**Head and tail rope assisted recovery improves quality of recovery from general anaesthesia in horses undergoing emergency exploratory laparotomy.**

**word count: 5885**

BACKGROUND:

In equine anaesthesia, the recovery period is critical, accounting for most anaesthesia related fatalities reported. Horses may recover unassisted or may be assisted, for example, using a head and tail rope recovery (HTRR) method.

OBJECTIVES:

To compare the impact of HTRR and unassisted recovery on quality of recovery (QR) in horses undergoing colic surgery under general anaesthesia (GA).

STUDY DESIGN: Single centre retrospective cross-sectional study, with prospective model performance analysis.

METHODS:

Clinical data were obtained from horses undergoing colic surgery over a 6-year period. Multivariable logistic regression analysis was used to identify the perioperative factors that affect QR. The final prediction model was assessed prospectively.

RESULTS:

Records from 502 general anaesthetics (490 horses) were included. Multivariable logistic regression analysis showed that HTRR (OR 2.2, 95% CI 1.4 to 3.3, P < 0.001) and sevoflurane administration (OR 1.6, 95% CI 1.2 to 2.3, P = 0.02) were associated with better QR when compared to unassisted recovery and isoflurane administration, respectively. Increasing GA duration (OR 1.0, 95% CI 0.99 to 1.0, P = 0.03), increasing intraoperative dosages (in mg/kg) of thiopental (OR 0.85, 95% CI 0.75 to 0.98, P = 0.02) or ketamine (OR 0.67, 95% CI 0.46 to 0.99, P = 0.04) were linked to poor QR. No statistically significant difference was found between recovery groups in terms of mortality.

MAIN LIMITATIONS:

The clinical prediction model obtained is only applicable to the specific facilities, recovery methodology, referral population, and anaesthetic protocols practiced at our institution.

CONCLUSIONS:

This study concludes that HTRR is significantly associated with better QR, compared to unassisted recovery, in horses undergoing colic surgery. Sevoflurane administration, in detriment of isoflurane, was associated with better QR. Other risk factors, such as increasing GA duration, the use of higher intra-operative dosages of ketamine and/or thiopental, were associated with poor QR.

KEYWORDS: Veterinary anaesthesia, Rope-assisted recovery, Unassisted recovery, Complications, Equine, Mortality, Morbidity

INTRODUCTION

In equine anaesthesia, recovery is a critical period, with two studies showing 81.0% to 92.0% of anaesthesia-related complications occurring during this period [1,2]. The anaesthetist may allow the horse to recover unassisted or may provide assistance using a range of available systems, including: hand assistance, sling systems, inflated air mattress, tilt table, recovery pool, and head-tail rope assistance [3–8]. Some authors have suggested that head and tail rope recovery (HTRR) may reduce the risk of major recovery-associated complications [3,9]. The lack of control groups in these studies makes this statement difficult to prove. Also, the difference in animal populations, surgical procedures, anaesthetic management protocols, facilities and recovery methods makes the comparison between assisted and unassisted recovery methods challenging.

A single centre, randomized, prospective, clinical trial, studying a population of healthy young horses undergoing elective surgeries showed a statistically significant improvement in quality of recovery (QR) scores when horses were recovered using an HTRR method [10]. A single centre, retrospective cross-sectional study, reviewing a population of horses undergoing surgical management of colic failed to identify a benefit of HTRR over unassisted recovery in terms of QR [11]. In terms of recovery-associated fatalities, neither study showed a statistically significant difference between either recovery method [10,11]. Although, a recent single centre, retrospective cross-sectional study, suggested that the application of HTRR method reduced the risk of fatal complications during recovery of horses undergoing surgical management of colic, but it failed to identify the same effect in horses undergoing elective procedures [2]. These three studies show conflicting results [2,10,11], revealing the lack of evidence in terms of the impact of HTRR in terms of QR in horses recovering from general anaesthesia (GA).

The aim of this study was to identify perioperative factors associated with QR in horses undergoing surgical management of colic under GA. The objective of the study was to compare the impact of HTRR and unassisted recovery on QR in horses undergoing surgical management of colic under GA. Our hypothesis was that HTRR improves QR in this subset of horses in our institution.

MATERIAL AND METHODS

Data collection

The case records of horses presented to the University of Liverpool Philip Leverhulme Equine Hospital for surgical management of colic between January 2014 and December 2019 were reviewed. Cases were included if horses were >6 months of age, weighted >200 kilograms, underwent surgical management of colic under GA, and QR score and recovery method was recorded. Horses dying at induction of GA or during surgery and patients subjected to euthanasia during surgery were excluded from the study as well as horses recovered by different methods other than head and tail rope recovery (HTRR) and unassisted (U). Perioperative variables included in the analysis are given in Table S1.

QR was evaluated using a descriptive scale, previously reported and correlated [12,13] with other composite scales [14] (Table S2). QR scores of 1 and 2 were defined as good recovery and QR scores higher than 2 were defined as poor recovery.

The outcome variable was QR, a binary categorical variable, (with odds ratio [OR] >1 indicating greater odds of good QR and OR <1 indicating reduced odds of good QR).

In order to evaluate the performance of the final clinical prediction model obtained, a prospective analysis was performed. Cases were recruited at the same referral hospital, fulfilling same inclusion criteria as in the retrospective part. Video recordings were obtained for all prospective cases as well as the same perioperative variables obtained for the retrospective part of the study. Three observers from separate institutions (ECVAA Diplomates: KR, KL and JH), blinded to the objective of the study and to the variables retained in the final model, evaluated those recordings for QR.

Data analysis

Statistical analysis was performed using SPSS Statistic version 27 for Windowsh. Data normality was evaluated using the Shapiro-Wilk test. Differences in continuous variables between HTRR and U recovery groups, as well as between good and poor QR groups, were analysed using two-tailed hypothesis tests. Where variables were normally distributed, an independent T-test was used, where data were not normally distributed, the Mann-Whitney U test was utilised. Results are reported as mean (± standard deviation) for normally distributed variables and median (interquartile range) for non-normally distributed ones. In all cases significance was assumed if P <0.05.

All variables were screened for association with outcome (good QR) using a univariable logistic regression model for continuous and categorical variables with an alpha level of 0.05. For categorical variables, reference categories were attributed to the highest number of occurrences in each category. Pearson’s rank correlation was used to establish signiﬁcance and strength of association between each of these variables and outcome. For highly correlated covariates (Pearson’s rank correlation > 0.7) [15], only those with the smallest P-values were selected.

A forward stepwise selection procedure was used to determine the final multivariable logistic regression model; all covariates were considered, and those with a Wald P-values <0.05 were retained at each step, in order to determine which explanatory variables would be included in the final model. The ﬁt of the ﬁnal multivariable model was assessed using the Hosmer–Lemeshow goodness-of-ﬁt test. Correlation of estimates was used to evaluate the strength of the linear relationship between explanatory variables. Specificity and sensitivity (95% CI) were calculated via a classification table as well as area under the curve of receiver-operator characteristic (AUC ROC) using the predicted values produced by the ﬁnal multivariable model and the observed values (poor and good QR). For interpretation of AUC ROC arbitrary ‘benchmarks’ were used: suggestive of no discrimination: AUC ROC < 0.5:, poor overall prediction accuracy: AUC ROC = 0.50-0.69, acceptable overall prediction accuracy: AUC ROC = 0.70-0.79, excellent overall prediction accuracy: AUC ROC = 0.80-0.89, outstanding overall prediction accuracy: AUC ROC ≥ 0.9 [16].

A formula was generated to predict the probability (P) of a good QR based on the ﬁnal multivariable model obtained:

$$P = \frac{e^{\left(β+α\_{1}X\_{1}+…α\_{n}X\_{n}\right)}}{1+e^{\left(β+α\_{1}X\_{1}+…α\_{n}X\_{n}\right)}}$$

Recovery method was screened for association with mortality, morbidity and catastrophic fractures/dislocations using a univariable logistic regression model with an alpha level of 0.05.

The final model constructed using multivariable logistic regression was assessed, prospectively, in order to test its accuracy. Ten events per variable in the final multivariable logistic regression model are necessarily to evaluate the accuracy of the model. Video recordings of the recoveries were obtained from two different angles and each observer scored each recovery once and an average score for each recovery was obtained by the sum of the scores divided by the number of observations. Inter-observer agreement, for the nominal variable recovery score, was calculated using the Fleiss’ kappa coefficient (κ). Arbitrary ‘benchmarks’ for the strength of agreement were used: κ = 0.01–0.20, slight; κ = 0.21–0.40, fair; κ = 0.41–0.60, moderate; κ = 0.61–0.80, substantial; κ = 0.81–1.00, almost perfect [17]. Using the explanatory variables obtained from the retrospective multivariable model, a probability of good QR was calculated for each prospective case using the mathematical formula previously mentioned. This probability was then compared with the observed values (poor and good QR). Specificity and sensitivity (95% CI) were calculated via classification table as well as AUC ROC using the predicted values produced by the ﬁnal multivariable logistic regression model and the observed values (poor and good QR). The criteria used to interpret the AUC ROC results was the same as for the retrospective part of the study.

RESULTS

Case details

A total of 885 cases requiring surgical management of colic under GA were identified. Only 502 general anaesthetics (490 horses) fulfilled the study inclusion criteria. Of the excluded general anaesthetics: 110 patients (12.4%, 95% CI 10.3 to 14.8%) were euthanised or died prior to general anaesthesia, 163 patients (18.4%, 95% CI 15.9 to 21.1%) were euthanised during general anaesthesia, 8 cases (0.9%, 95% CI 0.39 to 1.8%) died at induction of anaesthesia or during surgery, 75 cases (8.5%, 95% CI 6.7 to 10.5%) had incomplete anaesthetic records including method and recovery score not recorded, and 27 patients (3.1%, 95% CI 2.0 to 4.4%) were younger than 6 months of age and/or weighted less than 200 kilograms (Figure 1). Summary information regarding signalment and preoperative variables is included as supplementary data (Table S3 and S4).

The most common anaesthetic protocol recorded consisted of premedication with xylazine (0.6-1.0 mg/kg intravenous (IV) (398/502 cases: 79.3%, 95% CI 75.5 to 82.8%) and morphine (0.2 mg/kg IV) (499/502 cases: 99.4%, 95% CI 98.3 to 99.9%). Flunixin meglumine (1.1 mg/kg IV) was administered pre-operatively (393/502 cases: 78.3%, 95% CI 74.4 to 81.8%). General anaesthesia was induced with ketamine (2.2-2.7 mg/kg IV) and a benzodiazepine (0.05-0.07 mg/kg IV) (475/502 cases: 94.6%, 95% CI 92.3 to 96.4%). Regarding the choice of volatile anaesthetic administered for maintenance of anaesthesia: isoflurane was administered to 225/502 cases (44.8%, 95% CI 40.4 to 49.3%) and sevoflurane was administered to 277/502 cases (55.2%, 95% CI 50.7 to 59.6%). A lidocaine infusion (0.05 mg/kg/minute) was administered when deemed necessary to provide further analgesia (309/502 cases: 61.6%, 95% CI 57.1 to 65.8%). All horses received an infusion of Hartmann’s solution (4 mL/kg/hour). To sustain cardiovascular function an infusion of dobutamine was titrated to effect in most cases (454/502: 90.4%, 95% CI 87.5 to 92.9%). Colloids (191/502 cases, 38.0%, 95% CI 33.8 to 42.5%) hypertonic saline (104/502 cases, 20.7%, 95% CI 17.3 to 24.5%) and phenylephrine (77/502 cases, 15.3%, 95% CI 17.3 to 24.5%) were also administered in certain cases to aid cardiovascular function. A total of 162 cases were recovered from GA using HTRR (162/502, 32.3%, 95% CI 28.2 to 36.6%), and 340 horses (340/502, 67.7%, 95% CI 63.4 to 71.8%) recovered unassisted. Half of the cases did not receive an α-2 adrenoceptor agonist prior to recovery from anaesthesia (279/502, 55.6%, 95% CI 51.1 to 60.0%), while the other half (223/502, 44.4%, 95% CI 40.0 to 48.9%) received an α-2 adrenoceptor agonist prior to recovery from anaesthesia, the most used α-2 adrenoceptor agonist was romifidine (0.01-0.03 mg/kg IV) (138/223, 61.9%, 95% CI 55.2 to 68.3%).

Recovery Method

A total of 162 cases were recovered from GA using HTRR (162/502, 32.3%, 95% CI 28.2 to 36.6%), and 340 horses (340/502, 67.7%, 95% CI 63.4 to 71.8%) recovered unassisted. The Mann-Whitney U test showed a statistically significant difference in median (IQR) between recovery method groups [group HTRR and group unassisted recovery (U)] for recovery duration (group HTRR: 40 (25) minutes and group U: 35 (29) minutes; Mann–Whitney U = 22099.5, P = 0.005) and number of attempts to stand (group HTRR: 2 (2) attempts and group U: 3 (1.5) attempts; Mann–Whitney U = 18970.5, P < 0.001). There was a moderate strength of association (Pearson’s rank correlation > 0.5 to ≤ 0.7) [15] between unassisted recovery and lack of provision of sedation using α-2 adrenoceptor agonists prior to recovery from anaesthesia (Pearson’s rank correlation = 0.61, P value < 0.001). No other highly correlated covariates (none had a Pearson’s rank correlation >0.7) [15] were detected between recovery method and other peri-operative variables not related with the recovery period.

Recovery Quality

A total of 260 cases (260/502, 51.8%, 95% CI 47.3 to 56.2%) had a good QR and 242 cases (242/502, 48.2%, 95% CI, 43.8 to 52.7%) had a poor QR. Details of the anaesthetic protocol used and recovery variables of both groups are presented as supporting information (Table S5 and S6).

The results obtained from univariable logistic regression analysis, based on perioperative variables with an outcome of good QR, are presented as supporting information (Table S7).

The final multivariable logistic regression model based on perioperative variables with an outcome of good QR is shown in Table 1. The Hosmer and Lemeshow test indicated no evidence of poor fit for the model (P = 0.17). Five variables were found significantly associated with QR: HTRR method, sevoflurane administration, GA duration, and intraoperative administration of ketamine and/or thiopental.

The model was able to predict QR correctly in 63.3% (95% CI 56.9 % to 69.2%) of cases with a sensitivity of 66.2% (95% CI 60.0% to 71.8%) and specificity of 60.3% (95% CI 53.8% to 66.5%). The AUC ROC was 0.69 (95% CI 0.64 to 0.73), indicating a poor overall accuracy of the predictive model obtained. Based on the final model, predictive probabilities were calculated to examine the effects of HTRR recovery and sevoflurane administration on QR in this subset of horses (Figure 2). A formula was generated to predict the probability (P) of a good QR (GA duration displayed in minutes; administration of sevoflurane in oxygen represented as 1 and administration of isoflurane in oxygen as 0; HTRR method represented as 1 and unassisted method as 0; intraoperative administration of thiopental in mg/kg; intraoperative administration of ketamine in mg/kg):

$P=\frac{e^{\left(0.51+\left[-0.004\left(GA duration\right)\right]+\left[0.49\left(maintenance agent\right)\right]+\left[0.78\left(recovery method\right)\right]+\left[-0.16\left(thiopental\right)\right]+\left[-0.40\left(ketamine\right)\right]\right)}}{1+e^{\left(0.51+\left[-0.004\left(GA duration\right)\right]+\left[0.49\left(maintenance agent\right)\right]+\left[0.78\left(recovery method\right)\right]+\left[-0.16\left(thiopental\right)\right]+\left[-0.40\left(ketamine\right)\right]\right)}}$

Mortality

Recovery-associated fatalities (Table 2) were recorded in 22 cases (22/502, 4.4%, 95% CI 2.8 to 6.6%). No statistically significant difference associated with mortality was found between recovery method groups: 16/340 cases (4.7%, 95% CI 2.7 to 7.5%) in U group, and 6/162 cases (3.7%, 95% CI 1.4 to 7.9%) in HTRR group; (OR 0.78, 95% CI 0.30 to 2.0, P = 0.61). In terms of catastrophic fractures/dislocations in recovery, HTRR group only registered one fatality (0.6%, 95% CI 0.02 to 3.4%) compared to six fractures and one dislocation in the unassisted group (1.8%, 95% CI 0.83 to 4.2%), but the difference between groups was not statistically significant (OR 0.30, 95% CI 0.04 to 2.4, P = 0.26).

Morbidity

Minor recovery-associated complications (Table 3) occurred in 33 cases (33/502, 6.6%, 95% CI 4.6 to 9.1%). No statistically significant difference associated with morbidity was found between recovery method groups: 14/162 cases (8.6%, 95% CI 4.8 to 14.1%) in HTRR group and 19/340 cases (5.6%, 95% CI 3.4 to 8.6%) in U group (OR 1.6, 95% CI 0.78 to 3.3, P = 0.2).

Prospective performance analysis of the clinical prediction model

A total of 53 recoveries were recruited, although three cases were excluded: two horses weighed less than 200 kilograms and one horse was placed in recovery and died of respiratory arrest before regaining conscience and make an attempt to stand (Figure 3). Therefore, 50 recoveries were included in the analysis. A total of 28 horses recovered from GA using HTRR (56%, 95% CI 41.3 to 70.0%), and 22 horses (44%, 95% CI 30.0 to 58.8%) recovered unassisted. A summary of information regarding the relevant preoperative variables recorded in the prospective performance analysis of the clinical prediction model is available in Table S8. The scores recorded by the attending anaesthetist and the average scores of the three ECVAA Diplomates resulted in a moderate interrater agreement (k = 0.47, 95% CI 0.30 to 0.65). Moderate interrater agreement was also observed between the scores of the three ECVAA Diplomates (k = 0.48; 95% CI 0.38 to 0.59). The model was able to correctly predict QR in 70.0% of cases (95% CI 55.4 to 82.1%), with a sensitivity of 74.1% (95% CI 53.7 to 88.9%) and specificity of 65.2% (95% CI 42.7 to 83.6%). The AUC ROC was 0.72 (95% CI 0.57 to 0.86) indicating an acceptable overall diagnostic accuracy of the predictive model.

DISCUSSION

This retrospective study showed that HTRR recovery was associated with a better QR in a subset of horses undergoing surgical management of colic under GA.

A better QR was associated with HTRR recovery, administration of sevoflurane rather than isoflurane, shorter GA duration and lower intraoperative dosages of thiopental and ketamine.

An improvement in QR, associated with HTRR, was previously reported for healthy horses undergoing elective procedures [10]. Horses recovering using this method had fewer attempts to stand [10]. Other studies have failed to confirm a significant improvement in QR using HTRR for horses undergoing emergency exploratory laparotomies [11]. Our data shown that HTRR was associated with a better QR and fewer attempts to stand in this subset of horses. Horses with colic can be critically ill at presentation and there is often limited time for preoperative stabilisation. We hypothesise that the use of HTRR, in these debilitated horses, results in a more efficient way of achieving a safe standing position, by reducing the number of attempts required to stand.

In this subset of horses, maintaining anaesthesia using sevoflurane in oxygen provided a better QR when compared to isoflurane. Due to the low blood solubility of sevoflurane, which permits rapid alterations in alveolar concentrations, it has been proposed that this volatile anaesthetic provides good anaesthetic stability, favourable cardiovascular effects and rapid and coordinated recoveries [18–20]. When compared to halothane, sevoflurane resulted in greater cardiac output and better QR [21]. In a prospective, randomised cross-over trial sevoflurane, administered to maintain anaesthesia in healthy horses, resulted in better QR when compared to isoflurane [22]. Other experimental and clinical trials failed to prove the benefits of sevoflurane over isoflurane in terms of QR [23–26]. We hypothesised that sevoflurane may provide certain advantages over isoflurane, such as more favourable cardiovascular effects and more rapid and coordinated recoveries, which may directly impact on QR of debilitated patients such as the ones included in this subset of horses.

We demonstrated that QR is also influenced by prolonged GA duration. Studies have demonstrated that the risk of anaesthetic-related mortality and morbidity increases with the duration of anaesthesia and surgery time, possibly due to the cumulative effects of inadequate perfusion, hypoxia and acid-base abnormalities [1,2,27–29]. Duration of anaesthesia over ninety minutes has been shown to be a significant risk factor in the development of post-anaesthetic musculoskeletal injuries [28]. One retrospective case series, reflecting on equine recoveries after elective surgeries, showed that prolonged duration of anaesthesia had a negative impact on QR [13]. The same was not found in horses undergoing emergency abdominal surgery elsewhere [11]. We conclude that shorter GA duration has a positive influence on QR in horses recovering from emergency exploratory laparotomies.

Our data showed that QR is negatively influenced by a higher total dose of ketamine and thiopental administered intraoperatively in this subset of patients. Excitement in recovery after administration of high dosages of thiopental and ketamine have been reported in horses [30–32]. Recovery from thiopental depends on redistribution of the drug rather than elimination, therefore increasing doses may lead to excitement and poor recovery quality in horses [31,33]. Recovery from ketamine depends on rapid redistribution of the drug as well as active metabolite formation which explains the abrupt recovery observed after administration of high dosages of ketamine required to deepen the plane of anaesthesia [34].

When tested prospectively, the clinical prediction model obtained was able to predict QR with higher overall accuracy, sensitivity and specificity when compared to the data obtained retrospectively. The clinical prediction model explains only 70.0% of the variability in QR observed, this suggests that other, unmeasured variables are accountable for the remaining variability in QR. In addition, the AUC ROC indicates that the prediction model obtained has only an acceptable overall diagnostic accuracy, therefore this is a limitation of this study. Another of the limitations of this study is that the clinical prediction model obtained is only applicable to the specific facilities, recovery methodology, referral population, and anaesthetic protocols practiced at the University of Liverpool Philip Leverhulme Equine Hospital. This model has not been tested in a different environment therefore it’s performance in different conditions is unknown.

Even though the three observers evaluating the recovery recordings were blinded to the objective of the study and to the variables retained in the final model, there is still some potential to introduce a bias into the scoring process as it was not possible to blind the graders as to whether the horses were recovering with HTRR or unassisted. Another limitation is the fact that interrater agreement was moderate which exposes the lack of objectivity of the QR scoring systems used. In addition, the observers only scored each recovery once, therefore, intraobserver agreement could not be calculated.

Another limitation of this study is the differences in anaesthetic protocol practiced at our institution during the period studied, particularly in terms of choice of volatile anaesthetic agent, lidocaine PIVA and sedation prior to recovery. Unassisted recovery and no sedation administered prior to recovery were moderately associated with each other. Provision of sedation using α-2 adrenoceptor agonists bolus close to recovery from anaesthesia has been shown to improve QR in prospective, randomized cross-over trials in horses recovering unassisted [22,35–37]. A large retrospective clinical study showed some univariable association between provision of sedation with α-2 adrenoceptor agonists prior to recovery from anaesthesia and QR [38]. However, a definitive statistically significance was not present in the final multivariable logistic regression model for QR [38]. In our study, both variables, unassisted recovery and no sedation administered prior to recovery were forced into the multivariable logistic regression model and the variable sedation prior to recovery was not present in the final model. This indicated that is the recovery method that impacts on QR and not the lack or provision of sedation prior to recovery from GA. Although, only the lack or provision of sedation prior to recovery from GA were explored in this study, the influence of the dose of α-2 adrenoceptor agonist administered prior to recovery from GA was not included as a variable which presents as a limitation of the study.

In terms of recovery-associated fatalities and morbidities, our study did not report a statistically difference between recovery methods. This study is underpowered in order to detect any statistical differences in recovery-associated fatalities between both groups, due to the infrequent occurrence of these complications. A post hoc power calculation determined that the sample obtained in this study had 6.6% power to detect, as significant at the 5% level, a clinically significant difference in mortality in recovery. Further studies should be conducted to assess the influence of HTRR in terms of fatalities and morbidities in recovery.

This study concludes that HTRR significantly improves QR in horses undergoing surgical treatment of colic under GA. Under the conditions of this study, recoveries from sevoflurane were of better quality than those from isoflurane. Increased duration of anaesthesia and higher doses of thiopental and ketamine administered intraoperatively were significantly correlated with the likelihood of poor QR. Prospective, multicentre studies including a larger number of patients are required to assess if HTRR significantly reduces mortality and/or morbidity in patients undergoing GA for surgical management of colic.

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LIST OF FIGURE LEGENDS

Figure 1.Flow chart to show recruitment of cases undergoing general anaesthesia required for management of colic clinical signs at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. The flow chart shows the progression of such cases throughout the study.

Figure 2. Influence of recovery method and volatile anaesthetic agent on recovery quality. Positive unstandardised beta weights correspond to shorter general anaesthesia duration and lower intraoperative dosages of thiopental and ketamine (Table 1.). Note that, for the same unstandardised beta weight, the predictive probability for a good quality of recovery is higher for patients in head and tail rope recovery (HTRR) group than for patients in the unassisted (U) group. Also, for the same unstandardised beta weight, the predictive probability for a good quality of recovery is higher for patients receiving sevoflurane compared to patients receiving isoflurane as maintenance agent.

Figure 3.Flow chart to show recruitment of prospective cases undergoing general anaesthesia required for management of colic clinical signs at the University of Liverpool Philip Leverhulme Equine Hospital between March 2020 and December 2020. The flow chart shows the progression of such cases throughout the study.

Table 1. Multivariable logistic regression model\* for perioperative factors associated with good quality of recovery following 502 exploratory laparotomy surgeries under general anaesthesia (in 490 horses) for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. HTRR: head and tail rope recovery; U: unassisted recovery.

Table 2. Mortality causes of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the method of recovery, head and tail rope recovery (HTRR) (162 cases) and unassisted recovery (340 cases). Cases that suffer from fractures or dislocations, that were unable to stand or suffer from spinal cord myelopathy were euthanised in recovery, while the remaining horses died in recovery as a result of acute cardiovascular failure or upper airway obstruction. Data are presented as number of occurrences and percentage (95% CI).

Table 3. Morbidity causes of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the method of recovery, head and tail rope recovery (HTRR) (162 cases) and unassisted recovery (340 cases). Data are presented as number of occurrences and percentage (95% CI).

Table S1. Perioperative variables recorded from the clinical records. MAC: minimum alveolar concentration, ASA: American Society of Anesthesiologists, GA: general anaesthesia, ECVAA: European College of Anaesthesia and Analgesia, PIVA: partial intravenous anaesthesia.

Table. S2. Descriptive scale for evaluation of recovery quality in horses [12,13].

Table S3. Demographic variables of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the quality of recovery score (QR), poor QR (n = 242) and good QR (n=260). Data are presented as mean (standard deviation, SD) if normally distributed and as median (interquartile range, IQR) if not normally distributed. For normally distributed variables, an independent T-test, with an alpha level of 0.05, was used to analyse the difference in means (± standard deviation) of continuous variables between both groups (poor QR and good QR). For non-normally distributed data, a Mann-Whitney U test, with an alpha level of 0.05, was used to analyse the difference in median (interquartile range) of continuous variables between both groups (poor QR and good QR). For categorical variables an univariable regression analysis, with an alpha level of 0.05, was used to analyse the difference between groups (poor QR and good QR). ASA: American Society of Anestesiologists.

Table S4. Preoperative variables of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the quality of recovery score (QR), poor QR (n = 242) and good QR (n=260). Data are presented as mean (standard deviation, SD) if normally distributed and as median (interquartile range, IQR) if not normally distributed. For normally distributed variables, an independent T-test, with an alpha level of 0.05, was used to analyse the difference in means (± standard deviation) of continuous variables between both groups (poor QR and good QR). For non-normally distributed data, a Mann-Whitney U test, with an alpha level of 0.05, was used to analyse the difference in median (interquartile range) of continuous variables between both groups (poor QR and good QR). For categorical variables an univariable regression analysis, with an alpha level of 0.05, was used to analyse the difference between groups (poor QR and good QR). ECVAA: European College of Veterinary Anaesthesia and Analgesia; GA: general anaesthesia; OOH: out of hours; EAAPS-1: Equine Acute Abdominal Pain Scale-1 [39].

Table S5. Anaesthetic variables of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the quality of recovery score (QR), poor QR (n = 242) and good QR (n=260). Data are presented as mean (standard deviation, SD) if normally distributed and as median (interquartile range, IQR) if not normally distributed. For normally distributed variables, an independent T-test, with an alpha level of 0.05, was used to analyse the difference in means (± standard deviation) of continuous variables between both groups (poor QR and good QR). For non-normally distributed data, a Mann-Whitney U test, with an alpha level of 0.05, was used to analyse the difference in median (interquartile range) of continuous variables between both groups (poor QR and good QR). For categorical variables an univariable regression analysis, with an alpha level of 0.05, was used to analyse the difference between groups (poor QR and good QR).

Table S6. Recovery variables of 490 horses undergoing 502 exploratory laparotomy surgeries under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. Data are divided into two groups according to the quality of recovery score (QR), poor QR (n = 242) and good QR (n=260). Data are presented as mean (standard deviation, SD) if normally distributed and as median (interquartile range, IQR) if not normally distributed. For normally distributed variables, an independent T-test, with an alpha level of 0.05, was used to analyse the difference in means (± standard deviation) of continuous variables between both groups (poor QR and good QR). For non-normally distributed data, a Mann-Whitney U test, with an alpha level of 0.05, was used to analyse the difference in median (interquartile range) of continuous variables between both groups (poor QR and good QR). For categorical variables an univariable regression analysis, with an alpha level of 0.05, was used to analyse the difference between groups (poor QR and good QR).

Table S7. Univariable logistic regression model for perioperative factors associated with good quality of recovery following 502 exploratory laparotomy surgeries under general anaesthesia (in 490 horses) for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between January 2014 and December 2019. HTRR: head and tail rope recovery; U: unassisted; PIVA: Partial intravenous anaesthesia, ECVAA: European College of Veterinary Anaesthesia and Analgesia

Table S8. Anaesthetic variables of 50 cases undergoing exploratory laparotomy surgery under general anaesthesia for management of colic clinical signs performed at the University of Liverpool Philip Leverhulme Equine Hospital between March 2020 and December 2020. Data are divided into two groups according to the combined quality of recovery score (QR) attributed by the three ECVAA diplomats, poor QR (n = 23) and good QR (n = 27). Data are presented as mean (standard deviation, SD) if normally distributed and as median (interquartile range, IQR) if not normally distributed. HTRR: head and tail rope recovery; U: unassisted.

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