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RESEARCH PAPER

Measurement of respiratory system compliance and respiratory system resistance in healthy dogs undergoing general anaesthesia for elective orthopaedic procedures

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Abstract

Objective The aim of this study was to investigate normal values for the dynamic compliance of the respiratory system (Crs) and respiratory system resistance (Rrs) in mechanically ventilated anaesthetized dogs.

Study design Prospective clinical study.

Animals Forty healthy dogs undergoing elective orthopaedic surgery. Body weight was (mean ± SD) 26.8 ± 10.7 kg (range: 1.9–45.0 kg), age 4.7 ± 2.9 years (range: 0.1–10.6 years).

Methods Dogs were premedicated with acepromazine and methadone administered intramuscularly and anaesthesia induced with propofol intravenously. After endotracheal intubation the dog's lungs were connected to an appropriate breathing system depending on body weight and isoflurane in oxygen administered for maintenance of anaesthesia. The lungs were ventilated mechanically with variables set to maintain normocapnia (end-tidal carbon dioxide concentration 4.7–6.0 kPa). Peak inspiratory pressure, Crs, Rrs, tidal volume, respiratory rate and positive end-expiratory pressure were recorded at 5, 30, 60, 90 and 120 minutes after start of mechanical ventilation. Cardiovascular variables were recorded at time of collection of respiratory data.

Results General additive modeling revealed the following relationships: Crs = [0.895 × body weight (kg)] + 8.845 and Rrs = [−0.0966 × body weight (kg)] + 6.965. Body weight and endotracheal tube diameter were associated with Crs ($p < 0.001$ and $p = 0.002$ respectively) and Rrs ($p = 0.017$ and $p = 0.002$ respectively), body weight being linearly related to Crs and inversely to Rrs.

Conclusion and clinical relevance Body weight was linearly related to Crs while Rrs has an inverse linear relationship with body weight in mechanically ventilated dogs. The derived values of Crs and Rrs may be used for monitoring of lung function and ventilation in healthy dogs under anaesthesia.

Keywords airway resistance, anaesthesia, dogs, dynamic compliance, lung, mechanical ventilation.

Introduction

Compliance and resistance are two variables used in respiratory mechanics to describe lung function (Cohen & Pittard 2006).

Respiratory system compliance, often measured in respiratory physiology is the sum of the compliance of the lungs and chest wall. Lung compliance is defined as the change in lung volume per unit change in transmural (intrapleural to alveolar) pressure. Chest wall compliance is described as the change in lung volume per unit change in intrapleural to ambient pressure. For the calculation of both variables measurement of intrapleural pressure is required using an intrathoracic oesophageal balloon catheter.

Respiratory system resistance is more indicative of large airway function and is made up of tissue (chest wall and lung, Rtissue) and airway resistance, which is affected by gas flow within the airways. Gas flow will change when airway diameter and geometry are affected by changes in the volume and shape of the lungs and thoracic wall during the respiratory cycle (King et al. 2005).

For calculation of compliance of the respiratory system (Crs) and resistance of the respiratory system (Rrs) during anaesthesia, spirometry is utilised, measuring pressure differences, volumes and flow, negating the requirement for intrapleural pressure measurement. These values can be calculated on a breath by breath basis provided mechanical ventilation with positive pressure is employed for measurement of airway pressures. At the end of inspiration and expiration, pressures within the alveoli, airways and breathing system and therefore monitoring system are equal due to a lack of flow in either direction. Therefore correct measurements of Crs and Rrs require short no-flow periods at the end of inspiration and expiration. The difference between the pressure measured by the monitoring system plus the measurement of tidal volume (Vt) allows Crs to be calculated. The measured pressures and the flow during lung inflation are used to calculate the Rrs. The software in modern spirometry devices can derive the values for Crs and Rrs via linear regression techniques multiple times per breath. A recursive least squares method is then used to generate pressure, volume and flow values (Iotti et al. 1995).

Crs and Rrs are highly lung volume dependent (Westbrook et al. 1973; Hedenstierna 2009). As anaesthesia causes a reduction in functional residual capacity both variables are affected by anaesthesia itself as well as changes in lung parenchyma and airway properties. Together they may provide more accurate information to guide ventilation strategies during anaesthesia and long-term ventilation (Albaiceta et al. 2008; Zanella et al. 2010).

Body weight and obesity also influence lung mechanics. An increase in lean body weight correlates with an increased lung volume and therefore lung compliance. Obesity has also been shown to decrease compliance and increase resistance in humans by decreasing lung volume (Littleton 2012).

No normal clinical values for Crs and Rrs are available in the anaesthetized dog. Furthermore, extrapolated human data may not allow for appropriate clinical decisions regarding alteration of ventilator settings to be made. The aim of this study was to obtain values of Crs and Rrs in mechanically ventilated, healthy, anaesthetized dogs.

Methods

This prospective clinical trial was approved by the Veterinary Research Ethics Committee of the University of Liverpool (VREC15).

Animals

Forty healthy dogs comprising a range of breeds, age 4.7 ± 2.9 years (range: 0.1–10.6 years) were recruited from clinical elective orthopaedic cases over a 2 month period. All dogs underwent pre-anaesthetic clinical examination prior to general anaesthesia with special focus on the evaluation of the respiratory tract. Body condition score (BCS) was assessed according to the Nestle Purina system (2013) which is a scale of 1 to 9, 9 being the most obese. Those graded I or II on the American Society of Anesthesiologists (ASA) physical status classification were included in the study. Informed owner consent was gained prior to commencement of data collection. Dogs were excluded from the study if extra sedation was required in addition to the standard protocol, due to poor effect or temperament. Dogs were also excluded from the study if ventilator-patient asynchrony was detected.

Anaesthesia

A standard anaesthetic protocol was used for all dogs: pre-anaesthetic medication was achieved with acepromazine (ACP 2 mg mL^{-1} injection, Novartis, UK) 0.02 mg kg^{-1} and methadone (Methadone, Martindale Pharmaceuticals, UK) 0.3 mg kg^{-1} given intramuscularly. After 30 minutes an intravenous (IV) cannula was placed into a peripheral vein and anaesthesia induced with IV propofol (Vetofol, Norbrook Laboratories, UK) injection,