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RESEARCH PAPER

Efficacy of a portable oxygen concentrator with pulsed delivery for treatment of hypoxemia during equine field anesthesia

Paige Coutu*, Nigel Caulkett*, Daniel Pang*,† & Søren Boysen*

*Veterinary and Clinical Diagnostic Sciences, Faculty of Veterinary Medicine, University of Calgary, Calgary, AB, Canada

†Hotchkiss Brain Institute, University of Calgary, Calgary, AB, Canada

Correspondence: Paige Coutu, Western Veterinary Specialist and Emergency Centre, 1802-10th Ave SW, Calgary, AB T3C 0J8, Canada. E-mail: mpcoutu13@gmail.com

Abstract

Objective Hypoxemia is common during equine field anesthesia. Our hypothesis was that oxygen therapy from a portable oxygen concentrator would increase PaO_2 during field anesthesia compared with the breathing of ambient air.

Study design Prospective clinical study.

Animals Fifteen yearling (250 – 400 kg) horses during field castration.

Methods Horses were maintained in dorsal recumbency during anesthesia with an intravenous infusion of 2000 mg ketamine and 500 mg xylazine in 1 L of 5% guaifenesin. Arterial samples for blood gas analysis were collected immediately post-induction (PI), and at 15 and 30 minutes PI. The control group ($n = 6$) breathed ambient air. The treatment group ($n = 9$) were administered pulsed-flow oxygen (192 mL per bolus) by nasal insufflation during inspiration for 15 minutes PI, then breathed ambient air. The study was performed at 1300 m above sea level. One-way and two-way repeated-measures ANOVA with *post-hoc* Bonferroni tests were used for within and between-group comparisons, respectively. Significance was set at $p \leq 0.05$.

Results Mean ± SD PaO_2 in controls at 0, 15 and 30 minutes PI were 46 ± 7 mmHg (6.1 ± 0.9 kPa), 42 ± 9 mmHg (5.6 ± 1.1 kPa), and 48 ± 7 mmHg (6.4 ± 0.1 kPa), respectively ($p = 0.4$). In treatment animals, oxygen administration significantly increased PaO_2 at 15 minutes PI to 60 ± 13 mmHg (8.0 ± 1.7 kPa), compared with baseline values of 46 ± 8 mmHg (6.1 ± 1 kPa) ($p = 0.007$), and 30 minute PI values of 48 ± 7 mmHg (6.5 ± 0.9 kPa) ($p = 0.003$).

Conclusions These data show that a pulsed-flow delivery of oxygen can increase PaO_2 in dorsally recumbent horses during field anesthesia with ketamine-xylazine-guaifenesin.

Clinical relevance The portable oxygen concentrator may help combat hypoxemia during field anesthesia in horses.

Keywords anesthesia, equine, horse, hypoxemia, oxygen concentrator.

Introduction

Total intravenous (IV) anesthetic techniques are commonly used to anesthetize horses in the field for short procedures, such as castration. A popular technique involves the use of a xylazine, ketamine and guaifenesin (XKG) infusion to maintain anesthesia after appropriate induction (Young et al. 1993; Hubbell et al. 2010). Although blood pressure is usually well maintained under this and other

similar injectable protocols (Young et al. 1993; McMurphy et al. 2002), changes in arterial oxygen and carbon dioxide tension (PaO_2 and $PaCO_2$) are commonly seen (Muir et al. 1978; Taylor et al. 1998; Braun et al. 2009).

Decreases in PaO_2 indicate poor oxygenation and, during general anesthesia in healthy horses, can be attributed to hypoventilation, inadequate inspired oxygen, increased ventilation-perfusion mismatch and intrapulmonary shunts (Braun et al. 2009). Hypoxemia may develop, which can lead to cardiovascular complications intraoperatively, or to neurological damage, myopathy, and hepatic and renal failure or dysfunction postoperatively (Steffey et al. 1992). In field settings, hypoxemia may go undetected as pulse oximetry and blood gas analysis may not be available and the visual identification of cyanosis is unreliable (Comroe & Botelho 1947). At present, oxygen therapy in the field requires the use of portable compressed oxygen cylinders. There are ongoing costs associated with the use of cylinders and practitioners may be reluctant to travel with oxygen cylinders because of the risks associated with the transportation of compressed gas. A potential alternative is a portable battery-operated oxygen concentrator, which is safe to handle and requires minimal maintenance. The oxygen concentrators are commonly used in humans for the provision of oxygen at home or during air travel, in military applications and in remote medical facilities in the developing world (Friesen 1992; Shrestha et al. 2002). They have also been shown to be effective in the treatment of hypoxemia during injectable anesthesia in some wildlife species (Fahlman et al. 2012).

Portable oxygen concentrators are capable of producing oxygen concentrations of >90% through the use of molecular sieve technology. Two modes of delivery involving either continuous or pulsed-flow delivery are available (Friesen 1992). Continuous flow can be delivered at a maximum of 3 L minute^{-1} (SeQual Technologies Inc 2010). The pulsed-flow mode reduces oxygen waste during expiration and allows a significant increase in battery-powered operating time. This is achieved through the delivery of an oxygen bolus at the beginning of each inspiratory effort, which is controlled by the demand valve. Portable oxygen concentrators may prove to be an effective and safe means to treat or prevent hypoxemia during field anesthesia in horses. To the authors' knowledge, the use of these devices has not been evaluated in equine anesthesia. The purpose of this study was to determine if the oxygenation of horses anesthetized with a XKG infusion during a field castration procedure could be improved by the pulsed-flow delivery of oxygen from a battery-powered portable oxygen concentrator. The investigation was based on the hypothesis that the administration of oxygen by pulsed-dose flow via an oxygen concentrator would result in higher PaO_2 values in the treatment group. In the control group, without supplemental oxygen, it was hypothesized that there would be no change in PaO_2.

Materials and methods

Approval for animal use in this project was granted by the Animal Care and Use Committee of the University of Calgary (AC12-0032). Fifteen yearling colts were anesthetized under field conditions for a castration teaching laboratory at the University of Calgary Faculty of Veterinary Medicine. The castrations were performed in a covered arena bedded with rubber pellets. Procedures in the control group of the study were performed during a teaching laboratory in March 2012; procedures in the treatment group were performed in March 2013. All horses were deemed by physical examination to be healthy and free from cardiovascular or respiratory disease prior to anesthesia. Horses were housed in group pens and fasted the evening prior to the procedure. Water was available *ad libitum* until the time of the procedure. Students, assisted by experienced veterinary surgeons, performed castrations using both modified open- and closed-techniques, as previously described (Kramer 2006).

Body mass was estimated visually by an anesthesiologist as between 250 and 400 kg. Intramuscular (IM) acepromazine (0.03 mg kg^{-1}; Atravet; Boehringer Ingelheim, ON, Canada) was administered for premedication. Thirty minutes later, IV xylazine (0.5 mg kg^{-1}; Rompun; Bayer Inc., ON, Canada) and butorphanol (0.02 mg kg^{-1}; Torbugesic; Wyeth Animal Health, ON, Canada) were administered via a cannula placed in the jugular vein (14 gauge, 133 mm, Angiocath; Becton Dickinson, UT, USA). General anesthesia was induced with IV injection of ketamine (2 mg kg^{-1}; Ketalean; Bimeda-MTC Animal Health Inc., ON, Canada) and diazepam (0.05 mg kg^{-1}; Diazepam injection; Sandoz Canada Inc., QC, Canada). Using a lead rope attached to a halter, horses were assisted in transitioning from standing to lateral recumbency. Anesthesia was maintained by IV infusion of an XKG solution that

