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RESEARCH PAPER

Comparison of invasive and oscillometric blood pressure measurement techniques in anesthetized sheep, goats, and cattle

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Abstract

Objective To determine the level of agreement between an oscillometric (O-NIBP) and an invasive method (IBP) of monitoring arterial blood pressure (ABP) in anesthetized sheep, goats, and cattle.

Study design Prospective clinical study.

Animals Twenty sheep and goats, 20 cattle weighing <150 kg body weight, and 20 cattle weighing >150 kg body weight.

Methods Animals were anesthetized and systolic ABP (SABP), mean ABP (MABP), and diastolic ABP (DABP) were measured using IBP and O-NIBP. Differences between IBP and O-NIBP, and 95% limits of agreement (LOA) between SABP, MABP, and DABP values were assessed by the Bland–Altman method.

Results Mean difference ± standard deviation (range) between SABP, DABP, and MABP measurements in sheep and goats was 0 ± 16 (−57 to 38) mmHg, 13 ± 16 (−37 to 70) mmHg, and 8 ± 13 (−34 to 54) mmHg, respectively. Mean difference between SABP, DABP, and MABP measurements in small cattle was 0 ± 19 (−37 to 37) mmHg, 6 ± 18 (−77 to 48) mmHg, and 4 ± 16 (−73 to 48) mmHg, respectively. Mean difference between SABP, DABP, and MABP measurements in large cattle was −18 ± 32 (−107 to 71) mmHg, 7 ± 29 (−112 to 63) mmHg, and −5 ± 28 (−110 to 60) mmHg, respectively. The 95% LOAs for SABP, DABP, and MABP were −31 to +31, −19 to +44, and −19 to +34 mmHg, respectively in sheep and goats; were −37 to +37, −19 to +44, and −19 to +34 mmHg, respectively in small cattle; and were −81 to +45, −50 to +63, and −59 to +50 mmHg, respectively in large cattle.

Conclusions Agreement was poor between O-NIBP and IBP monitoring techniques.

Clinical relevance Arterial BP should be monitored in anesthetized sheep, goats, and cattle using IBP.

Keywords anesthesia, arterial blood pressure, cattle, goat, non-invasive blood pressure, sheep.

Introduction

Monitoring of arterial blood pressure (ABP) is useful when cardiovascular status is potentially compromised and during general anesthesia. Hypotension commonly occurs during general anesthesia due to the vasodilatory and negative inotropic effects of some anesthetic drugs and is associated with increased morbidity and mortality in a variety of species, including humans, dogs, cats, and horses (Grandy et al. 1987; Gaynor et al. 1999; Gordon & Wagner 2006; Bijker et al. 2007).

Invasive or direct ABP monitoring techniques are used in cattle, sheep, goats, and horses because they are recognized as the most accurate methods.

Invasive methods (IBP) of monitoring ABP require skill for catheter placement. Infection, thromboembolus, hematoma formation, and tissue necrosis may result (Heath 1989; Wagner & Brodbelt 1997). Non-invasive blood pressure monitoring (NIBP) techniques are easily applied and have a low incidence of complications, typically associated with prolonged use and application of excessive pressure within the cuff (Dorsch & Dorsch 2008). Direct ABP was compared with O-NIBP in one sheep, and the mean difference between direct and indirect values was 8 mmHg (Glen 1970). Oscillometric NIBP monitoring has been described in camelids, and one study determined O-NIBP to be inaccurate in anesthetized llamas and alpacas (Prado et al. 2008a; Georoff et al. 2010; Aarnes et al. 2012).

The aim of this study was to determine the level of agreement between O-NIBP and IBP in anesthetized sheep, goats, and cattle. It was hypothesized that the level of agreement between the two methods would support the use of O-NIBP monitoring in anesthetized sheep, goats, and cattle.

Materials and methods

Study design

Animals used for this study were presented to The Ohio State University Veterinary Medical Center between June 2008 and September 2009. Animals requiring surgery were used for this study. The study was performed in compliance with institutional guidelines for research on animals.

The anesthetist determined premedication and anesthetic induction drugs. Following orotracheal intubation, each patient was connected to a standard circle anesthetic circuit. Isoflurane in oxygen was delivered by use of an out-of-circuit precision isoflurane vaporizer. Pulse rate was monitored by direct arterial palpation over 15 seconds, and rhythm was monitored using an ECG (lead II), with the leads placed in a base-apex configuration. Intravenous fluids (lactated Ringer's solution) were delivered at a rate of 3–5 mL kg^{-1} $minute^{-1}$, via a preplaced jugular catheter. Heart rate and respiratory rate were recorded every 5 minutes throughout the procedure.

A 20-gauge 3.2 cm fluid filled catheter (Surflo; Terumo, MD, USA) for IBP was inserted into an auricular artery after clipping or shaving of hair and cleansing of the skin. Catheters were connected to an 83.8 cm long non-compliant IV tubing (MX451SL; Smiths Medical, OH, USA) and a 3-way stopcock (Kendall Solution Plus; Tyco Healthcare, MA, USA) filled with sterile saline. The 3-way stopcock was connected to a pressure transducer (Edwards Lifesciences, CA, USA), which was zeroed to atmospheric pressure. Care was taken to ensure that the IV tubing and pressure transducer were free of air bubbles. The IBP monitoring system was calibrated prior to the start of the study and on a weekly basis using a mercury manometer according to manufacturer specifications (Datascope 1996a).

A blood pressure cuff (Dura-Cuf; GE Healthcare, UT, USA) was positioned directly over the metacarpal artery, with the proximal end of the cuff 2.5 cm distal to the carpus for NIBP monitoring (Prado et al. 2008a,b; Georoff et al. 2010). If the patient was laterally recumbent, the cuff was positioned on the non-dependent limb (Prado et al. 2008a,b; Georoff et al. 2010). The limb circumference at this point was measured, and a cuff was chosen that was approximately 50% of the circumference of the limb, in congruence with guidelines that the cuff width should be 40–60% of the circumference of the limb (Geddes et al. 1980; Sawyer et al. 1991; Pedersen et al. 2002). If the measurement fell between two cuff sizes, the larger cuff was chosen. In cattle weighing >150 kg, the largest available cuff (14 cm) was used; in each case the cuff was smaller than the recommended cuff width based on the size of the limb. The position of the level of the forelimb at which the cuff was placed relative to the sternum was measured for patients in lateral recumbency and relative to the level of the scapulo-humeral joint for patients in dorsal recumbency. The blood pressure transducer was initially positioned horizontally level with the sternum for patients in lateral recumbency and level with the scapulo-humeral joint for patients in dorsal recumbency, and then re-positioned if necessary, to be at the same height as the cuff, which was confirmed by tape measure. The cuff was attached to the monitor (Passport; Datascope, NJ, USA) using the manufacturer's specified tubing. Manufacturer specified diagnostic and calibration tests including pneumatics tests and pressure calibration were performed on the NIBP system in accordance with manufacturer's directions and weekly throughout the duration of the study (Datascope 1996a).

Systolic ABP, mean ABP (MABP), and diastolic ABP (DABP) were measured and recorded every 5 minutes during the surgical procedure. Readings of O-NIBP and IBP were virtually simultaneous, with