

# Use of a human wrist blood pressure monitor for arterial blood pressure measurements in normotensive conscious dogs in comparison to veterinary high-definition oscillometry

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## Abstract

**Background:** The gold standard in canine blood pressure (BP) measurement is the invasive method; however, non-invasive blood pressure measurement techniques (NIBP) are more commonly used. The lack of small, lightweight, cheap, fast and portable NIBP still remains a point to improve in the emergency setting.

**Key Findings:** A human wrist blood pressure (WBP) device was evaluated in comparison with the veterinary high-definition oscillometry (HDO) in conscious normotensive dogs. Systolic and diastolic BPs were evaluated in two groups of dogs. The bias, the limits of agreement and correlation between variables were calculated. Twenty-five and 36 dogs were, respectively, included in Study No. 1 (dogs weighting  $\geq 10$  kg) and 2 (dogs weighting  $\geq 20$  kg). In both studies, correlation between the two devices was moderate. A better agreement was displayed for diastolic pressure and poor precision for both systolic and diastolic pressures measurements (as determined by wide limits of agreement). The WBP method underestimated both the systolic and diastolic BP with respect to the HDO method. The inclusion of bigger dogs (Study No. 2) with limb circumference more like to human limb dimension did not improve the agreement between considered methods.

**Significance:** The human WBP monitor considered is not suitable to replace the commonly used veterinary HDO for in-clinic BP monitoring in normotensive conscious dogs.

## KEYWORDS

blood pressure, high-definition oscillometry, normotensive dogs, wrist blood pressure monitor

## 1 | INTRODUCTION

Blood pressure (BP) is commonly measured in dogs and cats in an emergency setting. The need of a rapid and accurate triage evaluation has

induced emergency veterinarians to prefer peripheral pulse palpation to the challenging Doppler BP evaluation as a first approach to the critically ill patient (Ateca et al., 2018). However, metatarsal pulses palpation cannot be considered a substitute of BP measurement, and

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the need of non-invasive blood pressure measurement devices (NIBP) preferably small, lightweight and portable, still remains a point to improve in the emergency setting.

In veterinary medicine, the gold standard of BP measurement is intra-arterial measurement. However, cost, need to practice and presence of complication such as iatrogenic infection, bleeding and arterial embolization, make the invasive technique unusable in clinical practice (Sawyer et al., 1991). Therefore, the NIBP techniques such as the ultrasonic Doppler and the oscillometric technique or high-definition oscillometry (HDO) remain the most used methods. Considering that oscillometric and HDO devices are faster, easier to use and require little training, they are usually preferred to Doppler technique in the emergency setting. The HDO in particular allows to measure BP in dogs and cats with high heart rate, improves the accuracy recognizing arterial wall vibrations with high precision and provides a graphical analysis of BP (Taylor et al., 2017). Some studies carried out in both experimental and clinical settings evaluate the HDO performance in anaesthetized and conscious animals in comparison to other devices (Seliškar et al., 2013). Currently, there is no agreement which is the best technique. Some authors, comparing HDO and Doppler technique, suggested that the first one is to be preferred in accordance to a better agreement with the American College of Veterinary Internal Medicine (ACVIM) requirements for the validation of BP devices (Seliškar et al., 2013). However, since 1970, several NIBP devices have been compared to the gold standard in anesthetized and awake dogs without success. Currently, no veterinary NIBP devices respect human or veterinary validation criteria in dogs (Acierno et al., 2018). Even some human NIBP devices have been studied in dogs suggesting a possible interspecies exchange of some BP monitors (Hunter et al., 1990). The lack of BP monitor that met validation standards has favoured the spread of different technique, with the excel of the 'less unreliable' device. In 2010, Meyer et al. demonstrated a good correlation between the HDO monitor and the invasive gold standard method in dogs (showing very low bias for MAP) and in 2013, the HDO monitor has been defined the non-invasive reference technology in cats (Meyer et al., 2010; Martel et al., 2013).

The aim of this prospective study was to assess the bias and precision (level of agreement) of estimates of BP provided by a human wrist blood pressure monitor (WBP; DigiColor, Microlife Corporation, Taiwan) by comparison with the widespread HDO monitor (Memo Diagnostic Pro, S+B MedVet GmbH, Germany) in a population of normotensive conscious dogs. The human WBP monitor is in fact smaller, lighter weight and cheaper than HDO, and the presence of an autonomous battery and absence of wires allow its use in different critical care conditions. The hypothesis was that HDO and WBP monitor can be used interchangeably.

## 2 | MATERIALS AND METHODS

### 2.1 | Animals

This study was conducted between January 2016 and March 2016 (Study No. 1); and between September 2018 and December 2018

(Study No. 2). Dogs were recruited during routine clinical evaluation or from hospitalized dogs. Consent for each dog was obtained from the owners before the enrolment. Patients were considered eligible for the study according to the following criteria:

- Study No. 1: normotensive dogs, weighting  $\geq 10$  kg, aged over 5 months and with a limb circumference above the carpus higher than 10 cm;
- Study No. 2: normotensive dogs, weighting  $\geq 20$  kg, aged over 5 months.

All BP measurements were obtained according to the ACVIM consensus statement (Acierno et al., 2018; Brown et al., 2007). For the purpose of this study, normotension was defined according to mean BP (MAP). Dogs were determined to be normotensive if MAP was  $101 \pm 11$  mmHg (Meurs et al., 2000).

Patients with higher BP (maximum 150 mmHg) were also included if 'situational hypertension' was confirmed by normal subsequent BP evaluation in the 30 days following the inclusion date (Soares et al., 2012). Exclusion criteria were as follows: weight less than 10 kg, proximal pelvic limb circumference less than 10 cm, non-appropriate limb's morphology (short and/or irregular anterior limb), non-compliant patients, abnormal hydration status or volemia.

### 2.2 | Procedure

Minimal restraint was used, when necessary. Considering that BP measurements in dogs were significantly affected by body position, measurements were obtained in laterally recumbent body position (less variable than in the sitting position) (Rondeau et al., 2013). All sets of measurements were completed within 20 min. A single observer (EM in Study No. 1 and RF in Study No. 2) made all measurements using HDO and WBP devices consecutively. Dogs were placed in right lateral recumbency and measurements were taken on the non-dependent front leg. The HDO cuff provided by the manufacturer was selected according to the animal's limb circumference and to the manufacturer's instructions. Cuffs of both oscillometric devices were placed above the carpus. Limb circumference was measured. Measurements associated with recorded heart rates that did not match the dog's pulse rate were rejected. The first measurement was systematically discarded (Acierno et al., 2018). The consecutive 3, and preferably 5 values were recorded and averaged (Acierno et al., 2018). For each device, averaged systolic BP, heart rate and diastolic BP were registered.

### 2.3 | Statistical methods

A statistical software program (IBM SPSS Statistics, Version 20, New York, NY, USA) was used. The *p*-value was considered significant if  $< 0.05$ . The Kolmogorov-Smirnov test of normality was applied in order to analyze distribution. Variables were introduced as mean and standard deviation (SD), or as median and interquartile range (IQR) when normally/non-normally distributed, respectively.

**TABLE 1** Study No. 1: Patients weight, limb circumference and blood pressure

Parameters	Minimum	Maximum	Mean	SD
Weight (kg)	10	46	26.6	8.4
Limb circumference (cm)	10	20	15.56	2.27
HDO sys (mmHg)	117.66	177	149.70	16.94
WBP sys (mmHg)	97.66	168	127.77	14.34
HDO dia (mmHg)	64	123	90.89	16.47
WBP dia (mmHg)	42.5	111	79.43	16.59

Abbreviations: dia, diastolic blood pressure; HDO, high-definition oscillometry; WBP, wrist blood pressure; sys systolic blood pressure.

The Bland–Altman method was applied to define the agreement between the HDO and WBP methods. Mean difference between the two NIBP devices were calculated to obtain the bias. Standard deviation and limits of agreement at 95% (mean  $\pm$  1.96  $\times$  SD) were calculated. Correlation between variables was tested by the Pearson correlation coefficient or Spearman correlation test in accordance with variables distribution. The correlation was classified in accordance with the correlation coefficient as weak (0.1–0.3), moderate (0.4–0.6), strong (0.7–0.9) or perfect (1) (Dancey & Reidy, 2007; Rondeau et al., 2013).

### 3 | RESULTS

#### 3.1 | Study No. 1

Twenty-five dogs were included among the eligible population, including 14 female (seven spayed, seven intact) and 11 intact male dogs, aging between 7 and 228 months old ( $72.9 \pm 57.5$ ) and weighting between 10 and 46 kg ( $26.6 \pm 8.4$ ). Breeds included were mixed breed (four), Labrador Retriever (four), Golden Retriever (two), German Shepperd (two), Rottweiler (two), Beagle (two), other. Reasons for hospitalization (17) included soft tissue surgery (five), neurological pathologies (four), acute idiopathic gastroenteritis (three), orthopaedic surgery (two) and other pathologies requiring hospitalization (three).

Weight, limb circumference and blood pressure are reported in Table 1 (all the variables were normally distributed). Correlation between weight and limb circumference ( $r = -0.5, p = 0.011$ ) was moderate. Wrist blood pressure monitor failed to measure BP in four of 25 dogs probably due to a non-appropriate limb's morphology. Correlation between HDO and WBP methods in dogs was moderate (systolic pressure  $r = 0.49, p < 0.05$ ; diastolic pressure  $r = 0.51, p < 0.05$ ). Bias and limits of agreement (LOA) are reported in Table 2. The WBP method underestimated both the systolic and diastolic BP with respect to the HDO method. The WBP method performed better for the detection of diastolic BP than systolic BP, as indicated by the smaller bias and narrower limits of agreement.

#### 3.2 | Study No. 2

Thirty-six dogs were included among the eligible population, including 19 female (10 intact, nine spayed) and 17 male dogs (15 intact,

**TABLE 2** Study No. 1: Bias and limits of agreement (LOA)

Parameters	sys	dia
Bias	21.69	13.90
SD	13.12	10.57
Inferior LOA	(–)4.03	(–)6.82
Superior LOA	47.41	34.63

Note: Bias was defined as the mean difference between the two methods, and LOA were calculated as the bias  $\pm$  1.96 SD. Good agreement was defined as a bias and LOA within 15 mmHg.

**TABLE 3** Study No. 2: Patients weight, limb circumference and blood pressure

Parameters	Minimum	Maximum	Mean or median	SD or IQR
Weight (kg)	20	65	33.5	9.6
Limb circumference (cm)	13	23	17.27	2.07
HDO sys (mmHg)	118	192	150.48	17.66
WBP sys (mmHg)	111	178	130.68	12.61
HDO dia (mmHg)	62	130	86.67	16.40
WBP dia (mmHg)	53	121	79	72.2–90.2

Abbreviations: dia, diastolic blood pressure; HDO, high-definition oscillometry; IQR, interquartile range; WBP, wrist blood pressure; sys systolic blood pressure.

**TABLE 4** Study No. 2: Bias and limits of agreement (LOA)

Parameters	sys	dia
Bias	19.81	5.68
SD	13.94	14.51
Inferior LOA	(–)7.53	(–)22.77
superior LOA	47.14	34.12

Note: Bias was defined as the mean difference between the two methods, and LOA were calculated as the bias  $\pm$  1.96 SD. Good agreement was defined as a bias and LOA within 15 mmHg.

two spayed), aging between 7 and 180 months old (54; IQ 18–96) and weighting between 20 and 65 kg ( $30.6$ ; IQ 27.5–39.4). Breeds included were as follows: Labrador Retriever (seven), mixed breed (four), Golden Retriever (four), Rhodesian ridgeback (four), Rottweiler (three), Corso (three), American Staffordshire terrier (two), Bull mastiff (two), Australian Shepperd (two), other. Reasons for hospitalization (19) included acute idiopathic gastroenteritis (five), soft tissue surgery (five), orthopaedic surgery (three) neurological pathologies (two) and other pathologies requiring hospitalization (four).

Weight, limb circumference and blood pressure are reported in Table 3. Correlation between HDO and WBP methods in dogs was moderate (systolic pressure  $r = 0.62, p < 0.01$ ; diastolic pressure  $r = 0.56, p < 0.01$ ). Bias and LAO are reported in Table 4. The WBP method performed better for the detection of diastolic BP than systolic BP, as indicated by the smaller bias.

## 4 | DISCUSSION

The aim of this study was to compare a commercially available human wrist oscillometric device with the veterinary HDO device, commonly used in clinical practice. Particularly in critical setting, the availability of quick, effective and painless tools for BP evaluation is especially important, without mentioning the potential use of such devices in the general practice and in the home BP monitoring. This study evaluated the agreement of the two NIBP devices on conscious dogs. A standard protocol based on the ACVIM recommendation for BP measurement was used (Acierno et al., 2018; Brown et al., 2007).

Considering the single cuff size of the human WBP device, we decided to exclude small size dogs (< 10 kg). Furthermore, to avoid unreliable data came upon Study No. 1, we chose to optimize inclusion criteria (dogs weighting more than 20 kg) in Study No. 2. This was determined to encourage better dog pairing with the human device. In fact, Valtonen and Eriksson previously studied the effect of cuff width on the accuracy of BP measurement in dogs, showing that wide cuffs give often too low values for small dogs (Valtonen & Eriksson, 1970). Moreover, considering the circumference of the wrist reported in human studies (example: range 14–21, mean and SD  $17 \pm 2$ ), the inclusion of bigger dogs allowed us to reduce the difference in dog's wrist dimension and human one (Palatini et al., 2004).

Human WBP devices are easy to find, cheaper than veterinary ones, easy and quick to use (they give a response in few seconds) and they do not require complex usage training. Sometimes, general practitioner suggests their use in home environment to reduce patient displacement, manipulation, stress and anxiety and to avoid the well-known situational hypertension. However, to the authors' knowledge, there are no published studies available regarding the use of human WBP devices in dogs. Our results showed that this human WBP (WBP, DigiColor–Microlife Corporation) device underestimated both systolic and diastolic BP with respect to the HDO device (Memo Diagnostic Pro, S+B MedVet GmbH, Germany) in conscious dogs. Both studies No. 1 and 2 showed a moderate correlation between the two methods (WBP device and HDO). A better agreement was displayed for diastolic pressure and poor precision for both systolic and diastolic pressures measurements (as determined by wide limits of agreement). Unlike our expectation, even in Study No. 2 (including bigger size dogs with larger limb circumference that we expected to reduce the effect of cuff width on the accuracy of BP measurements), a good agreement was not achieved.

In conclusion, this specific WBP monitor underestimates both systolic and diastolic BP in normotensive conscious dogs with respect to the well-known HDO. This study shows the lack of interchangeability between WBP device and HDO in measuring BP in this population. Further studies are needed to evaluate the use of WBP monitor in non-normotensive dogs. For ethical and logistic reasons, results of indirect BP measurement in this study were not compared to values obtained with direct measurement techniques (considered gold standard), as HDO was suggested as a non-invasive reference technology.

## AUTHOR CONTRIBUTION

*Conceptualization, data curation, formal analysis, investigation, methodology, project administration and writing and original draft:* Elisa Martinelli. *Data curation, formal analysis, investigation, methodology and writing–review and editing:* Riccardo Ferriani. *Data curation, formal analysis, software and writing–review and editing:* AnnaMaria Zanaboni. *Investigation, methodology, resources and writing–review and editing:* Chiara Locatelli. *Supervision, validation, visualization and writing–review and editing:* Roberto Toschi Corneliani.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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None.

## DATA AVAILABILITY STATEMENT

Data available on request.

## ETHICS STATEMENT

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page have been adhered to. Animals were handled according to European Union Directive 2010/63/UE regarding the protection of animals used in scientific experiments.

## PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1002/vms3.817>.

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