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SHORT COMMUNICATION

Controlled mechanical ventilation with constant positive end-expiratory pressure and alveolar recruitment manoeuvres during anaesthesia in laterally or dorsally recumbent horses

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Abstract

Objective To compare the effects of controlled mechanical ventilation (CMV) and constant positive end-expiratory pressure (PEEP) and interposed recruitment manoeuvres (RMs) with those of CMV without PEEP on gas exchange during general anaesthesia and the early recovery period.

Study design Prospective, randomized clinical trial.

Animals A total of 48 Warmblood horses undergoing elective surgery in lateral (Lat) (n = 24) or dorsal (Dors) (n = 24) recumbency.

Methods Premedication (romifidine), induction (diazepam and ketamine) and maintenance (isoflurane in oxygen) were identical in all horses. Groups Lat-CMV and Dors-CMV (each n = 12) were ventilated using CMV. Groups Lat-RM and Dors-RM (each n = 12) were ventilated using CMV with constant PEEP (10 cmH_2O) and intermittent RMs (three consecutive breaths with peak inspiratory pressure of 60 cmH_2O, 80 cmH_2O and 60 cmH_2O, respectively). RMs were applied as required to maintain PaO_2 at > 400 mmHg (> 53.3 kPa). Dobutamine was given to maintain mean arterial blood pressure at > 60 mmHg. Physiological parameters were recorded every 10 minutes. Arterial blood gases were measured intra- and postoperatively. Statistical analyses were conducted using analyses of variance (ANOVAS), t tests and the Mann–Whitney U-test.

Results Horses in Dors-RM had higher PaO_2 values [478 ± 35 mmHg (63.7 ± 4.6 kPa)] than horses in Dors-CMV [324 ± 45 mmHg (43.2 ± 6 kPa)] during anaesthesia and the early recovery period. There were no differences between horses in groups Lat-CMV and Lat-RM. Other measured parameters did not differ between groups.

Conclusions and clinical relevance Ventilation with CMV, constant PEEP and interposed RM provided improved arterial oxygenation in horses in dorsal recumbency that lasted into the early recovery period, but had no benefit in horses in lateral recumbency. This mode of ventilation may provide a clinically practicable method of improving oxygenation in anaesthetized horses, especially in dorsal recumbency.

Keywords controlled mechanical ventilation, equine anaesthesia, oxygenation, positive end-expiratory pressure, recruitment manoeuvres, ventilation.

Introduction

During general anaesthesia, particularly in animals positioned in dorsal recumbency, horses develop a large alveolar–arterial oxygen partial pressure gradient and often become hypoxaemic even if controlled mechanical ventilation (CMV) is used with oxygen-rich gas. Poor oxygenation in horses is the result of ventilation–perfusion mismatch and the formation of atelectasis in dependent lung areas, which causes increased right-to-left shunting (Nyman et al. 1990).

The application of CMV with high inspiratory pressure for the recruitment of collapsed lung areas, in combination with sufficient end-expiratory pressure to keep these recruited lungs open, is well established in human anaesthesia and is known as the 'open lung' process (Papadakos & Lachmann 2002). A study in ponies anaesthetized with total intravenous anaesthesia (TIVA) found this ventilation model with stepwise recruitment manoeuvres (RMs) and positive end-expiratory pressure (PEEP) increases to be capable of significantly improving oxygenation, most probably by opening collapsed lung areas (Wettstein et al. 2006). A simplified open lung manoeuvre with the application of constant PEEP and interposed hyperinflation was able to improve oxygenation during colic surgery, which resulted in better oxygenation during the early recovery period (Hopster et al. 2011). However, this ventilation strategy was unable to open the lung completely or to keep it open without repeated recruitment (Hopster et al. 2011). No such studies have been undertaken in animals in lateral recumbency, although the positioning of horses is known to influence pulmonary efficiency (Steffey et al. 1977). In a recently published study, beneficial effects of a sustained high-pressure manoeuvre in combination with conventional CMV were observed in dorsally recumbent horses (Santos et al. 2013).

The aim of the present study was to assess gas exchange in horses undergoing surgery in lateral or dorsal recumbency during and immediately after anaesthesia when CMV was combined with constant PEEP and alveolar RM in comparison with CMV without PEEP or RM.

Materials and methods

Animals

With the permission of the informed owners, 48 client-owned horses [American Society of Anesthesiologists (ASA) classes I and II] presenting to our clinic for elective surgery in either lateral (group Lat, $n = 24$) or dorsal (group Dors, $n = 24$) recumbency were recruited. Patients were assigned randomly to either of two different modes of ventilation using a computer-generated randomization list: CMV as control (groups Lat-CMV and Dors-CMV), and CMV with constant PEEP and alveolar RMs (groups Lat-RM and Dors-RM). To detect statistical differences, a sample size of 12 horses per group was required. Exclusion criteria included ASA classification greater III.

Anaesthesia

All horses were premedicated with 0.04−0.08 mg kg^{-1} romifidine intravenously (IV) (Sedivet; Boerhinger Ingelheim GmbH, Germany). After induction with IV 0.05 mg kg^{-1} diazepam (Diazepam AbZ 10 mg; AbZ Pharma GmbH, Germany) and 2.2 mg kg^{-1} ketamine (Narketan; Vetoquinol GmbH, Germany), anaesthesia was maintained with isoflurane (Isofluran CP; CP-Pharma Handelsgesellschaft mbH, Germany) in oxygen. The vaporizer was adjusted to maintain an adequate depth of anaesthesia. Lactated Ringer's solution was administered at 10 mL kg^{-1} $hour^{-1}$ and dobutamine (Dobutamin-ratiopharm 250 mg; Ratiopharm GmbH, Germany) was given to effect to maintain a mean arterial blood pressure (MAP) of > 60 mmHg during anaesthesia (starting dose: 0.35 μg kg^{-1} $minute^{-1}$).

The transverse facial artery was cannulated with a butterfly catheter (18 gauge; Microflex; Vygon GmbH & Co. KG, Germany) and connected to a pressure transducer placed at the level of the right heart (PD 23 ID; Gould Statham Instruments, Inc., CA, USA) and zeroed to atmospheric pressure, for invasive blood pressure monitoring and arterial blood sampling. Arterial blood pressure, heart rate (HR), respiratory rate, inspired oxygen concentration (FIO_2) and expiratory isoflurane concentration ($F_E'Iso$) were monitored continuously with an anaesthetic multi-parameter monitor (Cardiocap/5; Datex-Ohmeda GmbH, Germany) and recorded every 10 minutes. Recording of data commenced 20 minutes after induction of anaesthesia.

Ventilation strategy

Following the induction of anaesthesia and endotracheal intubation, the horse was positioned on a

