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RESEARCH PAPER

Q5 Comparison of three continuous positive airway pressure (CPAP) interfaces in healthy Beagle dogs during medetomidine–propofol constant rate infusions

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Abstract

Objective To compare the efficacy of three continuous positive airway pressure (CPAP) interfaces in dogs on gas exchange, lung volumes, amount of leak during CPAP and rebreathing in case of equipment failure or disconnection.

Study design Randomized, prospective, crossover, experimental trial.

Animals Ten purpose-bred Beagle dogs.

Methods Dogs were in dorsal recumbency during medetomidine–propofol constant rate infusions, breathing room air. Three interfaces were tested in each dog in a consecutive random order: custom-made mask (M), conical face mask (FM) and helmet (H). End-expiratory lung impedance (EELI) measured by electrical impedance tomography was assessed with no interface (baseline), with the interface only (No-CPAP for 3 minutes) and at 15 minutes of 7 cmH_2O CPAP (CPAP-delivery). PaO_2 was assessed at No-CPAP and CPAP-delivery, partial pressure of inspired carbon dioxide ($PICO_2$; rebreathing assessment) at No-CPAP and the interface leak (ΔP_{leak}) at CPAP-delivery. Mixed-effects linear regression models were used for statistical analysis ($p < 0.05$).

Results During CPAP-delivery, all interfaces increased EELI by 7% ($p < 0.001$). Higher ΔP_{leak} was observed with M and H (9 cmH_2O) in comparison with FM (1 cmH_2O) ($p < 0.001$). At No-CPAP, less rebreathing occurred with M (0.5 kPa, 4 mmHg) than with FM (1.8 kPa, 14 mmHg) and with H (1.4 kPa, 11 mmHg), but also lower PaO_2 was measured with M (9.3 kPa, 70 mmHg) than with H (11.9 kPa, 90 mmHg) and FM (10.8 kPa, 81 mmHg).

Conclusions and clinical relevance All three interfaces can be used to provide adequate CPAP in dogs. The leak during CPAP-delivery and the risk of rebreathing and hypoxaemia, when CPAP is not maintained, can be significant. Therefore, animals should always be supervised during administration of CPAP with any of the three interfaces. The performance of the custom-made M was not superior to the other interfaces.

Keywords canine, CPAP, EIT, gas exchange, interface.

Introduction Q1

Continuous positive airway pressure (CPAP) is a noninvasive ventilation mode that maintains positive airway pressure during the entire spontaneous breathing cycle without inspiratory support (Garpestad et al. 2007). It is a noninvasive mode as endotracheal intubation is unnecessary, and can be provided by various interfaces (Clement et al. 2008; McNeill & Glossop 2012; Faria et al. 2015).

In humans, CPAP has been widely used to treat acute pulmonary oedema, chronic obstructive pulmonary disease and postoperative hypoxaemia (Squadrone et al. 2005; Masip 2007; McNeill &

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Glossop 2012). In dogs, CPAP might be indicated under similar conditions. Furthermore, CPAP is used to treat sleep apnoea in humans that results from upper airway obstruction (Giles et al. 2006). Brachycephalic dog breeds often show upper airway obstruction, which potentially could be prevented or treated with CPAP. CPAP ventilation is known to increase functional residual capacity (FRC) (Layon et al. 1986; Sehlin et al. 2015) and has been shown to reduce the work of breathing (Keidan et al. 2000), thereby decreasing respiratory muscle fatigue (Nikischin et al. 2011).

Leak around CPAP interfaces is one of the most common problems leading to inefficacy. An adequate CPAP machine is required to compensate for the leak (Parreira et al. 1997; Rabec et al. 2004), but better fit interfaces are still desirable. Furthermore, CPAP interfaces may cause rebreathing of carbon dioxide (CO_2), especially in the presence of equipment failure or disconnection of the CPAP machine (Farré et al. 2002).

Two interfaces for CPAP delivery have been studied in dogs, a face mask and a paediatric helmet (Briganti et al. 2010; Staffieri et al. 2014). Both interfaces resulted in improvement of the arterial partial pressure of oxygen (PaO_2) and had a reasonably good fit. In these studies, a Boussignac valve or a Venturi valve combined with flow meters were used to generate high flows to provide CPAP and to avoid rebreathing. The inherent equipment dead space of these interfaces and low interface tolerance without sedation (especially with the helmet) reinforces the need for an alternative to the interfaces currently available.

In humans, monitoring the efficacy of noninvasive ventilation modes, including CPAP, is achieved by clinical assessment, observation of chest wall movement and arterial blood gas analysis (British Thoracic Society Standards of Care Committee 2002; Mas & Masip 2014). The efficacy of both the helmet and face mask in providing CPAP has been previously evaluated in dogs using blood gas analysis (Briganti et al. 2010; Staffieri et al. 2014). Spirometry can be used with noninvasive ventilation in humans where the interface has a perfect fit (Mas & Masip 2014). This technique may be unreliable in dogs because the interfaces are expected to leak in the absence of an endotracheal tube.

Lung volume may be measured directly over the lung field using electrical impedance tomography (EIT) (Adler et al. 1998). EIT is a noninvasive, radiation-free imaging technique that provides accurate and breath-by-breath information of regional pulmonary ventilation distribution by impedance analysis (Bodenstein et al. 2009). It has been shown that the end-expiratory lung impedance (EELI) is a surrogate for the volume present in the lungs at the end of expiration (Hinz et al. 2003) and that EELI can serve as an estimation of FRC (Bellani et al. 2010; Teschner et al. 2010). Tidal volume (V_{Teit}) can be estimated by the total change of impedance over one breath (Bikker et al. 2009). These EIT measurements provide estimates of changes in lung volumes in dogs (Adler et al. 1998).

The aim of this study was to evaluate three CPAP interfaces in dogs using EIT variables (regional ventilation distribution, EELI and V_{Teit}), the degree of leak during CPAP, the degree of rebreathing in the presence of equipment failure or disconnection and measurement of cardiopulmonary variables. We hypothesized that all the interfaces would provide CPAP in dogs, with a newly designed mask (M) having reduced amount of leak and rebreathing as a result of lower equipment dead space and tighter fit.

Materials and methods

This study was approved by the Committee for Animal Experimentation of the Canton Zürich, Switzerland [no. ZH043/15 (26385)].

Animals

Ten healthy purpose-bred adult Beagle dogs (five females and five males), 55 ± 3 months old (mean ± standard deviation), with a body weight of 14.1 ± 2.4 kg and body condition score of 6 ± 1 out of 9, were enrolled in this study. The dogs were deemed to be in good health by physical examination with special focus on the lungs, haematocrit and standard biochemical blood analysis performed on the day before anaesthesia.

Preanaesthetic preparation and anaesthesia

The data were collected following another study (no. ZH001/15) on the effects of different doses of adenosine (same dose per dog) on myocardial perfusion. The dogs were anaesthetized in dorsal recumbency for 4.08 ± 0.01 hours, and anaesthesia was maintained with sevoflurane (50% O_2:50% air mixture). The lungs were mechanically ventilated using a volume-controlled ventilation mode to achieve an end-tidal carbon dioxide partial pressure ($P_{E'}CO_2$) of 4.8–5.1 kPa (36–38 mmHg). During this study, lactated Ringer's solution (Ringer-Lactate; Fresenius

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