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RESEARCH PAPER

The effect of two different intra-operative end-tidal carbon dioxide tensions on apnoeic duration in the recovery period in horses

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Abstract

Objective To compare the effect of two different intraoperative end-tidal carbon dioxide tensions on apnoeic duration in the recovery period in horses.

Study design Prospective randomized clinical study.

Animals Eighteen healthy client-owned adult horses (ASA I–II) admitted for elective surgery. Horses were of a median body mass of 595 (238–706) kg and a mean age of 9 ± 5 years.

Methods A standardized anaesthetic protocol was used. Horses were positioned in dorsal recumbency and randomly allocated to one of two groups. Controlled mechanical ventilation (CMV) was adjusted to maintain the end-tidal carbon dioxide tension ($P_E'CO_2$) at 40 ± 5 mmHg (5.3 ± 0.7 kPa) (group40) or 60 ± 5 mmHg (8.0 ± 0.7 kPa) (group60). Arterial blood gas analysis was performed at the start of the anaesthetic period (T0), at one point during the anaesthetic (T1), immediately prior to disconnection from the breathing system (T2) and at the first spontaneous breath in the recovery box (T3). The time from disconnection from the breathing system to return to spontaneous ventilation (RSV) was recorded. Data were analysed using a two sample *t*-test or the Mann–Whitney *U*-test and significance assigned when $p < 0.05$.

Results Horses in group60 resumed spontaneous breathing significantly earlier than those in group40, [52 (14–151) and 210 (103–542) seconds, respectively] ($p < 0.001$). Arterial oxygen tension (PaO_2), pH, base excess (BE) and plasma bicarbonate (HCO_3^-) were not different between the groups at RSV, however, PaO_2 was significantly lower in group60 during (T1) and at the end of anaesthesia (T2).

Conclusions and clinical relevance Aiming to maintain intra-operative $P_E'CO_2$ at 60 ± 5 mmHg (8.0 ± 0.7 kPa) in mechanically ventilated horses resulted in more rapid RSV compared with when $P_E'CO_2$ was maintained at 40 ± 5 mmHg (5.3 ± 0.7 kPa).

Keywords apnoea, horses, hypercapnia, recovery period, ventilation.

Introduction

In anaesthetized horses, the dose-dependent respiratory depression produced by isoflurane (Steffey et al. 1987) and the effect of recumbency may necessitate controlled mechanical ventilation (CMV) to improve pulmonary function (Day et al. 1995). Cessation of CMV may result in an apnoeic period of variable duration before spontaneous ventilation resumes (Wright & Hildebrand 2001). The impact of this apnoeic period and strategies to facilitate the

transition from mechanical to spontaneous ventilation have been investigated (Wright & Hildebrand 2001; Brosnan et al. 2012; Ida et al. 2013). Horses may be 'weaned-off' mechanical ventilation to ensure return to spontaneous ventilation (RSV) prior to transfer to recovery by reducing minute ventilation towards the end of surgery.

In comparison to abrupt discontinuation of CMV, however, this weaning process may result in a greater incidence of horses moving on the hoist during transfer to the recovery box (Wright & Hildebrand 2001). Weaning has been associated with hypoxaemia even with the use of oxygen-rich inspired gas (Wright & Hildebrand 2001; Santos et al. 2003). Apnoeic horses may remain normoxaemic owing to apnoeic mass movement oxygenation (AMMO) (Wright & Hildebrand 2001) but the effect of prolonged apnoea on this mechanism is not known.

Isoflurane elimination during recovery may also be affected by hypoventilation as the partial pressure of the volatile anaesthetic agent in the alveolar gas decreases as a function of alveolar ventilation (Eger 1974). It has been demonstrated that insufflation of 5–10% carbon dioxide (CO_2) in oxygen (O_2) in the immediate recovery period increases alveolar ventilation by inducing hypercapnic hyperpnoea, resulting in faster times to standing without affecting recovery quality (Brosnan et al. 2012). Normocapnia has been defined as arterial carbon dioxide tension ($PaCO_2$) 40 mmHg (5.33 kPa) (Wagner 1993) and mechanical ventilation should aim to maintain $PaCO_2$ between 35 and 50 mmHg (4.67–6.67 kPa) (Hartsfield 2007). However, considering the detrimental effects of CMV on cardiac output (Hodgson et al. 1986; Steffey et al. 1992; Mizuno et al. 1994), there may be cardiovascular benefits of mild hypoventilation, with some studies advocating maintaining $PaCO_2$ between 50–70 mmHg (6.67–9.33 kPa) (Kerr & McDonell 2009) or below 70–75 mmHg (9.33–10 kPa) (Taylor & Young 1993; Blissitt et al. 2008). Permitting mild to moderate hypercapnia may also facilitate the transition from CMV to spontaneous breathing. This study was designed to investigate the effect of two different intraoperative end-tidal carbon dioxide tension ($P_E'CO_2$) values on the duration of apnoea in the immediate recovery period. We hypothesized that maintaining intra-operative $P_E'CO_2$ values at 60 ± 5 mmHg (8.0 ± 0.7 kPa) (group60) would result in a faster RSV compared with maintaining $P_E'CO_2$ values at 40 ± 5 mmHg (5.3 ± 0.7 kPa).

Materials and methods

Study design

Prospective, randomized, controlled clinical study approved by the University of Liverpool Ethics Committee (VREC94). Systemically healthy (ASA I–II) adult horses (>3 years of age) presenting to The Philip Leverhulme Equine Hospital for elective orthopaedic or soft tissue surgery were eligible for inclusion if they were to be positioned in dorsal recumbency, showed no evidence of respiratory disease based on physical examination and informed owner consent was granted.

Anaesthetic protocol

Food but not water was withheld for at least 8 hours prior to induction of general anaesthesia. Preanaesthetic medication consisted of acepromazine maleate 0.03 mg kg^{-1} intramuscularly (IM) (Vetranquil; Ceva, France) 45 minutes prior to aseptic placement of a 12 gauge intravenous (IV) cannula (Intraflo 2; Vygon, France). Romifidine 50–80 μg kg^{-1} IV (Sedivet; Boehringer Ingelheim, UK) and morphine 0.2 mg kg^{-1} IV (Morphine Sulphate; Wockhardt, UK) were administered within 15 minutes of IV cannula placement. Induction of general anaesthesia using ketamine 2.2 mg kg^{-1} IV (Ketaset; Pfizer, UK) and diazepam 0.05 mg kg^{-1} IV (Diazepam; Hameln Pharmaceuticals, UK) was followed by orotracheal intubation. General anaesthesia was maintained using isoflurane (Isoflo; Abbott, UK) in 100% oxygen delivered via a large animal circle breathing system (LAVC 2000; Eickemeyer, Germany). The circle system was not prefilled with oxygen and isoflurane. The fresh gas flow was 10 L $minute^{-1}$ for the first 5 minutes, reduced to 10 mL kg^{-1} for the anaesthesia duration. Mechanical ventilation was delivered via a pressure-limited flow-controlled ventilator (Mark 7 Bird Servo; JD Medical Dist Co Inc., AZ, USA) and adjusted to maintain $P_E'CO_2$ at either 40 ± 5 mmHg (5.3 ± 0.7 kPa) (group40) or 60 ± 5 mmHg (8.0 ± 0.7 kPa) (group60). Both tidal volume and respiratory rate adjustments were carried out in a stepwise manner to adjust minute ventilation and achieve the target $P_E'CO_2$. A 20-gauge (Intraflon; Vygon) cannula was placed in the mandibular artery to permit invasive arterial blood pressure measurement and acquisition of samples for blood gas analysis. Arterial blood gas analysis was