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Does intraoperative low arterial partial pressure of oxygen increase the risk of surgical site infection following emergency exploratory laparotomy in horses?

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ABSTRACT

Decreased tissue oxygenation is a critical factor in the development of wound infection as neutrophil mediated oxidative killing is an essential mechanism against surgical pathogens. The objective of this prospective case series was to assess the impact of intraoperative arterial partial pressure of oxygen (PaO_2) on surgical site infection (SSI) in horses undergoing emergency exploratory laparotomy for acute gastrointestinal disease. The anaesthetic and antibiotic protocol was standardised. Demographic data, surgical potential risk factors and PaO_2, obtained 1 h after induction of anaesthesia were recorded. Surgical wounds were assessed daily for infection during hospitalisation and follow up information was obtained after discharge.

A total of 84 adult horses were included. SSI developed in 34 (40.4%) horses. Multivariate logistic regression showed that PaO_2, anaesthetic time and subcutaneous suture material were predictors of SSI (AUC = 0.76, sensitivity = 71%, specificity = 65%). The use of polyglycolic acid sutures increased the risk and horses with a PaO_2 value <80 mmHg [10.6 kPa] and anaesthetic time >2 h had the highest risk of developing SSI (OR = 9.01; 95% CI 2.28–35.64). The results of this study confirm the hypothesis that low intraoperative PaO_2 contributes to the development of SSI following colic surgery.

Introduction

Decreased tissue oxygenation is a critical factor in the development of wound infection due to the fact that neutrophil mediated oxidative killing is an essential mechanism against surgical pathogens (Allen et al., 1997). Human patients who develop decreased tissue oxygenation in the perioperative period are at risk of wound infection (Moller et al., 2002; Kabon et al., 2005; Koutsoumbelis et al., 2011) and several clinical investigations support the use of high perioperative inspiratory oxygen concentrations to reduce the risk of surgical site infection (SSI) in people (Belda et al., 2005; Barili, 2007; Maragakis, 2009).

Arterial hypoxaemia commonly develops in horses in dorsal recumbency anaesthetised for exploratory laparotomy despite delivery of 100% oxygen and use of mechanical ventilation (Day et al., 1995; Whitehair and Willits, 1999). Impaired pulmonary gas exchange mainly results from ventilation–perfusion mismatch and intrapulmonary shunting due to atelectasis in dependent lung lobes (Nyman and Hedenstierna, 1989; Nyman et al., 1990). Although some studies mention the potential influence of intraoperative and anaesthetic recovery complications on the risk of developing SSI in horses (Baxter, 1992; Wilson et al., 1995), few reports have included these risk factors within their data analysis (Gibson et al., 1989; Torfs et al., 2010).

SSI is a serious complication after colic surgery, occurring with a frequency of around 25%, and has been reported in several prospective studies (Honnas and Cohen, 1997; Smith et al., 2007; Bischofberger et al., 2010). SSI prolongs hospitalisation and predisposes to hernia formation (Gibson et al., 1989; French et al., 2002) and so identifying new risk factors and interventions to decrease the infection rate may contribute to reduce recovery periods and medical costs. The main objective of this prospective study was to test the hypothesis that low PaO_2 during the intraoperative period increases the incidence of SSI after exploratory laparotomy in horses.

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Materials and methods

Animals

One hundred and eighteen horses undergoing celiotomy for acute gastrointestinal disorders over a period of 3 years were initially included in the study under informed, written owner's consent. Exclusion criteria included horses less than 1 year of age, and horses undergoing repeated celiotomy within the period of 15 days from the initial surgery.

Preoperative data collection

Bodyweight, age, sex and breed were noted for each horse. Laboratory data obtained on admission for white blood cell count and preoperative values of packed cell volume and total serum protein concentration were recorded.

Intraoperative protocol

Sodium penicillin 22×10^3 IU/kg (Penilevel, Ern) plus gentamicin 4.4 mg/kg (Gentamicina, Braun) and flunixin meglumine 0.25 mg/kg (Finadyne, Intervet) were administered IV before induction of anaesthesia. All animals were sedated with romifidine 0.06 mg/kg (Sedivet, Boehringer Ingelheim) and butorphanol 0.02 mg/kg (Torbugesic, Fort Dodge) IV; anaesthesia was induced with diazepam 0.05 mg/kg (Valium, Roche) or 5% guaifenesin 50 mg/kg (Guaifenesina, Beringues) and ketamine 1.5–2 mg/kg (Imalgene, Merial) IV.

After oro-tracheal intubation horses were positioned in dorsal recumbency on the surgery table and were connected to a large animal circle breathing system (Model 2800, Mallard medical) that incorporated a ventilator (Rachel model, Mallard medical). Controlled intermittent positive pressure ventilation was initiated and anaesthesia was maintained with isoflurane in 100% oxygen. The ventilator was set to deliver seven to 10 breaths/min, at a flow rate to achieve an airway pressure of 25 cm H_2O, a positive end-expiratory pressure (PEEP) of 7 cm H_2O and adjusted to maintain an end-tidal partial pressure of CO_2 ($PE'CO_2$) between 40 and 50 mmHg (5.3 and 6.6 kPa).

The facial artery was catheterised for continuous arterial blood pressure monitoring. Heart rate (HR), invasive arterial blood pressure, pulse-oximetry, $PE'CO_2$ and end-tidal concentration of isoflurane were continuously monitored with a multi parameter monitor (V24C, Agilent). An arterial blood sample was obtained intraoperatively 1 h after induction of anaesthesia to determine blood gases, glucose and haemoglobin using a portable gas analyser (Istat, Heska). At the same time, rectal temperature, mean arterial pressure (MAP) and HR were recorded. Blood gas values were corrected for patient temperature.

In horses in which hypoxaemia ($PaO_2 < 80$ mmHg [10.6 kPa]) was detected and anaesthesia time was >2 h a second arterial blood sample was analysed. Ringer's lactate solution was infused at 10 mL/kg/h and horses with MAP < 60 mmHg were treated with dobutamine 3–5 µg/kg/min (Dobutamine Mayne, Mayne Pharma), and colloids 4 mL/kg (Hemohes, Braun). A continuous rate infusion of lidocaine at 30 µg/kg/min (Laocain, Intervet) was administered in those horses with increased isoflurane requirements to maintain a surgical plane of anaesthesia (based on usual clinical parameters).

The surgical site was aseptically prepared with povidone–iodine and alcohol and an iodophor impregnated adhesive drape was applied. The linea alba was closed in a continuous single suture pattern using 5 USP polyglycolic acid suture (Safil, Braun), subcutaneous tissue using 2/0 USP polyglycolic acid or 2/0 USP polydioxanone (PDS, Ethicon) followed by skin stapling. Surgical wounds were covered with a stent bandage that was maintained for 24 h. An abdominal bandage was placed only on those horses where an increased abdominal wall tension was anticipated (i.e. obesity, increased tension during suturing). Site of obstruction, surgical procedure, type of subcutaneous suture material used and duration of anaesthesia were recorded.

Postoperative treatments

Antibiotic treatment was based on the surgical diagnosis and was maintained postoperatively for up to 5 days. Penicillin was maintained in horses with non-strangulating obstructions and gentamicin was added in horses with strangulating obstructions or when enterotomy was performed. IV fluids were maintained using Ringer's lactate solution (5 mL/kg/h) during the first 24 h reduced to 2.5 mL/kg/h for up 36–72 h. Flunixin 0.25–0.5 mg/kg IV 8-hourly, dimethylsulfoxide 0.2 g/kg (DMSO, Oristà) 12-hourly IV, and dalteparin 50 UI/kg (Fragmin, Pfizer) 24-hourly SC, were administered according with the surgical procedure performed. Phenylbutazone 2.2–4.4 mg/kg (Butasyl, Pfizer) IV 12-hourly and lidocaine (30 µg/kg/min) were added based on the individual analgesic needs.

SSI follow-up

Surgical wounds were evaluated daily during hospitalisation by two surgeons who were unaware of the blood gas results. Evidence of infection was supported by the presence of at least two of the following criteria: fever, incisional drainage (appearing after the first 72 h from surgery) or purulent secretion, ultrasonographic imaging (presence of diffuse or localised subcutaneous pockets of hypoechoic fluid) and pain on palpation. Date of appearance of drainage and results of bacteriological cultures when performed were recorded. Follow-up information was obtained for horses discharged from the hospital within 2 weeks by contacting the referring veterinarians. SSI diagnosed by the referring veterinarians was based on presence of purulent drainage.

Statistical analysis

Descriptive results of quantitative variables are expressed as means ± standard error (SE). For categorical data, frequencies and percentages are reported. In the bivariate analysis, quantitative variables were compared with a Student's *t* test or a Wilcoxon test depending on data characteristics. For categorical variables a chi-squared test was used. Those variables with a *P* value <0.25 in the bivariate analysis or those considered clinically relevant, were included in a multivariate logistic regression model (Hosmer and Lemeshow, 2000). The final model was obtained using a backward variable selection method. A second model including possible interactions was also considered. Bivariate regression models were performed for each variable of the final model separately to compare adjusted with unadjusted effects. Model fitting was assessed using the Hosmer–Lemeshow test and the receiver operating characteristics (ROC) curve. Sensitivity and specificity for various cut-points were graphically assessed. Statistical analysis was performed using computerised statistical software SAS v9.2 (SAS Institute). The significance level was set at 0.05.

Results

From the 118 horses initially involved, 84 were finally included in the bivariate analysis. A flow diagram of the case dropout is shown in Fig. 1. The low number of animals belonging to different breeds other than the Andalusian (AB) were grouped together in order to compare them with the more prevalent breed. The most frequently diagnosed process was large bowel non-strangulating obstruction (42.8%). Enterotomies were performed in 28 horses (33.3%) and enterectomies in 20 (23.8%).

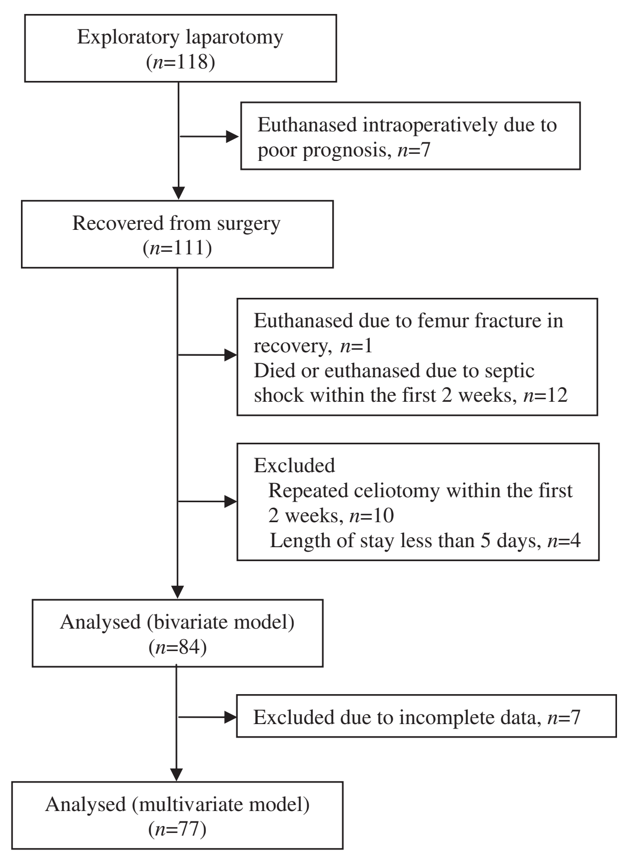

Fig. 1. Flow diagram of case recruitment and dropout through the study.