of SSI after colic surgery requiring prolonged treatment, increased likelihood of hernia formation (Ingle-Fehr et al., 1997; Mair and Smith, 2005b; Smith et al., 2007), and consequent delayed return to athletic activity (Davis et al., 2013) make SSI an important complication.

Conflicting findings from retrospective studies on SSI following colic surgery have led to lack of consensus among surgeons. While it seems logical that the proportion of horses developing SSIs would be higher following a clean/contaminated procedure, most studies report no association between enterotomy/enterectomy and SSI (Phillips and Walmsley, 1993; Ingle-Fehr et al., 1997; Galuppo et al., 1999; Coomer et al., 2007; Torfs et al., 2010; Anderson et al., 2014; Colbath et al., 2014). However, high operating room environmental bacterial colony forming units (CFU) and high post-recovery skin bacterial CFU were associated with SSI in one study (Galuppo et al., 1999). Other associations include large intestinal lesions (Phillips and Walmsley, 1993), wound closure performed by an inexperienced surgeon (Torfs et al., 2010), longer duration of surgery and hypoxaemia (Costa-Farré et al., 2014). Skin closure and wound protection methods have also been investigated. In one study, SSI did not differ when two-layer (body wall and skin suture) vs. three-layer closure was performed (Coomer et al., 2007), but in another study a three-layer closure was protective (Isgren et al., 2015). Use of a modified subcuticular suture pattern decreased SSI (Colbath et al., 2014), but subcutaneous closure with polyglycolic acid increased SSI (Costa-Farré et al., 2014). Skin stapling (vs. skin suture)

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was associated with SSI (Torfs et al., 2010). Using stent bandages increased SSI in one study (Mair and Smith, 2005a) but decreased it in another (Tnibar et al., 2013). The use of an abdominal bandage during the postoperative (PO) period appeared to decrease SSI (Smith et al., 2007). Younger horses and Standardbreds have also been reported to have fewer SSI (Wilson et al., 1995). These contradictory findings might result from the definition of SSI used, whether or not long-term follow-up was obtained, and differences in variables included in the analysis and how the variables were defined or categorised. Wide variations in SSI rates between veterinary hospitals and their inherent multifactorial associations make it difficult to form conclusions regarding optimal equine patient care.

It is our clinical impression that young horses tend to have fewer SSI than mature horses, and horses with long incisions extending into the cranial abdomen are more likely to develop SSI than horses with short, caudal abdominal incisions. We hypothesised that age and incision length would be more strongly associated with SSI than methods of wound closure and wound protection. To address our hypothesis, the objective of this study was to compare pre-, intra- and post-operative clinical variables between horses that did and did not develop a SSI following colic surgery.

Materials and methods

The study was an observational clinical cohort study. Informed consent was obtained at the time of hospital admission. Horses admitted to New Bolton Center for colic and recovering from exploratory abdominal surgery through a ventral midline laparotomy were included. Data were collected prospectively (Appendix: Supplementary Information 1) between December 2006 and May 2008 (group 1) and from August 2011 to September 2012 (group 2). Additional information pertaining to PO care and complications was obtained for both groups retrospectively from the medical record. Some data from group 1 were used in a separate study (Freeman et al., 2012); however, when specific variables associated with SSI were analysed using data from group 1, a number of trends towards significance were observed, prompting the collection of data prospectively (and retrospectively) from additional cases (group 2). Horses admitted during the intervening period were not included because prospective information (Appendix: Supplementary Information 1) was not routinely or reliably part of the medical record and therefore was unavailable.

SSI was defined as drainage of serous, purulent or serosanguineous fluid from the incision after the initial 48 h PO that persisted for at least 36 h (Freeman et al., 2012), either during hospitalisation or following discharge from hospital. Horses were classified as having (a) normal wound healing, or (b) SSI. SSI was the end-point of interest; any horse with a SSI at any time point was included but horses were required to have at least 12 days (for rationale, see Results) without signs of infection to be classified as normal wound healing. Horses without SSI that were euthanased or underwent repeat laparotomy within 12 days of surgery were excluded, as were horses without at least 12 days PO follow-up, unless they developed a SSI within the period available. Horses that had a second laparotomy after 12 days were included in the study for their first surgery only. Post-discharge information pertaining to incisional healing and complications including SSI was obtained by telephone questionnaire with the owner/caregiver.

Signalment and bodyweight were recorded. The prospective data collection sheet is provided in Appendix: Supplementary Information 1 and details of the standard surgical site preparation in Appendix: Supplementary Information 2. The effects of antimicrobial drug (AMD) re-dosing were investigated in surgeries ongoing 120 min after AMD administration corresponding to approximately twice the half-life of IV penicillin G (53 min in horses; Dürr, 1976).

Primary surgeon was classified as experienced (ACVS board-certified >5 years) vs. inexperienced (senior surgery resident, ACVS board-eligible or board-certified ≤5 years). The procedure was categorised as exploratory laparotomy (needle decompression/repositioning); jejunojejunostomy/jejunocaecostomy (JJ/JC); pelvic flexure enterotomy (PFE); high enema (HE); other enterotomy (small intestinal, typhlotomy, small colon); multiple enterotomies; large colon resection; or other. HE referred to intra-operative intraluminal lavage of the small colon with a nasogastric tube via the rectum. Because the type of surgical procedure was considered clinically important, for multivariable analysis, procedures were re-categorised based on the amount of contamination immediately adjacent to the incision as light contamination (JJ/JC, PFE, and HE) and heavy contamination (multiple enterotomies, other enterotomies, large colon resection, and other). Methods of skin closure were staples, suture, cyanoacrylate skin glue or none (subcutaneous tissue only). Skin incision length was measured after wound closure using the ruler on the scalpel blade handle. Incisional protection during recovery from general anaesthesia was classified as iodine-impregnated incise drape, stent or none. Use of an abdominal bandage during the PO period was recorded. A PO critical illness score (Freeman et al., 2012) was used to evaluate status during the first 3 days PO (scores 0–3 based on heart rate, mucous membranes, borborygmi, packed cell volume/total plasma protein). PO complications, duration of PO AMD administration, and length of hospital stay (LOS) were recorded.

Statistical analysis

Distributions of continuous variables were analysed. If data were normally distributed or could be normalised using log or other transformation, they were analysed continuously. If they could not be normalised and appeared multimodal, they were categorised based on univariate normal mixture decomposition estimation to determine the number of normal distributions and their share. A cutoff point was constructed based on the upper limit of the 95% confidence interval (CI) for the distribution with the major share. All categorical variables were analysed using a chi-square test or a Fisher's exact test. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. At minimum, the prospective data sheet (Appendix: Supplementary Information 1) was completed and the medical record available. No assumptions were made regarding missing data points and they were left blank in the statistical analysis. The number of data points for each variable was recorded.

Variables with $P < 0.2$ at the univariable stage were included in a multivariable analysis performed using a logistic fit and likelihood ratio tests. When the multivariable model was evaluated, variables with $P > 0.2$ were sequentially removed such that the final model included variables with $P < 0.05$. Clinically relevant two- and three-way interactions between significant variables were also evaluated. OR and 95% CI were calculated. Clinically relevant variables were forced back into the model to determine if there was any improvement in the model with their inclusion. Overall model fit, area under the curve (AUC) of the receiver operator characteristic (ROC), the corrected Akaike Information Criterion (AICc), and Goodness-of-fit test were used to evaluate each iteration of the model. Statistical analysis was performed using JMP Pro 12 (SAS) and STATA 14.1 (Statacorp).

Results

Appendix: Supplementary Information 3 provides a flow diagram of the study protocol. There were a total of 238 colic surgeries from which horses recovered during the study period. Two horses were admitted a second time for colic, at 12 and 49 days PO, and only admission one was included; therefore, there were 236 potentially eligible horses. Forty-one of the 236 potentially eligible horses (17%) developed a SSI; 35/227 (15%) horses underwent single and 6/9 (67%) horses underwent repeat laparotomy. In this study, SSI occurred between 2 and 21 days following surgery. The 75th percentile was 12 days, which was used as the decision point for including horses in the study population or not, and for designating horses with no signs of SSI as having normal wound healing.

Ultimately, 185 of the 236 potentially eligible horses fulfilled the study inclusion criteria. Exclusion reasons were as follows: death within 12 days PO ($n = 23$); lack of follow-up ($n = 21$); and repeat laparotomy within 12 days PO ($n = 7$). Groups 1 and 2 included 96 and 89 horses, respectively. Among horses that fulfilled the inclusion criteria, 36/185 developed a SSI (20%). SSI occurrence was similar in group 1 (19%) and group 2 (20%). Statistical comparisons and effect size comparisons were made between groups 1 and 2 for selected variables. As no significant differences were identified ($P = 0.082$–0.800), the two groups were combined. Data for 42 clinically relevant non-significant variables are included in Appendix: Supplementary Information 4.

Results of univariable analysis are shown in Table 1. Because age had a multimodal distribution, cut-off values were determined for categorical analysis. SSI occurred more frequently in horses 12–19 years old than other age categories ($P = 0.001$). Ponies/miniature horse ($n = 0/11$) and Draft horse ($n = 0/7$) categories had no SSI and could not be included in the multivariable analysis. Furthermore, because Standardbreds ($n = 1/22$), Arabians ($n = 1/7$), and Crossbred horses ($n = 1/6$) each had only one horse with SSI, they were grouped together with ponies/miniature horses and Draft horses as 'other' for the multivariable analysis and used as the referent. Antimicrobial prophylaxis was based on the clinical judgement of individual surgeons. Horses administered potassium penicillin and gentamicin or enrofloxacin (to provide gram-negative coverage in