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RESEARCH PAPER

Q6 Ability of pulse wave transit time to detect changes in stroke volume and to estimate cardiac output compared to thermodilution technique in isoflurane-anaesthetised dogs

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Abstract

Objective To evaluate the ability of pulse wave transit time (PWTT) to detect changes in stroke volume (SV) and to estimate cardiac output (CO) compared with the thermodilution technique in isoflurane-anaesthetized dogs.

Study design Prospective, experimental study.

Animals Eight adult laboratory dogs.

Methods The dogs were anaesthetized with isoflurane and mechanically ventilated. Reference CO (TDCO) was measured via a pulmonary artery catheter using the thermodilution technique and reference SV (TDSV) was calculated. PWTT was calculated as the time from the electrocardiogram R-wave peak to the rise point of the pulse oximeter wave. Estimated CO (esCO) was derived from PWTT after calibration with arterial pulse pressure (both non-invasive and invasive methods) and TDCO. Haemodynamic changes were induced by administration of phenylephrine (vasoconstriction), high isoflurane (vasodilatation and negative inotropy) and dobutamine (vasodilatation and positive inotropy). Trending between percentage change in PWTT and TDSV was assessed using concordance analysis and receiver operator characteristic (ROC) curve. The agreement between esCO and TDCO was evaluated using the Bland–Altman method.

Results The direction of percentage change between consecutive PWTT and the corresponding TDSV showed a concordance rate of 95%, with correlation coefficients of −0.86 ($p < 0.001$). Area under the ROC curve for the change in PWTT to detect 15% change in TDSV was 0.91 ($p < 0.001$). TDCO compared with esCO calibrated with invasive and non-invasive blood pressure showed a bias (precision of agreement) of 0.58 (1.54) and 0.57 (1.59) L min^{-1} with a percentage error of ±61% and ±63%, respectively.

Conclusions and clinical relevance In isoflurane-anaesthetized dogs, PWTT showed a good trending ability to detect 15% changes in SV. This technique is easy to use, inexpensive, non-invasive and could become routine anaesthetic monitoring. However, the agreement between absolute esCO and TDCO was unacceptable. Q3

Introduction

Measurement of stroke volume (SV) and cardiac output (CO) can facilitate cardiovascular management during anaesthesia. Goal-directed therapy with monitoring of CO improved postoperative outcome in high-risk surgical patients (Gan et al. 2002; Donati et al. 2007; Aya et al. 2013; Cecconi et al. 2013; Ripolles-Melchor et al. 2016). Assessment of trend in SV and CO is also important for cardiovascular responsiveness to treatments with inotropic, vasoactive and fluid therapy (Guinot et al. 2015; Hasanin 2015). Therefore, clinically feasible accurate measurement of SV and CO in veterinary practices should be investigated.

The thermodilution technique with a pulmonary artery catheter is considered the clinical standard method to measure CO (TDCO) in dogs based on the Stewart–Hamilton equation since it was described

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(Fegler 1954) and tested in dogs using regression analysis, resulting in a good agreement with the Fick method (Hendriks et al. 1978). However, the placement of a pulmonary artery catheter is clinically invasive and challenging in veterinary practice and associated with increased postoperative complications in human medicine (Sakka et al. 2000; Harvey et al. 2005). Hence, several minimally invasive methods for CO measurement have been tested in dogs (Bektas et al. 2012; Morgaz et al. 2014; Canfran et al. 2015; Garofalo et al. 2016; Kutter et al. 2016).

Pulse wave transit time (PWTT) is the time from the electrocardiogram (ECG) R-wave peak to the rise point of the pulse oximeter wave (Sugo et al. 2010). The rise point of the pulse wave is defined as the point at which the differentiated pulse wave reached 30% of its peak amplitude (Fig. 1). PWTT has proven to be inversely proportional to SV and has a strong correlation with SV in dogs (Sugo et al. 2010) and human volunteers (Ishihara et al. 2004). Based on this relationship, Sugo et al. (2010, 2012) developed a system to estimate SV (esSV) and CO (esCO) using PWTT. This requires an initial 3-minute period of stable haemodynamics for calibration against another CO measurement system or an automatic patient information calibration and arterial pulse pressure (Ishihara et al. 2004). It is easy to use, inexpensive, minimally invasive and requires only routine anaesthetic monitoring (pulse oximetry, ECG, non-invasive or invasive arterial blood pressure monitoring). In a canine experiment, the correlation of esCO compared with CO obtained using electromagnetic flow metres on the aorta was high ($r = 0.825$); however, the agreement between two methods was not clearly reported (Sugo et al. 2010).

Because a high correlation does not always indicate good agreement between the two methods, precision of agreement with percentage error using Bland–Altman analysis should be used to assess the interchangeability of two methods (Critchley et al. 2010).

Therefore, the aims of this study were: 1) to evaluate the ability of percentage change in PWTT to detect a trend of thermodilution SV (TDSV) correctly and 2) to evaluate the agreement between TDCO and esCO both over a wide range of CO in isoflurane-anaesthetized dogs.

Materials and methods

The study was approved by the Animal Ethics Committee of Massey University (Protocol Number: 14/112). Eight adult laboratory Foxhounds were used. These eight dogs participated in a concurrent study to validate a non-invasive blood pressure (NIBP) monitor based on the American College of Veterinary Internal Medicine issued guidelines for validation of monitors for non-invasive measurement of blood pressure in dogs and cats (Brown et al. 2007). The dogs were determined to be healthy based on history, physical examination, stable bodyweight and blood work analysis.

Anaesthesia and instrumentation

Food was withheld overnight and water was provided *ad libitum*. An 18 or 20 gauge catheter (Optiva IV catheter Radiopaque; Smiths Medical International Ltd, UK) was placed into a cephalic vein for anaesthetic induction. Anaesthesia was induced with propofol (Propofol; Norbrook NZ Ltd, New Zealand) to

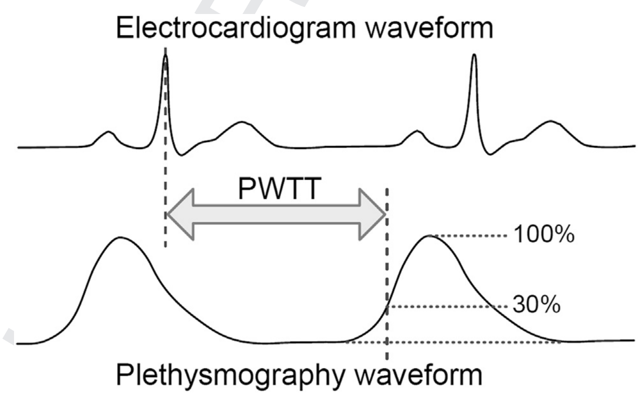

Figure 1 Pulse wave transit time (PWTT). PWTT was calculated as the time from the electrocardiogram (ECG) R-wave peak to the rise point of the pulse oximeter wave. The rise point of the pulse wave was defined as the point at which the pulse wave reached 30% of its peak amplitude.

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