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RESEARCH PAPER

Agreement of high definition oscillometry with direct arterial blood pressure measurement at different blood pressure ranges in horses under general anaesthesia

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Abstract

Objective To determine the agreement of high definition oscillometry (HDO) with direct arterial blood pressure measurements in normotensive, hypotensive and hypertensive horses during general anaesthesia.

Study design Experimental study.

Animals Seven healthy warmblood horses, aged 3–11 years, weighing 470–565 kg.

Methods Measurements from a HDO device with the cuff placed around the base of the tail were compared with pressures measured invasively from the facial artery. High blood pressures were induced by intravenous (IV) administration of dobutamine (5 μg kg^{-1} $minute^{-1}$) over ten minutes followed by norepinephrine (0.1 mg kg^{-1} IV) and low pressures by increasing the inspired fraction of isoflurane and administration of nitroglycerine (0.05 mg kg^{-1} IV). For analysis three pressure levels were determined: high (MAP>110 mmHg), normal (60 mmHg<MAP<110 mmHg) and low (MAP< 60 mmHg). Bland-Altman analysis was used for comparison between non-invasive and invasive measurements.

Results A total of 245 paired measurements of systolic (SAP), mean (MAP) and diastolic (DAP) pressures were obtained. The HDO device underestimated blood pressure at hypertensive and normotensive levels and overestimated blood pressure at hypotensive levels. Best agreement was obtained for SAP and MAP within normotensive limits. At normotension, bias ± standard deviation for SAP, MAP and DAP were 0.1 ± 19.4 mmHg, 0.5 ± 14.0, 4.7 ± 15.6, respectively. At high pressure levels bias and SD were 26.1 ± 37.3 (SAP), 4.2 ± 19.4 (MAP), 1.5 ± 16.8 (DAP) and at low pressures −20.0 ± 20.9 (SAP), −11.4 ± 19.6 (MAP), −4.7 ± 20.1 (DAP), with HDO measurements at a MAP <50 mmHg often failing.

Conclusion and clinical relevance Good agreement with invasive arterial blood pressures was obtained with HDO at normotensive levels in horses. At high and low pressure ranges HDO was unreliable. Therefore, if haemodynamic instability is expected, invasive measurement remains preferable.

Keywords arterial blood pressure, cardiovascular, equine, oscillometry.

Introduction

Measuring systemic arterial blood pressure is a key element of anaesthetic monitoring in horses. Invasive blood pressure monitoring is the most accurate and reliable method (Riebold & Evans 1985) and arterial catheterization provides the additional

advantage of facilitating arterial blood sampling for gas analysis. However, in some circumstances a reliable, automated non-invasive blood pressure measurement device would be useful, for example, when arterial catheterization is not possible, during very short procedures in healthy horses, before the arterial catheter is placed or in conscious horses. Various oscillometric monitors have been used in horses (Giguère et al. 2005) but poor agreement with the direct method has been reported at low blood pressure levels, during movement and in the presence of cardiac arrhythmias or bradycardia (Brown & Holmes 1981). Memo Diagnostic is a new veterinary high definition oscillometry (HDO) device. The manufacturers claim that the device is more accurate than traditional oscillometric blood pressure monitors, particularly for hyper- or hypotensive ranges of blood pressure. This device is available as a version for small animals as well as for horses (Memo Diagnostic Equine). Different studies have investigated its reliability in small animals (Petric et al. 2010; Wernick et al. 2010) but, to our knowledge, there are no reports evaluating the agreement between the HDO device and invasive blood pressure measurements in anaesthetized horses at different blood pressure ranges.

Material and nethods

Seven Warmblood horses aged 3–11 years old and weighing 470–565 kg were anaesthetized for terminal experimental abdominal surgery approved by the local animal welfare committee (protocol number 33.14-42502-04-11/0572). Prior to anaesthesia horses were assessed to be healthy by physical exam and haematology.

Horses were premedicated intravenously (IV) with xylazine (Xylapan, Vetoquinol, Germany) until profoundly sedated (0.8–1.1 mg kg^{-1}). Anaesthesia was induced with 2.2 mg kg^{-1} ketamine (Narketan, Vetoquinol, Germany) and 0.05 mg kg^{-1} midazolam (Midazolam-ratiopharm, ratiopharm GmbH, Germany) IV. Following orotracheal intubation the horses were positioned in dorsal recumbency and immediately connected to a large animal anaesthesia machine (Vet.-Tec. Model JAVC 2000, J.D. Medical Distributing Company, AZ, USA) via a circle breathing system. Anaesthesia was maintained with isoflurane (Isofluran CP, CP-Pharma, Germany) in oxygen (4–8 L $minute^{-1}$) and from induction onward, balanced by a continuous rate infusion of xylazine (12.5 μg kg^{-1} $minute^{-1}$). Pressure cycled intermittent positive pressure ventilation was initiated after connection to the anaesthesia machine and this was adjusted to maintain an end-tidal CO_2 of between 4.7 to 6 kPa (35–45 mmHg). Standard anaesthetic monitoring included: sidestream capnography; pulse oximetry; a lead II ECG; inspiratory and end-expiratory gas concentrations; and body temperature via a nasal probe (Cardiocap 5 monitor, Datex-Ohmeda GmbH, Germany).

For invasive blood pressure monitoring the skin over the transverse facial artery was aseptically prepared before cannulation of the artery with a 20 gauge over the needle catheter (Introcan Safety, B Braun, Germany). The catheter was connected to a pre-calibrated electronic pressure transducer (DTXPlus, Becton Dickinson GmbH, Germany) via non-compliant fluid-filled extension lines, and the pressure transducer was positioned and zeroed at the level of the sternal manubrium. Systolic (SAP), diastolic (DAP) and mean arterial pressure were measured continuously and displayed on a multiparameter monitor (Cardiocap 5 monitor, Datex-Ohmeda GmbH, Germany). A fast flush test and visual evaluation of the arterial pressure waveform were performed at the beginning of the experiment and regularly at 20 minute intervals to avoid excessive over or underdamping.

For oscillometric blood pressure measurement the HDO monitor Memo Diagnostic Equine (S+B medVet GmbH, Germany) was used. The cuff was placed around the base of the tail with the bladder centred over the middle coccygeal artery. The width of the cuff was approximately 40% of circumference of the tail. To account for the effects of hydrostatic pressure the vertical distance between the pressure transducer and the cuff was measured and a correction factor (1 cm = 0.74 mmHg) applied. This value was then subtracted from the pressures measured by the HDO device. The HDO device was linked to a laptop for real time visualization of the oscillometric pulse waves. Oscillometric measurements were manually started every five minutes and SAP, MAP and DAP were recorded together with the SAP, MAP and DAP readings obtained simultaneously by the invasive technique.

During the first phase of the study 5–10 mL kg^{-1} $hour^{-1}$ Lactated Ringers solution (Ringer-Laktat-Lösung, B. Braun Melsungen AG, Germany) and 1–5 μg kg^{-1} $minute^{-1}$ dobutamine (Dobutamin-ratiopharm, ratiopharm GmbH, Germany) were continuously infused and the rates were adapted to achieve normotension; mean arterial blood pressure (MAP) was maintained