Veterinary Anaesthesia and Analgesia 2017, **xxx**, 1–10 http://dx.doi.org/10.1016/j.vaa.2016.10.007

RESEARCH PAPER

Q11 Evaluation of three tidal volumes (10, 12 and 15 mL kg^{-1}) in dogs for controlled mechanical ventilation assessed by volumetric capnography: a randomized clinical trial

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Abstract

Objective To evaluate three routinely used tidal volumes (V_T: 10, 12 and 15 mL kg^{-1}) for controlled mechanical ventilation (CMV) in lung-healthy anaesthetized dogs by assessing alveolar ventilation (VT_{alv}) and dead space (DS).

Study design Prospective, randomized clinical trial.

Animals A total of 36 client-owned dogs.

Methods Dogs were randomly allocated to a V_T of 10 (G_{10}), 12 (G_{12}) or 15 (G_{15}) mL kg^{-1}. After induction CMV was started. End-tidal carbon dioxide tension was maintained at 4.7–5.3 kPa by changing the respiratory frequency (f_R; $6 < f_R < 30$ breaths minute^{-1}). After 29 minutes, cardiovascular and respiratory variables were recorded for 3 minutes using a multiparameter monitor, volumetric capnography (VCap) and a blood gas analyser. The ratios of VT_{alv} to body weight (VT_{alv} kg^{-1}) and airway DS to V_T (VD_{aw}/V_T), Bohr's DS (VD_{Bohr}), Enghoff's DS (VD_{BE}) and the volume of expired carbon dioxide per breath ($VTCO_{2,br}$) were calculated. Mean airway pressure (MawP), f_R and peak inspiratory pressure (PIP) were recorded. Data were analysed using one-way ANOVA and Student–Newman–Keuls tests with a statistical significance set at $p < 0.05$.

Results No differences were observed for demographic data and cardiovascular variables between groups. A total of three dogs were excluded due to technical difficulties and one due to $f_R > 30$. VT_{alv} kg^{-1} ($p = 0.001$) increased and VD_{Bohr} ($p = 0.002$) decreased with greater V_T. $VTCO_{2,br}$ ($p = 0.017$) increased and VD_{aw}/V_T ($p = 0.006$), VD_{BE} ($p = 0.008$) and f_R ($p = 0.002$) decreased between G_{10} and G_{15}. PIP ($p = 0.013$) was significantly higher in G_{15} compared with that in G_{10} and G_{12}. No changes were observed in MawP.

Conclusions and clinical relevance A V_T of 15 mL kg^{-1} is most appropriate for CMV in lung-healthy dogs (as evaluated by respiratory mechanics and VCap) and does not impair cardiovascular variables.

Keywords anaesthesia, canine, dead space, overdistension, volumetric capnography.

Introduction

Controlled mechanical ventilation (CMV) supports the respiration of lung-healthy patients during general anaesthesia. According to veterinary literature, the tidal volume (V_T) for CMV of lung-healthy dogs during general anaesthesia ranges from 10 to 15 mL kg^{-1} (Hopper & Powell 2013). For decades, veterinarians have adhered to those recommendations, although to the authors' knowledge there is no scientific evidence whether that specific V_T range is appropriate for CMV in lung-healthy dogs. There is still a lack of scientific investigations on the optimum V_T and the corresponding dead space (DS) in lung-healthy dogs. A recent study showed that a V_T of 8 mL kg^{-1} with or without positive end-expiratory

Please cite this article in press as: Bumbacher S, Schramel JP, Mosing M Evaluation of three tidal volumes (10, 12 and 15 mL kg^{-1}) in dogs for controlled mechanical ventilation assessed by volumetric capnography: a randomized clinical trial, Veterinary Anaesthesia and Analgesia (2017), http://dx.doi.org/10.1016/j.vaa.2016.10.007

pressure (PEEP) is inappropriate to ventilate healthy anaesthetized dogs (De Monte et al. 2015).

New guidelines for long-term ventilation strategies in human anaesthesia and intensive care medicine suggest administering a V_T as low as 6–8 mL kg^{-1} to avoid ventilator-induced lung injury (VILI) (Gattinoni et al. 2010). The reason for the discrepancy between humans and dogs regarding V_T needs to be elucidated and might be due to higher physiological DS in dogs (Fowler 1948; Mosing et al. 2010).

Volumetric capnography (VCap) is a tool to evaluate respiratory mechanics and DS. In VCap, the exhaled carbon dioxide (CO_2) tension is plotted against the volume of one exhaled tidal breath (Figure 1) (Fletcher et al. 1981). By mathematical approximation of the CO_2 curve, airway DS (VD_{aw}), alveolar ventilation (VT_{alv}), physiological DS as well as alveolar DS (VD_{alv}) and the volume of expired CO_2 per breath ($VTCO_{2,br}$) can be calculated (Tusman et al. 2009, 2012). VD_{aw} is the fraction of V_T that does not reach the alveoli. Consequently, this part is not participating in gas exchange and represents the volume of the conducting airways. VD_{alv} consists of alveoli with an infinite ventilation to perfusion ratio (V/Q) (Fletcher et al. 1981; Suarez-Sipmann et al. 2014). Physiological DS is the sum of VD_{aw} and VD_{alv}, and represents the total volume of V_T not participating in gas exchange. Bohr's DS (VD_{Bohr}) is a noninvasively measured representation of physiological DS and is little affected by venous admixture (low V/Q). Enghoff's DS (VD_{BE}) can be considered as an index of global gas exchange (Enghoff 1938). In contrast to VD_{Bohr} equation, the one modified by Enghoff includes the arterial tension of CO_2 (arterial partial pressure of CO_2, $PaCO_2$) and hence depends on all causes of V/Q mismatch (Tusman et al. 2012).

The aim of this study was to evaluate three V_T (10, 12 and 15 mL kg^{-1}) routinely used for CMV by assessing DS and VT_{alv} under clinical conditions in lung-healthy dogs. We hypothesized that a V_T of 10 mL kg^{-1} would be insufficient due to the high VD_{aw} volume in dogs, 12 mL kg^{-1} would be most appropriate and 15 mL kg^{-1} may overinflate the alveoli and cause an increase in VD_{alv}, increasing both physiological DS variables (VD_{Bohr} and VD_{BE}).

Materials and methods

This randomized prospective clinical trial had ethical approval from the cantonal Veterinary Office of the Canton of Zurich (Nr. ZH 289/14). Written owner consent was obtained for each dog.

Animals

A total of 36 client-owned dogs of various breeds were included in this study. Each dog was allocated a body condition score (BCS) ranging from 1 to 9, according to the validated World Small Animal Veterinary Association's BCS chart (www.wsava.org/sites/default/files/Body%20condition%20score%20chart%20dogs.pdf). Inclusion criteria were body weight ≥12 kg, an American Society of Anaesthesiologists classification

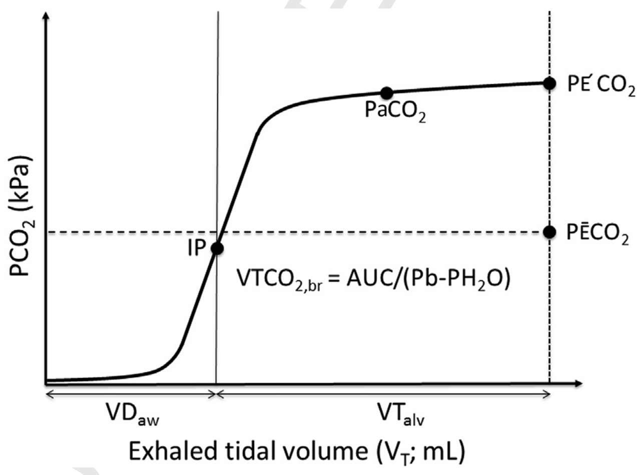

Figure 1 Graphical plot of volumetric capnography (VCap)-derived variables. Carbon dioxide (CO_2) concentration is plotted against the exhaled volume of one tidal breath. The CO_2 curve illustrates the volume ($VTCO_{2,br}$) and distribution of CO_2 in the respiratory tract per single breath. AUC, area under the curve; IP, the inflection point that divides the exhaled tidal volume into airway and alveolar compartment; $PaCO_2$, pressure of alveolar CO_2 (midpoint between IP and PE CO_2 on the VCap curve); Pb, barometric pressure; PE CO_2, pressure of end-tidal CO_2; $P\bar{E}CO_2$, pressure of mixed expired CO_2; PH_2O, water vapour pressure; V_T, tidal volume; $VTCO_{2,br}$, volume of exhaled CO_2 per breath.

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