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RESEARCH PAPER

Comparison of Doppler, oscillometric, auricular and carotid arterial blood pressure measurements in isoflurane anesthetized New Zealand white rabbits

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Abstract

Objective To assess agreement between carotid arterial pressure and auricular arterial, thoracic limb Doppler or thoracic limb oscillometric blood pressure measurements.

Study design Prospective experimental study.

Animals Six adult New Zealand white rabbits.

Methods Rabbits were anesthetized with isoflurane in oxygen at 1, 1.5 and 2 MAC on two separate occasions. Catheters in the auricular and the contralateral external carotid artery were connected to calibrated pressure transducers via non-compliant tubing. Inflatable cuffs of width equal to approximately 40% of the limb circumference were placed above the carpus on both thoracic limbs with a Doppler transducer placed distal to the cuff on one. Systolic (SAP) and mean (MAP) arterial blood pressure measurements were obtained at each dose, on each occasion. Agreement between measurement techniques was evaluated by repeated measures Bland Altman analysis with carotid pressure as the reference. Variation in bias over the measurement range was evaluated by regression analysis.

Results Carotid MAP and SAP ranged from 20 to 65 mmHg and 37 to 103 mmHg respectively. Bias and 95% limits of agreement for auricular and oscillometric MAP were 7 (0–14) and −5 (−21–11) mmHg, respectively, and for auricular, oscillometric and Doppler SAP were 23 (8–37), −2 (−24–20) and 13 (−14–39) mmHg, respectively. Bias varied significantly over the measurement range ($p < 0.001$) for all three SAP techniques but not for MAP measurements.

Conclusions and clinical relevance Limits of agreement for all measurements were large but less so for MAP than SAP. Variation in bias with SAP should be considered when using these measurements clinically.

Keywords arterial pressure, blood pressure measurement, isoflurane, rabbit.

Introduction

Rabbits appear to be particularly susceptible to the cardiovascular depressant effects of inhalant anesthetics and are often hypotensive at surgical planes of anesthesia (Imai et al. 1999; Harvey et al. 2012). This observation may contribute to the increased mortality rate associated with general anesthesia in rabbits compared to dogs and cats (Brodbelt et al. 2008). By compromising blood flow to vital organs, hypotension may contribute to delayed recovery, intra or post-operative organ dysfunction or death.

Accurate blood pressure measurement is necessary to evaluate the incidence and severity of hypotension, as well as the efficacy of methods taken to rectify the problem. Multiple methods are

available for blood pressure measurement, with direct measurement generally considered to be the most accurate (Reeves 1995). Other advantages of arterial catheterization for blood pressure monitoring include provision of continuous measurement, waveform display and access for arterial blood sampling. Disadvantages of this technique are numerous and include the need for technical skill in order to catheterize an artery, risk of hemorrhage, thrombosis, or embolism, inadvertent intra-arterial injection, availability and expense of equipment. Indirect methods of blood pressure measurement are less invasive, require less skill, and are associated with fewer complications but may be less accurate.

In rabbits, one of the most common sites for arterial catheterization is an auricular artery as it is easily catheterized percutaneously. Auricular arterial pressures have been used as the comparison to assess the performance of Doppler blood pressure assessment in rabbits (Harvey et al. 2012). Some previous studies, however, have suggested that auricular arterial pressures are substantially lower than those measured from a central artery (Imai et al. 1999). In addition, the magnitude of this discrepancy may be variable over a range of measured pressures (Ypsilantis et al. 2005).

The objectives of this study were to compare the level of agreement between thoracic limb Doppler, thoracic limb oscillometric and auricular arterial blood pressure with blood pressure measured from the carotid artery in isoflurane anesthetized, normothermic rabbits.

Materials and methods

Animals

Six healthy adult female New Zealand white rabbits weighing 3.8 ± 0.6 kg (mean ± SD) were used in this study with the approval of the Institutional Animal Care and Use Committee. Food and water were not withheld prior to anesthesia.

Induction anesthesia and instrumentation

Anesthesia was induced with isoflurane in oxygen delivered into an induction chamber and then face mask. Each rabbit's trachea was then intubated with a cuffed endotracheal tube and anesthesia maintained with isoflurane in oxygen delivered via a Bain circuit with a fresh gas flow rate of 200 mL kg^{-1} $minute^{-1}$.

A 22-gauge 2.5 cm catheter (Insyte catheter; Becton, Dickinson and Company, UT, USA) was placed in the lateral saphenous vein for intravenous (IV) delivery of isotonic crystalloid fluid (Lactated Ringer's Solution; Baxter Healthcare, IL, USA) at 3 mL kg^{-1} $hour^{-1}$. A 24-gauge 1.9 cm catheter (Insyte catheter; Becton, Dickinson and Company) was placed percutaneously into an auricular artery and a 22-gauge 4.4 cm catheter (Intracan; B Braun, Melsungen, Germany) was placed into the contralateral external carotid artery via surgical dissection for measurement of arterial pressure.

A calibrated temperature probe was placed into the esophagus to the level of the heart for constant temperature monitoring. Core body temperature was maintained between 38 and 39 °C by use of circulating warm water blankets and forced air warming units (Bair Hugger; Arizant Healthcare Inc., MN, USA) as needed.

Each rabbit was positioned in right-lateral recumbency. Systolic, diastolic and mean arterial blood pressure (SAP, DAP and MAP) from the carotid and the auricular artery, and temperature were monitored continuously and recorded by use of a physiograph (Physiograph; Gould Instrument Systems, OH, USA) and acquisition software (Ponemah version 3.0; Gould Instrument Systems). All pressure transducers were calibrated against a mercury manometer with the zero point set at the level of the sternum.

Size 1 blood pressure cuffs (bladder width 21 mm, bladder length 60 mm, Spacelabs Healthcare, WA, USA) were placed above the carpus on both thoracic limbs. One was attached to an oscillometric blood pressure measurement device (Cardell 9405; Sharn Veterinary, FL, USA). The other was attached to a sphygmomanometer and a pediatric Doppler crystal (Parks Medical Electronics Inc., NV, USA) placed on the medial aspect of the limb, just above the carpus but distal to the cuff. Whether Doppler and oscillometric device were placed on right or left limb was allocated at random.

Experimental design

In conjunction with another study (Barter & Epstein 2013) each rabbit was anesthetized on two occasions, both with three concentrations of isoflurane and once each with controlled or spontaneous ventilation. On each occasion following instrumentation, the end-tidal isoflurane concentration (F_EIso) was randomly set at 1.0, 1.5 or 2.0 times