Veterinary
Anaesthesia and Analgesia
Formerly the Journal of Veterinary Anaesthesia

Veterinary Anaesthesia and Analgesia, 2016, **43**, 388–396 doi:10.1111/vaa.12331

RESEARCH PAPER

Comparison of cardiac output measurements using transpulmonary thermodilution and conventional thermodilution techniques in anaesthetized dogs with fluid overload

Takaharu Itami*, Yusuke Endo†, Kiwamu Hanazono*, Tomohito Ishizuka*, Jun Tamura†, Kenjiro Miyoshi†, Tadashi Sano† & Kazuto Yamashita†

*Veterinary Teaching Hospital, Graduate School of Veterinary Medicine, Hokkaido University, Sapporo, Hokkaido, Japan
†Department of Small Animal Clinical Sciences, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido, Japan

Correspondence: Kazuto Yamashita, Department of Small Animal Clinical Sciences, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido 069-8501, Japan. E-mail: yamasita@rakuno.ac.jp

Abstract

Objective To evaluate the agreement between cardiac output (CO) values obtained using a transpulmonary thermodilution technique (TPTDCO) and conventional thermodilution technique (TDCO) in anaesthetized dogs with fluid overload.

Study design Prospective experimental study.

Animals Six healthy Beagle dogs aged 7–8 years.

Methods Dogs were anaesthetized with sevoflurane in oxygen, and catheters were inserted for TPTDCO and TDCO measurement. After instrumentation, baseline CO was measured using each technique at a central venous pressure (CVP) of 3–7 mmHg. Dogs were subsequently administered lactated Ringer's solution and 6% hydroxyethyl starch to induce fluid overload. CO measurements were obtained using each technique at CVP values of 8–12 mmHg, 13–17 mmHg, 18–22 mmHg and 23–27 mmHg. Agreements between CO measurements obtained with the respective techniques were analysed using Dunnett's test, Pearson's correlation coefficient and Bland–Altman analysis.

Results Thirty pairs of CO values were obtained, ranging from 1.45 L minute^{-1} to 4.69 L minute^{-1} for TPTDCO and from 1.30 L minute^{-1} to 4.61 L minute^{-1} for TDCO. TPTDCO and TDCO values correlated strongly ($r^2 = 0.915$, $p < 0.001$). The bias and mean relative bias between TPTDCO and TDCO were 0.26 ± 0.30 L minute^{-1} (limits of agreement − 0.29 to 0.81 L minute^{-1}) and 9.7%, respectively.

Conclusions and clinical relevance TPTDCO and TDCO measurements obtained in anaesthetized dogs during fluid overload exhibited good agreement. Accordingly, transpulmonary thermodilution provides an accurate measurement of CO in dogs with fluid overload.

Keywords cardiac output, dog, fluid overload, thermodilution, transpulmonary.

Introduction

The maintenance of optimal cardiac output (CO) is an important goal of haemodynamic management in anaesthetized and critically ill patients. Currently, thermodilution (TD) is the standard clinical method

of measuring CO. However, this technique requires the placement of a pulmonary artery (PA) catheter through the right atrium and ventricle, which increases the risk for possible complications such as inhibition of tricuspid valve movement and embolism of the PA (Perel et al. 1987; Rooke et al. 1995), as well as morbidity and mortality, in humans (Connors et al. 1985; Linton et al. 2000; Sandham et al. 2003), dogs (Schregel et al. 1991), and other animals (Shih et al. 2009). In addition, PA catheter-guided therapy was not found to improve survival or organ function or reduce intensive care unit stay durations among human patients (Harvey et al. 2005; Wheeler et al. 2006). In recent years, concern regarding the safety of PA catheters used for the conventional TD technique has increased, and less invasive alternative techniques for CO measurement are being developed (Corley et al. 2003).

The pulse-induced contour cardiac output (PiCCO) system provides real-time continuous CO monitoring via pulse contour analysis. In human medicine, the PiCCO system has been used to monitor CO during general anaesthesia and intensive care since the late 1990s and is considered a reliable CO measurement technique (McLuckie et al. 1996; Tibby et al. 1997; Sakka et al. 1999; Holm et al. 2001; Della Rocca et al. 2002; Pauli et al. 2002; Schiffmann et al. 2002). The PiCCO system also allows the measurement of extravascular lung water (EVLW) and the pulmonary vascular permeability index (PVPI) (Katzenelson et al. 2004; Easley et al. 2009). To improve accuracy, pulse contour CO (PulseCO) values are periodically calibrated using CO measurements obtained via the PiCCO system transpulmonary thermodilution cardiac output (TPTDCO) technique. TPTDCO employs a central venous catheter for thermal indicator injection, and a thermistor-tipped catheter placed in the femoral artery to detect thermal dilution. In humans, the use of PA catheters has been associated with an increased rate of complications, especially arrhythmia, relative to the use of central venous catheter-guided therapy (19.4% *versus* 8.4%, respectively) (Wheeler et al. 2006). Therefore, TPTDCO facilitates CO measurement while reducing or eliminating the complications and morbidity associated with PA catheterization.

A previous study conducted in dogs suggested that the PiCCO system might serve as a less invasive method of monitoring CO in cases of severe bleeding and hypovolaemic shock (Friedman et al. 2002). Recently, Morgaz et al. (2014) reported that the PiCCO system appears to accurately monitor CO in dogs, as values determined using the TPTDCO technique agreed with those determined using the conventional TD technique (TDCO) under different haemodynamic conditions induced by norepinephrine infusion (1 μg kg^{-1} $minute^{-1}$) and an excessive dose of sevoflurane [end-tidal sevoflurane concentration (F_E'Sevo) 4.6%]. However, although the administration of a large volume of fluid is often required for haemodynamic stabilization in anaesthetized or critically ill patients, to the present authors' knowledge, no reports have described the accuracy of TPTDCO and PulseCO with the PiCCO system in dogs with fluid overload. Therefore, we hypothesized that TPTDCO and PulseCO values would correlate with conventional TDCO values in dogs with fluid overload. Although the novel CO measurement techniques developed for use in humans might be valuable in veterinary medicine, the accuracy and suitability of these technologies must be evaluated in individual species. Proper validation studies require a comparison of the new method with an established method over a wide range of haemodynamic function, with appropriate statistical analyses. The present study aimed to compare the agreement between TPTDCO or PulseCO and TDCO values in anaesthetized dogs with fluid overload.

Materials and methods

Animals

Six Beagle dogs (three non-pregnant females and three males, all intact) were used. The, mean ± standard deviation (SD) age of the dogs was 7.3 ± 0.5 years (range: 7–8 years). Their mean ± SD weight was 13.8 ± 3.6 kg (range: 9.0–19.2 kg). The dogs received care according to the principles of the Guide for the Care and Use of Laboratory Animals prepared by Rakuno Gakuen University. The Animal Care and Use Committee of Rakuno Gakuen University approved this study (VH23B14). The dogs were judged to be in good to excellent health based upon the results of a physical examination, ultrasonographic cardiac function analysis, complete blood cell count and serum biochemical analysis. Approximately 1 month before the experiment, the minimum alveolar concentration (MAC) of sevoflurane was determined in all dogs using a tail clamp technique (Steffey &