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Factors associated with survival of horses following relaparotomy

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Summary

Reasons for performing study: Relaparotomy may be required to investigate and manage complications that occur following surgical management of colic.

Objectives: To report factors associated with survival following relaparotomy.

Study design: Retrospective cohort study.

Methods: Records of horses that had undergone exploratory laparotomy for treatment of colic over a 10-year period (2002 – 2012) and had undergone relaparotomy <8 weeks following the initial surgery were reviewed. Descriptive data were generated and association with survival time was modelled using Cox proportional hazards models.

Results: Relaparotomy was performed in 96 horses at <8 weeks following initial surgery at a median of 4 days. This represented 6.3% of horses that underwent laparotomy during the study period (n = 1,531). Relaparotomy was most frequently undertaken based on signs of persistent postoperative colic (76%; n = 73). Short-term survival for horses undergoing relaparotomy due to persistent colic was 53%, incisional dehiscence 50% postoperative reflux 37%, haemoperitoneum 17% and septic peritonitis 0%. Median survival was 6 days for all horses undergoing relaparotomy and 778 days for those that recovered following anaesthesia. Non-survival was associated with increased packed cell volume at 24 h following initial laparotomy (HR 1.06, 95% CI 1.04–1.10, P = 0.009), peritonitis as a reason for undertaking relaparotomy (HR 4.41, 95% CI 1.43–13.6, P = 0.01) and adhesions found at relaparotomy (HR 1.77, 95% CI 1.03–3.04, P = 0.04). Increased likelihood of survival was associated with colic signs being the reason for performing relaparotomy (HR 0.48, 95% CI 0.26–0.88, P = 0.02) and small intestinal distension found at relaparotomy (HR 0.53, 95% CI 0.29–0.96, P = 0.04).

Conclusions: This study has provided information about survival rates and risk factors for survival in horses undergoing relaparotomy that can assist clinicians and owners when determining whether to perform relaparotomy and in predicting the likely surgical outcome.

Introduction

Relaparotomy may be required to investigate and manage complications that occur following surgical treatment of acute abdominal pain (colic). Indications for relaparotomy include recurrent or persistent postoperative pain/colic, persistent postoperative reflux (POR) that is suspected to be related to a mechanical obstruction or due to postoperative ileus (POI) that is non-responsive to medical therapy

and dehiscence of the body wall [1,2]. Reported rates of relaparotomy following initial laparotomy vary from 8-19% [1, 3-5]. Epiploic foramen entrapment (EFE) identified at initial laparotomy and postoperative ileus (POI) are factors previously reported to be significantly associated with increased likelihood of performing relaparotomy [6].

Few studies have specifically reported on the outcome of horses undergoing relaparotomy [1,3,5,7]. Evidence-based information can assist decision-making about management of horses that have developed complications following laparotomy, based on factors such as likely survival of horses following relaparotomy and costs of treatment. Findings at relaparotomy may be a sequelae of primary lesions such as anastomotic complications, progression of primary lesions such as ischaemic necrosis of gut, recurrence of primary lesions such as large colon displacement, may be an unrelated finding not associated with the lesion identified at initial surgery or may be due to surgical error [1,2,3,5]. Reported rates of intraoperative death or euthanasia during relaparotomy are 21–25% [1,3,7] and for all horses undergoing relaparotomy, short-term survival (survival to hospital discharge) is reported to be 40–45% [1,7]. Relaparotomy has been associated with a 12 fold-increased risk of incisional hernia formation [8].

There is currently limited information about factors significantly associated with long-term survival of horses that have undergone relaparotomy and on rates of survival in different groups of horses undergoing relaparotomy. This knowledge can assist clinicians and owners when determining whether to perform relaparotomy and in more accurately predicting the likely outcome following relaparotomy. Therefore, the aims of the present study were to identify factors associated with survival following relaparotomy in a UK hospital population and to describe patterns of survival in different groups of horses requiring relaparotomy.

Materials and methods

Study population

Medical records of all horses that underwent exploratory laparotomy for investigation and treatment of colic at the Philip Leverhulme Equine Hospital, University of Liverpool, UK over a 10-year period (1 January 2002 - 31 December 2012) were reviewed retrospectively. Horses were included in the study if they underwent a second (repeat) laparotomy procedure within 8 weeks of the first surgery for a related condition. Variables of interest were selected from hospital records and were entered onto a computer database. These included signalment, clinical parameters prior to and after the first laparotomy, the initial surgical lesion identified and procedure performed (Supplementary Item 1). Data were also collected on reasons for performing relaparotomy, the number of days between initial surgery and relaparotomy, surgical approach (original midline incision vs. paramedian incision), findings at surgery and additional surgical procedures performed. Postoperative complications and number of days in the hospital following relaparotomy were also recorded. POR was defined as net reflux of >2 L obtained on passage of a nasogastric tube on at least one occasion [9]. A telephone questionnaire was used to obtain data about survival and postoperative complications following hospital discharge. Between 2002 and 2008 this follow-up was part of a study on colic survival [10,11]; data subsequent to this were obtained by the study authors or by the colic database administrator. All horses remained in the study until they died or were lost to follow up e.g. change of ownership. The term death includes horses that died or were euthanased.

Data analysis

Descriptive data were generated for variables of interest and for causes of death or euthanasia. Survival time (in days) was measured as a continuous variable starting from the date of induction of anaesthesia for relaparotomy until death or censoring. Survival time was used to construct Kaplan-Meier plots of cumulative probability of survival [12]. Association with survival time was examined

using univariable Cox proportional hazards models. The functional form of the relationship between continuous predictor variables and survival time was modelled using penalised Cox regression. Smoothing splines were fitted to the data and the shape of each relationship was tested for non-linearity [13]. Variables that showed some evidence of univariable association with the outcome ($P<0.2$) were evaluated in a multivariable Cox proportional hazards model that was constructed using a backward stepwise elimination procedure. Where variables were highly correlated (Pearson correlation coefficient >0.9), the most statistically significant variable was selected and variables with >33% of missing observations were excluded from the initial model building procedure. Variables were retained in the model if they significantly improved the fit of the model (likelihood ratio statistic $P\leq0.05$). All initially excluded variables were then retested in the final model and biologically plausible interaction terms for variables remaining in the final model were assessed.

The proportional hazards assumption of the Cox regression model was evaluated graphically by plotting complementary log–log and Kaplan-Meier survival curves for categorical variables and scaled Schoenfeld residuals for all variables (continuous or categorical) remaining in the final model. Influential observations were examined by plotting delta-betas for each variable in the final model against survival time. Critical probability was set at 0.05 for all analyses. Data analysis was performed using the statistical packages Stata[a] and the 'survival' statistical package version 2.38.1[14] on R software environment version 3.2.0 [15].

Results

Relaparotomy was performed in 96 horses at <8 weeks following initial surgery. This represented 6.3% of horses that underwent laparotomy for treatment of colic and stood following general anaesthesia during the study period (n = 1,531). Horses that underwent relaparotomy included 38 (40%) mares and 58 (60%) males and had a median age at initial presentation of 12 years (range 0.7–22 years). Breed was recorded in 91 cases and included Thoroughbred (TB) and TB cross breeds (n = 34), Warmbloods (n = 20), Cobs (n = 13), ponies (n = 10), Arabians (n = 5) and other breeds (n = 9).

The median weight of horses undergoing relaparotomy was 515.5 kg (range 190–870 kg). These breed and age distributions are similar to our hospital colic population. Findings at initial laparotomy are summarised in Table 1. Relaparotomy was undertaken at a median of 4 days (range 0–56 days) following initial laparotomy. Twenty-four (25%) horses underwent relaparotomy >8 days following initial laparotomy.

Reasons for undertaking relaparotomy, main pathological findings at relaparotomy and the overall rates of short-term survival are shown in Table 2. The surgical approach used was recorded in 91 horses; this was midline in 74 horses (81%) and paramedian in 17 (19%). At initial laparotomy an end-to-end jejuno-jejunal anastomosis (EEJJA) had been performed in 22 horses (23%), an end-to end jejuno-ileal (EEJIA) anastomosis in one horse (1%) and a side-to-side jejuno-caecal anastomosis (SSJCA) in 20 horses (21%). Anastomotic revisions were performed in 29 horses (30%) at relaparotomy. A total of 29 horses (30.2%) were euthanased at relaparotomy based on likely very poor to grave prognosis for survival. All horses undergoing relaparotomy due to septic peritonitis (n = 4) were euthanased on the operating table. Reasons for euthanasia in these cases were diffuse peritonitis and extensive adhesions that were not possible to resect surgically (n = 1), an abscess and associated adhesions at an ileal stump that were not surgically accessible (n = 1), leakage of ingesta from the antimesenteric border of an EEJJA (n = 1) and an ileal biopsy site (n = 1). The latter 2 cases had evidence of systemic inflammatory response syndrome (SIRS) and were euthanased on the operating table at the request of the owners for financial and welfare reasons. When adhesions were identified at relaparotomy (n = 29), 13 (44.9%) horses were euthanased on the operating table whereas if small intestinal distention due to POI or a mechanical obstruction unrelated to adhesions was evident at relaparotomy (n = 39), 6 (15.4%) were euthanased.

A flow diagram detailing the numbers of horses and the outcome at each stage is provided in Figure 1. The study recorded a total of 55,062 days of survival. Overall short-term survival (survival to hospital

discharge) of all horses included in the study was 44.8%, with a median survival time of 6 days (Fig 2). Short-term survival for horses that recovered from anaesthesia following relaparotomy (n = 67) was 64.2% and these horses had a median survival time of 778 days (Fig 2). For horses that were recovered following relaparotomy (n = 67), postoperative complications developed in 40 horses during hospitalisation post- relaparotomy; 27 horses had no recorded complications. One or more complications were recorded for each of these horses and included incisional infection (n = 22), persistent POR (n = 20), colic (n = 17), jugular thrombophlebitis (n = 5) and laminitis (n = 3). A total of 43 horses that had undergone relaparotomy were discharged from the hospital at a median of 10 days following relaparotomy (range 6–30 days). Median survival for these horses exceeded the follow-up period (Fig 2). Of horses that developed post-relaparotomy colic during hospitalisation (n = 17), 9 (53%) were discharged from the hospital and 7/20 (35%) that developed persistent POR post-relaparotomy survived to hospital discharge. Severe colic that was non-responsive to analgesia was the primary reason for death following hospital discharge where this information was known (10/12 horses; 83%).

Variables that were significantly associated with non-survival following relaparotomy on univariable analysis (Supplementary Item 1) were: heart rate (HR) and packed cell volume (PCV) 24 hours following initial laparotomy, colic signs following initial laparotomy, colic signs or peritonitis as the primary reason for relaparotomy and adhesions or small intestinal distention found at relaparotomy. The lesion identified at initial laparotomy, whether SI resection was performed, the type of anastomosis performed, days between initial laparotomy and relaparotomy and both PCV and HR prior to performing relaparotomy had no significant effect on the outcome on univariable analysis (Supplementary Item 1). The results of a final multivariable model are shown in Table 3. Non-survival (Figs 3 and 4) was associated with increased PCV at 24 h following initial laparotomy, peritonitis as a reason for undertaking relaparotomy and adhesions found at relaparotomy (Supplementary Item 2). Increased likelihood of survival was associated with colic signs being the reason for undertaking relaparotomy and small intestinal distention found at relaparotomy. In this

model the proportional hazards assumption was met and no influential observations were identified (Supplementary Items 2 and 3).

Discussion

The current study has reported survival in different groups undergoing relaparotomy and has identified factors associated with non-survival following relaparotomy. This information can assist with informed decision making by clinicians and owners when determining whether to undertake relaparotomy based on likely outcome following surgery.

Relaparotomy was performed in 6.5% of horses that had undergone laparotomy in the previous 8 weeks in the current study. It is difficult to make direct comparisons with other studies due to differing inclusion criteria based on the timescale between initial and repeat laparotomy. The 8-week time period following initial laparotomy was chosen in the current study based on the work performed by Gorvy *et al*. [5] which demonstrated that 77% of relaparotomy cases presented within 2 months of the first surgery. The decision to perform relaparotomy may be influenced by a number of factors including costs of treatment, use of prokinetic agents rather than surgical decompression of SI in the management of suspected POI [16] and knowledge that relaparotomy is a risk factor for significantly reduced postoperative survival in some colic studies [7,10,11,17].

Information about rates and patterns of survival following relaparotomy enables a more accurate prognosis to be provided to owners/carers of horses undergoing this procedure. The pattern of survival was similar to horses following laparotomy [4] with an initial steep decline in survival that progressively levelled out over time. Short-term outcomes of horses undergoing relaparotomy in the present study were similar to earlier studies that reported overall short-term survival of 40–49% and

51–62% survival for those that recovered from general anaesthesia following relaparotomy [1,3,6]. However, a slightly higher percentage of horses were euthanased/died at relaparotomy (30.2%) in this study compared to the latter studies (22–25%). In humans, relaparotomy is performed in 0.5–22% of patients following laparotomy and mortality rates range from 22–71%, with abdominal sepsis being associated with highest rates of mortality [18,19,20]. Horses undergoing relaparotomy for investigation of abdominal sepsis were approximately 4 times less likely to survive in the present study compared to horses in which this was not the reason for relaparotomy. This group represents only a small proportion of horses in the present study. In 2 of the latter cases, extensive adhesions or an inaccessible abscess and adhesions had already developed but in the 2 horses with leakage from anastomosis or enterotomy, development of concurrent severe SIRS contributed to the decision to perform euthanasia on the operating table. Therefore, where abdominal sepsis is suspected, early relaparotomy should be considered.

Relaparotomy was most frequently undertaken in the present study due to abdominal pain. This finding is consistent with that of Mair and Smith [1] but in contrast to Dunkel *et al*. [6] where persistent POR was the predominant reason for relaparotomy [6]. Horses undergoing relaparotomy due to persistent colic signs were approximately twice as likely to survive as those undergoing relaparotomy where persistent signs of colic were not a reason for undertaking relaparotomy. This finding was unexpected due to the fact that postoperative colic has been previously identified as a risk factor for non-survival following initial laparotomy [21]. This finding may be due to the fact that horses undergoing relaparotomy for reasons other than persistent colic had more serious disease associated with a poor prognosis such as POI or septic peritonitis.

Evidence of generalised small intestinal (SI) distention at relaparotomy was associated with a two-fold increase in likelihood of survival compared to cases in which this was not evident. Further investigation of these data revealed that generalised small intestinal distention was more frequently

associated with colic signs and with a mechanical cause of intestinal obstruction other than adhesions (e.g. impaction at or kinking of intestine at an anastomosis) compared to horses with a functional obstruction (POI) or horses in which adhesions were found. Generalised SI distention at relaparotomy may therefore represent cases in which there was normal intestinal function and the option to manually resolve a simple obstruction or to surgically revise an anastomosis. The latter cases would therefore appear to be good candidates for undertaking relaparotomy if there is no response to medical management. No cases of EGS underwent relaparotomy as an ileal biopsy is routinely performed at the study hospital in all cases in which EGS may be suspected based on presenting clinical signs and findings at initial laparotomy, eliminating the need to confirm a diagnosis at relaparotomy.

In the current study, horses in which adhesions were identified at relaparotomy were almost 2 times less likely to survive compared to horses in which adhesions were not identified. Application of sodium carboxymethyl cellulose (SCMC) directly onto gut or instilled into the abdomen and omentectomy were used intermittently in horses undergoing initial or repeat laparotomy as methods to potentially reduce adhesion formation [21] in the current study based on clinician preference. Use of SCMC or performing an omentectomy were not always recorded and so it was not possible to investigate any potential effect of these factors on relaparotomy and outcome following relaparotomy. Abdominal adhesions have been identified to be a significant risk factor for non-survival in horses that have undergone laparotomy in several studies, emphasising the importance of strategies to minimise their development at initial laparotomy and the immediate postoperative period [1,5,23]. It is interesting that in the study by Gorvy *et al*. the presence of adhesions did not influence long-term survival in horses undergoing relaparotomy which is in contrast to the current study. There may be some effect of bias as 44% of horses in which adhesions were identified at relaparotomy were euthanased on the operating table. However, the horses euthanased had extensive adhesion formation that would have required multiple resections or removal of large lengths of SI incompatible with long-term survival, or cases in which affected areas of intestine were surgically inaccessible for management of adhesions.

High PCV and HR 24 hours following initial laparotomy were both significantly associated with reduced survival following relaparotomy on univariable analysis. Only PCV at 24 hours following initial laparotomy remained in a final model and this was a linear association. Neither PCV or HR at 48 hours following initial laparotomy and immediately prior to undertaking relaparotomy were significantly associated with outcome but a large amount of these data were missing which may have had an influence on this association and merits further investigation in future studies. Increased PCV following initial laparotomy may represent horses that are in SIRS or have underlying severe haemodynamic imbalances and consequently may be more likely to develop other associated complications such as POI, laminitis or thrombophlebitis [24]. Therefore, knowledge of the systemic PCV at 24 hours following initial laparotomy should be taken into account when making a decision whether to perform relaparotomy and in horses in which this was high, the prognosis for survival despite relaparotomy may be worse compared to those with normal values.

In the present study, time between initial surgery and relaparotomy was not significantly associated with survival. Despite different inclusion criteria regarding timing of relaparotomy in relation to initial laparotomy, time between surgical procedures was similar to the findings of Mair and Smith [1] and Dunkel *et al*. [6]. Optimal timing of relaparotomy is currently unknown in horses. There is a similar lack of data to support an optimal time for relaparotomy to be undertaken in humans but the outcome is generally considered to be more favourable when undertaken early [27] and when performed 'on demand' rather than as a planned intervention [18]. In humans, relaparotomy is ideally performed when the patient is in optimal condition for surgery and the patient's condition has not deteriorated to a point where surgical intervention itself would be a life-threatening event [20]. Early and frequent postoperative imaging including abdominal computed tomography (CT), monitoring of clinical data and reduced clinical threshold for early relaparotomy in high-risk patients are used to support timely and appropriate selection of human patients for relaparotomy [19, 28]. Whilst abdominal CT cannot currently be performed in adult horses, it is an option in foals/small ponies but

the benefits would have to be considered against the risk of general anaesthesia and economic costs. At present, frequent and early monitoring using abdominal ultrasound, clinical data and reduced clinical threshold for relaparotomy in horses at high risk of relaparotomy would appear to be optimal practice.

Relaparotomy was performed most frequently through the original midline incision in the present study with 19% being performed via a paramedian approach. This had no significant effect on outcome (Supplementary Item 1), although the numbers in the paramedian group may have been too small to have detected any significant differences in postoperative complications compared to the midline incision group. The abdominal approach used for relaparotomy in the present study is consistent with others, where relaparotomy was performed via the original midline incision in 89–100% of cases [1,6,29,30]. This is supported by Boone *et al*. [2] who investigated the differences in healing between repeat laparotomy performed via an original midline incision compared to one performed via a right paramedian approach 14 days apart. They demonstrated no significant differences in healing between the midline and right laparotomy incisions and that there was significantly more oedema in horses in which a right ventral paramedian approach had been used.

This was a retrospective study and it may have lacked power to detect smaller differences between different groups of horses undergoing relaparotomy due to the relatively small number of horses. However, a number of factors were identified to be significantly associated with survival following relaparotomy. Recall bias was minimised for cases undergoing surgery between 2002-2008 due to the fact that telephone questionnaires were conducted at regular intervals as part of an ongoing prospective survival study. However, owners/carers may have been less able to accurately recall events such as death of the horse or it being sold between 2008-2012. Euthanasia may also bias the results due to the fact that horses which had a chance to survive may have been euthanased intra- or post-operatively due to a combination of likely poor prognosis, welfare and economic factors.

Euthanasia on economic grounds was infrequently performed at relaparotomy in the present study; economic constraints were a common reason for relaparotomy not being performed. Previous studies at the same institution have shown no effect of surgeon on postoperative survival; therefore this was not recorded as a variable in this study [11], nor did we investigate rates of technical error. Technical error was identified in 14% of horses undergoing early relaparotomy and presumed in a further 31% in one study [31]. Anastomotic leakage and haemoperitoneum following relaparotomy in the present study may have been associated with technical error and both were associated with poor survival following relaparotomy. This demonstrates the importance of clinical audit in monitoring rates of relaparotomy, postoperative survival and identifying whether the need for repeat surgical intervention was associated with technical error during the initial laparotomy.

The decision to perform relaparotomy can be difficult and the potential benefits have to be considered together with costs and likely outcome during discussions between clinicians and horse owners/carers. Increased PCV 24 hours following initial laparotomy, undertaking relaparotomy due to evidence of septic peritonitis and finding adhesions at relaparotomy were factors significantly associated with reduced survival following relaparotomy in a multivariable model. Horses that underwent relaparotomy due to colic signs and where small intestinal distention was evident at relaparotomy were associated with increased likelihood of survival. This study provides information that may be used to assist informed-decision making when considering whether to undertake relaparotomy and provides information about survival in different groups of horses that have undergone this procedure.

Authors' declarations of interest

No competing interests have been declared.

Ethical animal research

This study was approved by the University of Liverpool Veterinary Research Ethics Committee under generic colic research. Owner consent was not stated.

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Authorship

D.C. Archer and J.A. Findley conceived and designed the study. R. Burgess and J.A. Findley collected the data. D.C. Archer performed data analysis and interpretation. S. Salem assisted with statistical analysis and interpretation. All authors drafted the paper and have read and approved the final version.

Table 1: Lesions identified as the primary cause of colic at initial laparotomy in 96 horses that subsequently underwent relaparotomy.

Surgical lesion identified at initial laparotomy	Number (%)
Pedunculated lipoma obstruction	20 (20.8)
Epiploic foramen entrapment	7 (7.3)
Other strangulating small intestinal lesion	16 (16.7)
Simple obstruction/non-strangulating small intestinal lesion	20 (19.8)
Large colon displacement/impaction	16 (19.8)
Large colon volvulus (>270^0)	8 (7.3)
Caecal lesion (intussusception/impaction)	2 (2.1)
Other diagnosis	7 (7.3)

Table 2: Numbers of horses and overall short-term survival (proportion of horses that survived to hospital discharge) based on the reason for performing repeat laparotomy and the main findings at surgery. Some horses would have fulfilled more than one category.

		No. of horses (%)	Overall short term survival (%)
Reason for repeat laparotomy			
	Colic signs	73 (76)	39 (53.4)
	Persistent postoperative reflux (POR)	19 (20)	7 (36.8)
	Haemoperitoneum	6 (6)	1 (16.7)
	Peritonitis	4 (4.2)	0 (0)
	Incisional dehiscence	2 (2)	1 (50)
	Other	7 (7)	2 (29)
Pathological finding at relaparotomy	Small intestinal distention	39 (41)	21 (54)
	Adhesions	29 (30)	7 (24)
	Non-viable intestine	20 (21)	10 (50)
	Recurrent large colon displacement	14 (15)	6 (43)
	Anastomotic obstruction	13 (14)	8 (62)
	Anastomotic leakage	4 (4)	1 (25)
	Septic peritonitis	10 (10)	1 (10)
	Intra-abdominal haemorrhage	7 (7)	3 (43)

Table 3: Final, multivariable Cox proportional hazards model for non-survival in horses undergoing relaparotomy.

Variable	Number (%)	Hazard ratio	95% Confidence intervals	P value
PCV 24h following initial laparotomy (%)	Median 38	1.06	1.04 - 1.10	0.009
Colic signs the reason for undertaking relaparotomy				
No	23 (24)	Ref.		
Yes	73 (76)	0.48	0.26 – 0.88	0.0172
Peritonitis the reason for undertaking relaparotomy				
No	92 (96)	Ref.		
Yes	4 (4)	4.41	1.43 – 13.6	0.01
Adhesions found at relaparotomy	67 (70)	Ref.		
No	29 (30)	1.77	1.03 – 3.04	0.04
Yes				
Small intestinal distention found at relaparotomy				
No	57 (59)	Ref.	0.29 – 0.96	0.04
Yes	39 (41)	0.53		

Number of observations in the final model = 83, Ref. = reference category, PCV = packed cell volume, RL = repeat laparotomy.

Figure legends

Fig 1: Flow chart detailing the outcome for 96 horses that underwent repeat laparotomy at different stages relative to initial and repeat laparotomy being performed.

Fig 2: Kaplan-Meier plots of the cumulative probability of survival in all 96 horses undergoing relaparotomy (relaparotomy whole cohort), the 67 horses that were recovered from anaesthesia

following relaparotomy (survived surgery group) and the 43 horses that were discharged from the hospital following relaparotomy (discharged home group).

Fig 3: Kaplan-Meier plots of the cumulative probability of survival following relaparotomy of univariable Cox proportional hazards models for the variables 'Colic signs between initial and repeat laparotomy [relaparotomy]', 'Peritonitis the reason for undertaking repeat laparotomy', 'Adhesions found at repeat laparotomy' and 'Small intestinal [SI] distention found at repeat laparotomy'.

Fig 4: P-spline smoother plot, with 95% confidence intervals (dotted lines) from univariable penalised Cox proportional regression models of survival following repalarotomy. This graph demonstrates the linear relationship between packed cell volume (PCV) at 24 hours following initial laparotomy (continuous variable) and survival.

Supplementary Information

Supplementary Item 1: Variables associated with survival following undertaking repeat laparotomy.

Supplementary Item 2: Proportional hazards assumptions.

Supplementary Item 3: Factors associated with increased survival.

Manufacturer's address

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