Complications associated with closure of the linea alba using a combination of interrupted vertical mattress and simple interrupted sutures in equine laparotomies

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Abstract

Objectives (1) Evaluate the occurrence and variables associated with incisional morbidities (IMs) after ventral median laparotomy when using interrupted vertical mattress sutures (IVMS) and (2) determine the occurrence of abdominal bandage-associated complications in horses.

Methods Occurrence of IM and bandage-associated complications were determined after single laparotomies (SL group; n=546 horses) and repeat laparotomies (RL group: multiple laparotomies within four weeks; n=30 horses) in horses that survived ≥7 days postoperatively. Univariate analysis and multivariate logistic regression were performed to evaluate variables associated with IM.

Results The IM rate was 9.52 per cent in the SL group and 33.33 per cent in the RL group. The actual infection rate was 5.31 per cent in the SL group and 26.67 per cent in the RL group. Overall, long-term clinically relevant wound complications was 1.68 per cent. After multivariate analysis, increased anaesthesia duration was associated with IM and performing an enterotomy and postoperative intravenous lidocaine administration were associated with incisional infection in the SL group; no parameter remained significant in the RL group. Bandage-related complications were recorded in 2.95 per cent of the cases.

Conclusions These results suggest that the use of IVMS for closure of the linea alba is another viable option for closure and that an abdominal bandage does not appear to cause significant complications.

Introduction

Although rarely life threatening, laparotomy incision morbidities (IMs) are of concern as they increase hospitalisation cost and duration and may prevent return to athletic function.[1 2] Numerous studies have investigated preoperative, intraoperative and postoperative techniques that influence the rate of incisional complications and have put forward various protective and risk factors.[1–5] Perioperative antibiotic protocol, anaesthesia time, relaparotomy, wound lavage, abdominal bandaging, surgeons experience, subcutaneous suture layers, wound protection and type of suture material used are among the factors most often reported to influence the complication rates.[1]

Few studies investigated linea alba closure method as a risk factor, likely since most available in vivo studies describe the use of continuous suture patterns. The latter is often favoured for its even distribution of biomechanical force across the incision and the minimal amount of suture material used and its fast application.[2 6] The major inconvenience in case of breakage is potential evisceration or hernia formation due to complete disruption of the closure.[6] Although an

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interrupted suture closure is more likely to avoid these complications, only few in vivo studies have reported its use. Near-far-far-near,[7] inverse cruciate[8] and simple interrupted sutures[9] have been investigated, but to our knowledge, the use of interrupted vertical mattress sutures (IVMS) has not, except as retention sutures.[6] For over a decade, in our hospital, the abdominal walls of laparotomies have been closed routinely with IVMS interspersed with various interrupted sutures, and all abdomens have been supported with bandaging as from recovery.

Following a study showing the benefit of wound protection after laparotomy,[10] abdominal bandaging has become an advisable clinical practice after colic surgery. Nevertheless, studies investigating potential side effects of abdominal bandaging are not available.

The objectives of the present study are to report the outcomes of a surgical colic population, specifically: (1) to identify the occurrence and risk factors for IM after single and repeat laparotomies when using IVMS; (2) to determine the occurrence of abdominal bandage complications; and (3) to obtain follow-up information regarding survival, complications related to the incision or to the bandage and return to previous or intended use.

We hypothesised that the occurrence of IM, in particular infection, would be similar to published in vivo studies and that elastic bandage wear during at least 10 days would not be associated with major complications.

Material and methods

Cases selection

Medical records of horses that survived ≥7 days following a ventral midline laparotomy for gastrointestinal disease at the Equine Clinic of the University of Liège- Belgium (September 1, 2004–August 31, 2016) were reviewed by the same person (AS). Horses aged ≤4 months and those with incisional complications related to an earlier surgery outside our hospital were excluded. Follow-up information was obtained ≥12 weeks postoperatively by telephone questionnaire with the owner or the rider. Furthermore, in case of readmission of the horse in the clinic, the follow-up evaluation was obtained by both direct interview of the owner/rider and by examination of the horse. Questions pertained to whether the horse survived, if complications related to the incision or to the bandage occurred after discharge from the hospital and whether the horse was able to return to previous or intended use.

Definitions

The single laparotomy (SL) group included single laparotomies or repeat laparotomies (RL) >4 weeks apart. The RL group included horses that required ≥2 laparotomies within four weeks. This four-week cut-off was chosen following demonstration that, at this time point, the strength of the sutured linea alba was not significantly different from controls.[11]

Based on other reports,[12 13] wounds were classified without complication when mild to moderate oedema without heat and pain at palpation or a small volume of serous or serosanguinous subcutaneous collection or discharge for <24 hours was present.

Incisional morbidities included cases presenting with serous/serosanguinous subcutaneous collection/discharge lasting ≥24 hours, purulent discharge, haemorrhagic collection/hematoma formation, herniation and dehiscence. Incisional infection was defined as per Centers for Disease Control and Prevention (CDC) guidelines: wound with the presence of purulent secretions, whatever their duration, with or without positive bacterial culture (see Surgical Site Infection (SSI) Event. https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf (accessed 6 January 2020)).[14] Wounds were always categorised by their worst complication.

Bandage-associated complications were defined as the presence of skin irritation, pressure sores, whitening of the hair and scars.

Surgical procedure and perioperative management

Within the five minutes prior to induction, horses received intravenous sodium penicillin (20,000 UI/kg, Penicilline 5.000.000 IE/UI, Kela Pharma) alone or in combination with gentamicin (6.6 mg/kg, Gentakel 5%, Kela Laboratoria) in addition to flunixin meglumine (1.1 mg/kg, Emdofluxin 50, Ecuphar) and xylazine (0.6 mg/kg, Proxylaz 2%, Prodivet Pharmaceuticals). Anaesthesia was induced intravenously (ketamine, 2.2 mg/kg, Anesketin, Eurovet,and midazolam, 0.06 mg/kg, Dormicum, Roche) and maintained by isoflurane (Isoflo, Abbott) in oxygen or oxygen/air mixture. Intermittent positive pressure ventilation was instigated, and arterial blood samples were taken regularly for analysis of partial pressure of oxygen and carbon dioxide. Depending on the dirtiness of the hair, the abdomen was entirely shaved or clipped. When the

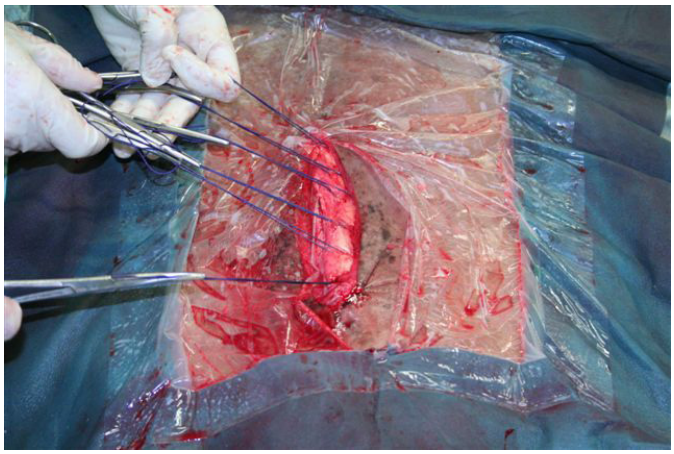

Figure 1 Closure of the linea alba: all vertical mattress sutures were preplaced and maintained under tension by the assistant for even distribution of the tension, allowing the surgeon to knot each vertical mattress suture separately.

abdomen was clipped, a 20 cm wide band centred on the linea alba was also shaved. For males, the prepuce and penis were thoroughly washed using several cycles of 3.75 per cent povidone iodine soap rinsed with tap water until macroscopically clean, a stack of swabs was placed and the prepuce was sutured closed following the placement of a urinary catheter. The abdomen was then aseptically prepared with three washing cycles of 3.75 per cent povidone iodine soap rinsed with tap water followed by five minutes sterile scrub with 3.75 per cent povidone iodine wiped off with 70 per cent isopropyl alcohol swabs. Finally, a 3 per cent povidone iodine in isopropyl alcohol solution was applied to the surgical site and let to dry. The abdomen was routinely draped by application of a double layer of sterile draping, and a non-iodophor adhesive drape (Dermincise, Vygon) was applied over the median part of the ventral abdomen. The ventral median laparotomy was performed cranial to the umbilicus. For repeat laparotomies, the approach to the abdomen was through the initial incision. All surgeries were performed by 1 of 6 experienced surgeons assisted by a resident, intern or student. Incisions were closed in three layers. A series of IVMS (USP 2 or 6 polyglactin 910) were applied on the linea alba. The IVMS was placed in a far-far-near-near order of bites. The far-far loop penetrates the abdominal muscle at an angle of 90° approximately 1.5 cm from the linea alba incision. The near-near loop enters the muscle at approximately 0.5 cm from the incision and traverses the rectus plate completely (Blair Donati type) or in the middle of its thickness (Donati type), depending on the thickness of the linea alba. A series of IVMS were preplaced approximately 3 cm apart and eventually knotted after all were placed under tension simultaneously (figure 1). Intermediate simple interrupted, cruciate or inverted cruciate sutures (USP 2 or 6 polyglactin 910) were applied in between IVMS in order to fully appose the body wall, which was controlled by assuring the tip of a needle holder could no longer pass through the abdominal incision (figure 2). The spacing between appositional sutures was approximately 7–10 mm. Depending on the surgeon, the linea alba was lavaged with saline before closure of the subcutaneous tissue using a simple continuous USP 0 polyglactin 910 or polyglecaprone 25. The skin was closed using simple interrupted USP 0 polyester/polypropylene or staples. According to surgeon's preference, the incision was then covered with a stack of swabs held in place by a large non-iodophore incise drape. In all cases, an abdominal bandage consisting of a Gamgee cotton pad covering the wound and elastic adhesive bands was applied as tightly as possible on the hoisted horse before assisted recovery. Directly after the recovery, the incise drape (when applied) and the abdominal bandage were removed, and the surgical site was inspected before a fresh antiseptic ointment (Nitrofural, Furacine soluble dressing 2 mg/g, Sanico NV/SA, or povidone iodine,

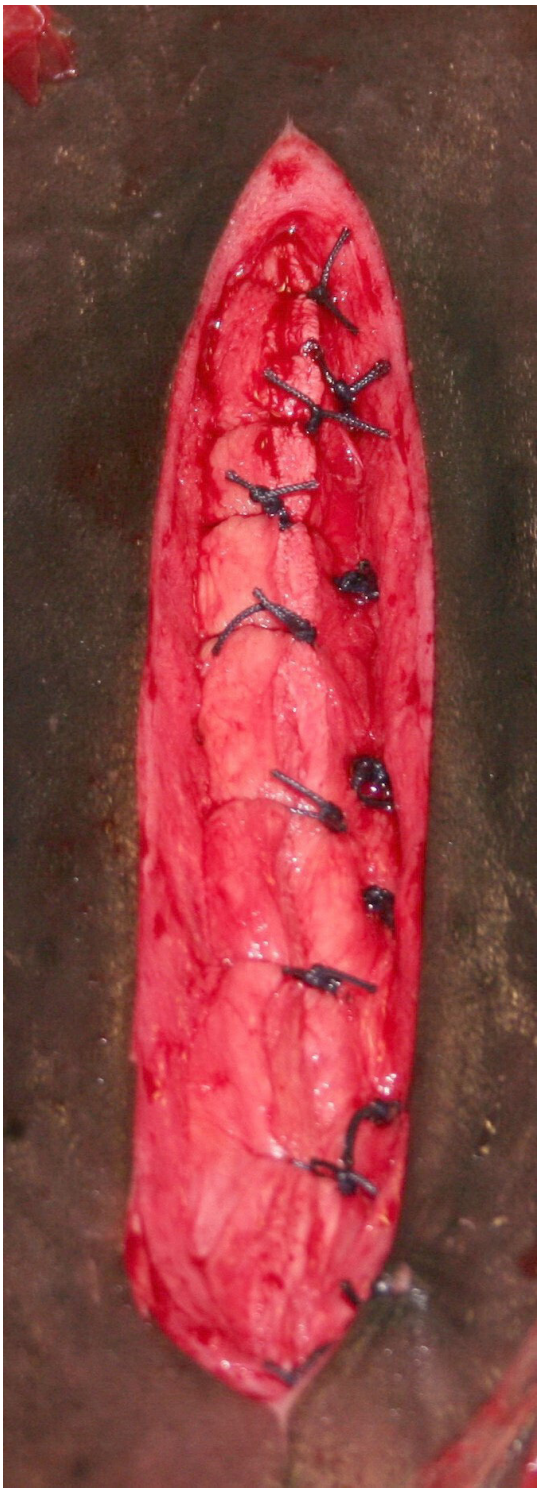

Figure 2 Final appearance of the closed linea alba.

Iso-Bétadine Gel 10%, Mylan or Silver Sulfadiazine, Flammazine 1% crème, Alliance Pharmaceuticals Limited) containing abdominal bandage was applied that also had two rolled Gamgee cotton pads on each side of the dorsal spine. Postoperatively, antibiotic administration consisted of sodium penicillin (20 000 UI/kg intravenous, every six hours) and gentamicin (6.6 mg/kg intravenous, once daily) usually for 7–8 days. Enoxaparin (150 mg/horse SC, once daily- Clexane 150 mg, Sanofi) was administered for a minimum of three days after surgery, while non-steroidal anti-inflammatory drugs (phenylbutazone 2.2 mg/kg

intravenous every 12 hours, Fenylbutazon 20%, VMD or, depending on the clinician, flunixin meglumine, 1.1 mg/kg intravenous every 12 hours) were given during five days postoperatively. Intravenous lidocaine (Laocaine, MSD Santé Animale) was administered to most horses that developed or were at risk of developing postoperative ileus and to a majority of horses with strangulated large or small intestinal lesions. Abdominal bandages were changed approximately every two days or more frequently in case of wound complication. The surgical site was inspected at every bandage change including ultrasonographic assessment in case of suspicion of complication. Skin sutures were removed after 10 days, and a last abdominal bandage was applied for 3–5 days. The duration of hospitalisation was usually 10 days (longer for horses that experienced significant postoperative complications).

Statistical analysis

As a first step, chi-square tests to compare proportions and *t* tests to compare means of all potential risk factors for IM were used to identify significant risk factors. Variables evaluated for risk factors of IM are displayed in table 1. For the RL group, the majority of the variables were identical for both surgeries, but if they were different, only variables related to the second surgery were taken into account for the statistical analysis.

Next, any potential risk factor that had a P<0.10 association with IM or infection was included on a multivariate logistic regression model. Stepwise, forward and backward selection methods were applied to this model to determine risk factors significantly associated (P<0.05) with IM. All computations were performed with a commercial statistical software (SAS, V.9.1.3) using the LOGISTIC, FREQ and TTEST procedures.

Table 1 Statistical variables included in the study

Categorical variables	Class
Breed	Warmblood types/ ponies/ Arabian and their crosses/American horses (Appaloosa, Quarter Horses and Paint Horses)/ others
Sex	Mare/gelding/stallion
Pregnancy	Yes/ no
Lactating mare	Yes/ no
Preoperative antibiotic	Penicillin alone/penicillin+gentamicin
Location of the gastrointestinal lesion	Small intestine/large intestine/mixed
Enterotomy performed	Yes/ no
Resection and anastomosis performed	Yes/ no
Intra-abdominal antibiotic administration	Yes/ no
Surgeon	A/B/C/D/E/F
Abdominal drain placed cranially to the incision	Yes/no
Changing gloves before wound closure	Yes/no
Linea alba suture size for vertical mattress sutures	USP 2/USP 6
Linea alba suture size for intermediate sutures	USP 2/USP 6
Linea alba lavage	Yes/no
Subcutaneous suture type	Polyglactin 910/polyglecaprone 25
Skin closure type	Interrupted sutures/staples
Incise drape placed over the incision at the end of the surgery	Yes/no
Quality of recovery from anaesthesia	Good (≤3 attempts to stand)/difficult (≥4 attempts to stand)
Postoperative administration of intravenous lidocaine	Yes/no
Postoperative complications:	
Ileus	Yes/no
Endotoxaemia	Yes/no
Pain	Yes/no
Diarrhoea	Yes/no
Thrombophlebitis	Yes/no
Respiratory troubles	Yes/no
Hyperlipemia	Yes/no
Renal insufficiency	Yes/no
Laminitis	Yes/no
Septic peritonitis	Yes/no
Quantitative variables	**Class**
Age at the time of surgery (years)	Continuous variable
Weight (kg)	Continuous variable
HR before surgery	Continuous variable
PCV before surgery	Continuous variable
Length of the laparotomy incision	Continuous variable
Anaesthesia duration (min)	Continuous variable
Lowest PaO_2 during anaesthesia	Continuous variable

HR, heart rate; PaO_2, arterial partial pressure in oxygen; PCV, packed cell volume.

Results

Horses

Of the 1062 laparotomies performed over the study period, and after excluding nine donkeys, seven horses aged <4 months and three with incisional complications related to an earlier surgery outside our hospital, 272 horses died/were euthanased during the surgery and 16 during the recovery from anaesthesia. Of the horses that recovered from anaesthesia, 149 died/were euthanased <7 days postoperatively. Six hundred and six laparotomies performed in 564 horses met the inclusion criteria of which 60 in 30 horses entered the RL group.

Mean±SD age was 10±5.69 years (only 13 animals were <12 months), and mean weight was 500±124 kg; there were 246 mares, 267 geldings and 51 stallions. Breeds were Warmbloods (n=382; 67.7 per cent), ponies (n=67; 11.9 per cent), Arabians or Arabian Cross (n=24; 4.2 per cent) and Appaloosa/Quarter/Paint Horses (n=22; 3.9 per cent); the remaining 69 horses consisted of multiple different breeds.

Wound data

Mean±SD length of the incision was 17.67±3.07 cm (n=377). Mean±SD number of interrupted vertical mattress sutures used was 6.69±1.30 (n=355). Mean±SD number of interrupted intermediate sutures was 9.69±2.30 (n=347). The mean±SD of laparotomy wound closure (recorded from the first stitch on the linea alba until the last staple/ stitch on the skin) was 29.85±6.81 minutes (n=285).

Incisional morbidities

The overall IM occurrence was 9.52 per cent (52/546) in the SL group and 33.33 per cent (10/30) in the RL group and distributed as follows: serous to serosanguinous discharge (n=19, of which two where in the RL group), haematoma (n=3, all in the SL group), sinus suture tract/localised infection (n=9, all in the SL group), superficial infection over more than 1/3 of the incision (n=27, of which 7 where in the RL group), acute complete wound breakdown due to deep incisional infection and septic peritonitis (n=1, in the RL group), acute linea alba and subcutaneous dehiscence due to a fall (n=1, in the SL group) and hernia formation without infection (n=2, both in the SL group). Seven of these occurred after hospital discharge (serous discharge=2, localised infections=4, infection over >1/3 of the incision=1).

The odds of developing IM in the RL group was 4.77 higher than in the SL group (OR: 4.77; 95 per cent CI 2.12 to 10.73; P=0.0002).

The actual incisional infection occurrence was 5.31 per cent (29/546) in the SL group and 26.67 per cent (8/30) in the RL group. The odds of developing an incisional infection in the RL group was 6.51 higher than in the SL group (OR 6.51; 95 per cent CI 2.67 to 15.88; P<0.0001).

Analysis of risk factors for incisional morbidities

Potential risk factors associated with occurrence of IM and of incisional infection in the univariate analysis are shown in tables 2 and 3.

In the multivariate analysis, only the duration of anaesthesia was a predictor of IM in the SL group. The OR for each additional minute of anaesthesia was 1.009 (95 per cent CI 1.003 to 1.015; P=0.0016). No parameter remained significant in the multivariate analysis for the RL group.

Specific to incisional infection, in the multivariate analysis, only the postoperative administration of intravenous lidocaine (OR 3.960; 95 per cent CI 1.140 to 13.760; P=0.030) and enterotomy (OR 2.580; 95 per cent CI 1.027 to 6.485; p=0.0438) were predictors of infection in the SL group. For the RL group, the univariate analysis revealed that postoperative diarrhoea was associated with an increased risk of infection, but this parameter did not remain significant in the multivariate analysis.

Abdominal bandage complications

Skin irritation on the flanks or back were reported either during bandage changes or at bandage removal in 2.95 per cent of the cases (17/576 as repeat laparotomies were counted as a single event).

Long-term follow-up

The duration of the follow-up ranged from three months until 11 years and 11 months (median: 3.00 years/n=417). When the follow-up was very long, information were gathered several times during the entire follow-up period. One hundred and thirty-five cases were re-examined at least once by the authors. Ninety-four cases were lost to follow-up (of these, seven had experienced IM during hospitalisation) and 65 died or were euthanased during hospitalisation or after discharge from the clinic (of these, six had experienced IM postoperatively). The cause of the death/euthanasia was related to the wound incision in only one case (acute breakdown following severe incisional infection and septic peritonitis).

Table 2 Means (SD) for continuous variables and number of horses (%) for categorical variables for horses with and without incisional morbidities

Group	Variable	Class	Incisional morbidities	No incisional morbidity	P value
SL group	Age (years)	Continuous	11.24 (6.15)	9.78 (5.66)	0.08
	Duration of anaesthesia (minutes)	Continuous	185.70 (66.80)	161.60 (45.46)	0.02
	Quality of recovery	Good (≤3 attempts to stand)	16 (6.78%)	220 (93.22%)	0.06
		Difficult (≥4 attempts to stand)	16 (12.70%)	110 (87.30%)	
	Postoperative administration of intravenous lidocaine	Yes	40 (11.43%)	310 (88.57%)	0.05
		No	12 (6.19%)	182 (93.81%)	
RL group	Sex	Mare	3 (50%)	3 (50%)	0.05
		Gelding	5 (22.73%)	17 (77.27%)	
		Stallion	2 (100%)	0 (0%)	
	Linea alba lavage	Yes	10 (41.67%)	14 (58.33%)	0.05
		No	0 (0%)	6 (100%)	
	Subcutaneous suture type	Polyglactin 910	0 (0%)	6 (100%)	0.05
		Polyglecaprone 25	10 (41.67%)	14 (58.33%)	
	Postoperative administration of intravenous lidocaine	Yes	10 (37.04%)	17 (62.96%)	0.08
		No	0 (0%)	3 (100%)	
	Postoperative pain	Yes	3 (18.75%)	13 (81.25%)	0.07
		No	7 (50%)	7 (50%)	
	Postoperative diarrhoea	Yes	0 (0%)	6 (100%)	0.01
		No	10 (41.67%)	14 (58.33%)	
	Postoperative hyperlipaemia	Yes	0 (0%)	3 (100%)	0.08
		No	10 (37.04%)	17 (62.96%)	

SL group: cases that underwent a single laparotomy or multiple laparotomies performed at ≥4-week interval; RL group: cases that underwent multiple laparotomies within four weeks.
P values are from univariate comparisons between horses with and without incisional morbidities.
RL, repeat laparotomy; SL, single laparotomy.

Table 3 Means (SD) for continuous variables and number of horses (%) for categorical variables for horses with and without incisional infection

Group	Variable	Class	Incisional infection	No incisional infection	P value
SL group	Breed	Warmblood types	18 (4.90%)	349 (95.10%)	0.05
		American horses (App, QH and PH)	0 (0%)	22 (100%)	
		Arabians and their crosses	2 (8.33%)	22 (91.67%)	
		Ponies	1 (1.49%)	66 (98.51%)	
		Others	8 (11.76%)	60 (88.24%)	
	Duration of anaesthesia (min)	Continuous	192.30 (66,35)	162.20 (46.64)	0.03
	Enterotomy performed	Yes	10 (13.89%)	62 (86.11%)	0.02
		No	19 (4.01%)	455 (95.99%)	
	Postoperative administration of intravenous lidocaine	Yes	25 (7.14%)	352 (92.86%)	<0.01
		No	4 (2.06%)	190 (97.94%)	
	Postoperative ileus	Yes	15 (7.94%)	174 (92.06%)	0.05
		No	14 (3.93%)	342 (96.07%)	
	Postoperative thrombophlebitis	Yes	1 (1.41%)	70 (98.59%)	0.01
		No	28 (5.88%)	448 (94.12%)	
	Postoperative renal insufficiency	Yes	0 (0%)	45 (100%)	<0.01
		No	28 (5.69%)	464 (94.31%)	
	Postoperative laminitis	Yes	0 (0%)	9 (100%)	<0.01
		No	29 (5.40%)	508 (94.60%)	
RL group	Breed	Warmblood types	6 (23.08%)	20 (76.92%)	0.09
		Arabians and their crosses	0 (0%)	1 (100%)	
		Ponies	2 (100%)	0 (0%)	
		Others	0 (0%)	1 (100%)	
	Sex	Mare	1 (16.67%)	5 (83.33%)	0.05
		Gelding	5 (22.73%)	17 (77.27%)	
		Stallion	2 (100%)	0 (0%)	
	Linea alba lavage	Yes	8 (33.33%)	16 (66.67%)	<0.10
		No	0 (0%)	6 (100%)	
	Subcutaneous suture type	Polyglactin 910	0 (0%)	6 (100%)	<0.10
		Polyglecaprone 25	8 (33.33%)	16 (66.67%)	
	Postoperative administration of intravenous lidocaine	Yes	8 (29.63%)	19 (70.37%)	0.08
		No	0 (0%)	3 (100%)	
	Postoperative pain	Yes	2 (12.50%)	14 (87.50%)	0.06
		No	6 (42.86%)	8 (57.14%)	
	Postoperative diarrhoea	Yes	0 (0%)	6 (100%)	0.01
		No	8 (33.33%)	16 (66.67%)	
	Postoperative hyperlipaemia	Yes	0 (0%)	3 (100%)	0.08
		No	8 (29.63%)	19 (70.37%)	

SL group: cases that underwent a single laparotomy or multiple laparotomies performed at ≥4-weeks interval. RL group: cases that underwent multiple laparotomies within four weeks.
P values are from univariate comparisons between horses with and without incisional infection.
App, Appaloosa ; PH, Paint Horse; QH, Quarter Horse.

A small hernia (≤5 cm diameter) was reported in four cases (all of which had incisional infection) and a large hernia was reported in three cases (two after infection and one due to muscular dehiscence without infection). A slightly softer consistency of the ventral region with no or minimal abdominal deformation was reported in nine horses (of these, five had an incisional infection, one had a haematoma and three had no reported IM before). Overall, long-term clinically relevant wound complications is 1.68 per cent (7/417).

Eleven (2.63 per cent) out of 417 cases with follow-up were reported to have bandage-associated morbidities. These were limited to the occurrence of small scars or a few white hairs on the dorsal spine.

Information regarding to the horse's activity was available for 371/417 cases. The majority (n=303) returned to their previous or intended activity (former or higher level of performance for sport horses). Twenty were still in convalescence training at time of follow-up. A decreased level of activity was reported in 48 cases. The most common reasons cited were lameness, recurrent colic or simply the owners' choice. The laparotomy incision was not the cause of a decrease in activity in any of the cases where follow-up was obtained.

Discussion

In the present study, the IM and infection rates were 9.52 per cent and 5.31 per cent, respectively, after a single colic surgery and 33.33 per cent and 26.67 per cent after repeat laparotomy. These results compare favourably to other studies reporting ranges from 7.4 per cent to 42.2 per cent in single[8 15–20] and 56 per cent to 68.4 per cent after repeat laparotomy.[16 21 22] Attention, however, needs to be drawn to the use of dissimilar definitions of complications in different studies making direct comparison difficult. Certain studies consider any type of incisional drainage as incisional infection, whereas in others, purulent discharge is a key mandatory feature for infection.[1] In our opinion, serous to sero-haemorrhagic discharge of a few days duration

has to be differentiated from a purulent discharge since the first is generally self-resolving, whereas the latter significantly extends the need for extra wound care and leads to major long-term implications, particularly the occurrence of herniation.[1 17] For this reason, and supported by the recent established SSI definitions of the CDC (see Surgical Site Infection (SSI) Event, https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf (accessed 6 January 2020)), we chose to use incisional infection as defined by a purulent discharge. Nevertheless, in order to permit comparisons with other studies using a wider definition, we included any type of discharge in the definition of IM.

Another aim of our study was to investigate the use of the IVMS pattern, which compared favourably with previous reports using continuous or other interrupted patterns for closure of the linea alba in horses with colic.[8 15–22] Whereas Rinnovati and colleagues[9] demonstrate simple interrupted technique was associated with low complication rates, the interrupted near-far-far-near technique has long been incriminated as a risk factor for wound complications.[7] Yet, the IVMS results in minimal compromise to microcirculation[23] and is considered most appropriate for regions under tension including when there is risk of abdominal distension and infection.[24 25] This may well be why compared with other equine studies, the long-term incidence of herniation in this study is low.[1] As we know from human medical literature, the ORs for wound dehiscence and incisional herniation are halved when using interrupted patterns compared with continuous ones[25] particularly in cases where infection is at high risk.[24] This would be counterintuitive towards the knowledge that the amount of foreign material left behind in a wound does increase the risk for infection and continuous patterns are believed to leave less suture material behind. Nevertheless, this may not necessarily be the case since the amount of suture used depends on the actual pattern on the distance between bites and the wound to stitch distance.[26]

Consistent with other studies,[27 28] an increased anaesthesia duration was revealed to be a risk factor for incisional morbidities. This emphasises the importance of reducing the overall anaesthetic time. The time taken to close the linea alba contributes to the overall anaesthetic time. Closure time was recorded for a series of cases and revealed to be around 30 minutes for a mean length of the incision of 17.7 cm. One simple continuous suture would likely be faster placed. Yet, our laparotomy incisions are relatively short (when compared with other studies[29]), and it is therefore unlikely that the suture pattern is a significant factor in extending anaesthesia time.

Particularly in horses, long anaesthesia duration has been associated with a poor quality of recovery which, in turn, could increase the risk of IM. However, this association was not found in the present population, potentially because adhesive elastic abdominal bandages were placed before the recovery, and as they were not easily dislodged, they provided some physical support and protection to the freshly created incision.

The association between the surgical procedure and incisional infections has provided conflicting results among studies. A recent study[29] revealed that procedures heavily contaminated (ie, multiple enterotomies and large colon resection) were associated with an increased risk of developing an incisional infection than procedures lightly contaminated (enterotomy of the pelvic flexure and other enterectomies). In our study, no difference was made between types of enterectomy and types of enterotomy. However, we found that performing an enterotomy but not an enterectomy was a risk factor of incisional infection. Emptying the intestinal content may spread more bacteria into the environment and could therefore be considered more contaminated than an enterectomy (where the intestinal lumen is occluded adjacent to the resected ends) or a procedure without access to the intestinal lumen. Therefore, protection of the laparotomy incision should be encouraged during more contaminated procedures.

Contrary to other studies,[13 28] postoperative intravenous lidocaine was associated with an increased risk of incisional infection. This result is surprising as it has been shown that lidocaine has an antimicrobial activity against common equine pathogens.[30] Yet, it is likely that lidocaine was administrated to a category of horses having other risk factors for incisional infection that were not specifically evaluated in our study. In fact, in our hospital. lidocaine treatment is initiated as standard in all cases with strangulated lesions or those that are considered at high risk of postoperative ileus, often patients that are sicker initially and more likely to develop SIRS, hence more at risk of wound infection, where this may therefore result in a confounding factor to the lidocaine administration with other parameters not investigated. In any case, adding to the identified increased incisional complication risk in the present study, the actual benefits of the use of lidocaine in equine colic surgery have recently been questioned, and its use may need to be reviewed.[31]

Laparotomy incision lengths have been shown as major risk factors for IM.[29] Our study does not associate this parameter as a risk factor, probably due to the overall small size of our incisions (mean±SD: 17.67±3.07 cm) with only a few above the risk factor threshold of 27 cm.[29] Aiming at minimising the length of the laparotomy incision may therefore be a key contributor to reducing IM. However, this reduction of the wound's length has to be balanced with maintaining a sufficient length in order to reduce trauma to the incision, which could affect the incisional health, especially in procedures that would require manipulating a distended large colon out of the laparotomy.

Whether there is benefit of abdominal bandaging in preventing IM is an ongoing debate.[10 12 32] Our study did not use a control group. Yet the relatively low prevalence of IM encountered might suggest the benefit of bandaging. Indeed, a previous study indicated that the contamination of the surgical site during the anaesthetic recovery and the early postoperative period may play an important role in the development of an incisional infection.[33] In addition to their protective role, abdominal bandages can provide some support to the laparotomy incision and reduce peri-incisional oedema, which are suggested ways with which morbidity due to incisional infection may be reduced.[34] The role of abdominal support, even if sometimes challenged, can be supported by the small number of herniation and dehiscence found in our study.

Several issues have been reported with the use of elastic bandages. They have been associated with a caudal migration to a greater degree than commercially available bandages, which may allow males to urinate in or on the bandage.[34] However, elastic bandages were applied tightly in our clinic and bandages migrated caudally in only a few cases, and urine scalding of the bandages was never reported. The complications related to the elastic adhesive bandages (skin irritation, secretions, scar or whitening of a small area of hairs), recorded in less than 3 per cent of the cases were considered as minimal blemishes by the majority of the owners. With the aim of reducing these complications in new cases, we have increased the thickness of the cotton pads applied on each side of the dorsal spine and we provided owners with an adhesive remover for easier and less traumatic removal of the bandage at home.

This study has several limitations in addition to those previously discussed. Among them, the study design should be cited. Indeed, the absence of randomised control groups including other suture types on the linea alba and without an abdominal bandage has led to comparison of our results to other reports in the literature. However, convincing our clinicians to use a control group would have been difficult because of their positive experience with the use of IVMS and an elastic abdominal bandage. Some missing data and horses lost to follow-up are also related to the retrospective design of the study. Another limitation is the fact that some horses relied on owner/rider evaluation to assess the horse's incision for the long-term evaluation. Nevertheless, a precise telephone questionnaire with owner/rider was used. Although it can be recognised this method is not totally ideal, the WHO has recognised telephone conversation as acceptable for SSI follow-up if personnel contact is challenging to achieve (see 'WHO - Protocol for surgical site infection surveillance with a focus on settings with limited resources', https://www.who.int/infection-prevention/tools/surgical/SSI-surveillance-protocol.pdf (accessed 26 December 2019)).

Conclusions

The favourably low overall IM and infection rates reported in the present study suggest a safe and appropriate method was used for abdominal closure and management after laparotomy. This included the use of an IVMS pattern and placement of an abdominal bandage during recovery and continuing for >10 days. Considering that the development of IM and in particular surgical SSI is a multifactorial event, it has to be confirmed if this approach is also valid in other institutions. In any case, based on the current study, protecting the laparotomy incision during more contaminated procedures and optimising anaesthesia times should contribute to decreased IM in any setting.

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