

## RESEARCH PAPER

# Validity and reliability of Doppler ultrasonography and direct arterial blood pressure measurements in anaesthetized dogs weighing less than 5 kg

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## Abstract

**Objective** To assess the validity and reliability of Doppler ultrasonography (DOP) as compared with invasive arterial blood pressure measurements in anaesthetized dogs weighing less than 5 kg.

**Study design** Controlled, prospective, clinical study.

**Animals** A total of 41 privately owned dogs weighing less than 5 kg.

**Methods** The dogs were anaesthetized, and an intra-arterial catheter was aseptically placed in the dorsal pedal artery of the pelvic limb to perform invasive blood pressure (IBP) measurement. The contralateral metatarsal surface of the foot was clipped in order to perform DOP. Both techniques were used to record blood pressure measurements every 5 minutes during surgical procedures. The blood pressure measurements were categorized into two groups: hypotensive [mean arterial pressure (MAP) < 60 mmHg] and normotensive (MAP between 60 and 120 mmHg). A linear mixed model was used to compare the DOP and IBP values. The results were evaluated according to the requirements of the American College of Veterinary Internal Medicine (ACVIM) guidelines for the validation of devices.

**Results** DOP provided higher values compared to the systolic arterial blood pressure (SAP) and MAP of IBP measurements. The closest agreement between the two techniques was found for SAP; the bias was 8.6, and limits of agreement (LOA) were -32.9 and 50.4. Similar results were observed

when the IBP technique was categorized. The closest agreement was for SAP in animals categorized as normotensive; the bias was 8.2, and LOAs were -32.8 and 49.2. The level of agreement between DOP and IBP did not meet the ACVIM recommendations.

**Conclusions and clinical relevance** Our results suggest there is poor agreement between DOP and IBP measurements in anaesthetized dogs weighing less than 5 kg. Hence, the use of DOP in these animals could be misleading.

**Keywords** anaesthesia, arterial blood pressure, dogs, Doppler, non-invasive blood pressure.

## Introduction

Arterial blood pressure monitoring is one of the most useful measures used during the anaesthetic procedure to avoid and/or treat hypotension, a common peri-anaesthetic complication in small animal veterinary practice (Wagner & Brodbelt 1997; Haskins 2007; Moens & Coppens 2007). Several methods can be used to measure blood pressure (BP), including non-invasive or indirect methods, such as the Doppler ultrasonography (DOP) technique and oscillometry, as well as invasive or direct methods, including intra-arterial catheterization.

Although invasive blood pressure (IBP) monitoring is considered the gold standard in veterinary medicine (Bodey & Michell 1996; Stepien & Rapoport 1999), because it is more accurate than non-invasive methods (Wagner & Brodbelt 1997; Waddell 2000), it is more expensive than non-

invasive methods and can lead to erroneous results in the hands of a non-experienced operator (Waddell 2000). Consequently, clinicians often base their therapeutic decisions on non-invasive blood pressure (NIBP) readings (Bosiak et al. 2010).

NIBP measurements are commonly used by clinicians, because the equipment is portable and relatively inexpensive, and measurements are easier to perform (Brown et al. 2007; Haskins 2007). However, these measurements exhibit variable precision and accuracy as compared to the invasive method and are prone to erroneous reading under certain circumstances; for example, during hypotension (Bosiak et al. 2010; Garofalo et al. 2012). Oscillometric monitors are automated and report systolic arterial pressure (SAP), mean arterial pressure (MAP) and diastolic arterial pressure (DAP) at regular intervals. These are usually used in dogs heavier than 5 kg because of decreased accuracy in smaller patients (Gains et al. 1995; Waddell 2000; Ypsilantis et al. 2005).

DOP is a non-invasive technique that provides a continuous audible tone of the pulse rate (Binns et al. 1995; Waddell 2000; Chetboul et al. 2010; Seliškar et al. 2013). Studies in small animals have demonstrated controversial DOP readings, as some show correlation between DOP readings and SAP (Haberman et al. 2006; Kennedy & Barletta 2015), whereas others show a closer correlation with MAP (Caulkett et al. 1998; Zehnder et al. 2009).

Although direct comparison between devices is often difficult or impossible (Wernick et al. 2012), it is important to understand the accuracy of certain NIBP monitoring devices, as compared to the gold standard, which is the IBP measurement (Bosiak et al. 2010; Seliškar et al. 2013). This comparison is performed to determine whether the NIBP device could be useful for measuring arterial blood pressure. The American College of Veterinary Internal Medicine (ACVIM) has released a consensus statement recommending validation studies for blood pressure measurement devices in animals, based on criteria and recommendations of the Association for the Advancement of Medical Instrumentation. This document includes a suggested protocol for measuring BP, and BP device efficacy is validated if the following conditions are met: the mean difference between the device and the gold standard is <10 mmHg with a standard deviation (SD) of <15 mmHg. Additionally, at least 50% of all measurements of the method being validated must lie within 10 mmHg of the reference method (the gold standard) and 80% of

measurements must lie within 20 mmHg; furthermore, the correlation between the two methods should exceed >0.9 (Brown et al. 2007).

The aim of this study was to compare Doppler ultrasonic flow monitor measurements with IBP monitoring in anaesthetized dogs weighing 5 kg or less, under clinical situations, and to determine whether DOP shows better agreement with direct-SAP or with direct-MAP in dogs of this size. And additional goal was to assess if the DOP values meet the ACVIM requirements when it is compared to direct-SAP and direct-MAP.

## Materials and methods

This study was approved by the Ethical Commission of Animal and Human Experimentation (Spanish Government, Authorization number DARP8004), and informed consent was obtained from all dog owners.

### Animals and inclusion criteria

The study was carried out in the Fundació Hospital Clínic Veterinari—Universitat Autònoma de Barcelona (FHCV—UAB), from January 2013 to December 2015. A total of 41 privately owned dogs were included in this study (16 males and 24 females). The inclusion criteria included the following: dogs that were admitted for a surgical procedure at FHCV—UAB, weighed less than 5 kg, and in which an arterial catheter was possible to be placed into the dorsal pedal artery. No exclusion criteria were applied for the disease state of the animals or for the anaesthetic protocol used, because these factors were considered irrelevant to the aim of the study.

### Procedure

Dogs were premedicated with 0.4 mg kg<sup>-1</sup> morphine intramuscularly (IM), 0.4 mg kg<sup>-1</sup> methadone IM or 0.02 mg kg<sup>-1</sup> buprenorphine IM, and some were also sedated with 0.02–0.05 mg kg<sup>-1</sup> acepromazine IM or 0.002–0.005 mg kg<sup>-1</sup> medetomidine IM. Induction was performed with 2–4 mg kg<sup>-1</sup> propofol intravenously (IV), 1–2 mg kg<sup>-1</sup> etomidate IV, 1 mg kg<sup>-1</sup> IV alfaxalone or 0.005 mg kg<sup>-1</sup> fentanyl IV, in all cases followed by 0.5 mg kg<sup>-1</sup> diazepam IV. After induction, an orotracheal tube was placed in all dogs. Maintenance of anaesthesia was performed with isoflurane 2% in oxygen 100%, using a Mapleson F circuit and a fresh gas flow of 600 mL kg<sup>-1</sup> minute<sup>-1</sup>.

Dogs were administered an infusion of lactated Ringer's solution (Ringer Lactato Braun; B. Braun,

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