Comparative study between cuff sizes in the determination of systolic blood pressure, by non-invasive methods in anesthetized dogs

Estudo comparativo entre a numeração de manguitos utilizados na determinação da pressão arterial sistólica por métodos não invasivos em cães anestesiados

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ABSTRACT

The measurement of systolic blood pressure (SBP) is a variable of paramount importance in clinical routine, obtained and measured according to published guidelines for dogs. The study evaluated the influence of cuff size on the determination of systolic blood pressure (SBP) values in dogs, comparing two non-invasive methods. Eighteen healthy dogs of different breeds and ages were used, clinically evaluated and undergoing elective surgeries. SBP was measured using vascular Doppler and high-definition oscillometric methods during the anesthetic period, using both ideal-sized cuffs and smaller cuffs. The dogs were divided into groups, Group 1 composed of dogs with ideal cuff no. 2, Group 2 dogs with ideal cuff no. 3 and Group 3 ideal cuff no. The results showed that smaller cuffs significantly overestimated the mean SBP values compared to the ideal cuff values, regardless of the method used. It was concluded that cuffs with a lower than ideal number overestimate SBP values in anesthetized dogs, regardless of the non-invasive method used.

**Keywords:** 1-Measurement; 2- Pressure; 3-Blood; 4-Canine

RESUMO

A medida da pressão arterial sistólica (PAS) é uma variável de suma importância na rotina clínica, obtida e medida de acordo com diretrizes publicadas para cães. O estudo avaliou a influência do tamanho do manguito na determinação dos valores da pressão arterial sistólica (PAS) em cães, comparando dois métodos não invasivos. Foram utilizados 18 cães hígidos, de diferentes raças e idades, avaliados clinicamente e submetidos a cirurgias eletivas. A PAS foi medida por Doppler vascular e métodos oscilométricos de alta definição durante o período anestésico, utilizando manguitos de tamanho ideal e manguitos menores. Os cães foram divididos em grupos, Grupo 1 composto por cães com nº de manguito ideal 2, Cães do Grupo 2 com manguito ideal no. 3 e Grupo 3 manguito ideal não. Os resultados mostraram que manguitos menores superestimaram significativamente os valores médios da PAS em comparação aos valores ideais do manguito, independentemente do método utilizado. Concluiu-se que manguitos com número inferior ao ideal superestimam os valores de PAS em cães anestesiados, independente do método não invasivo utilizado.

**Palavras-chave:** 1-Aferição; 2- Pressão ;3- Sangue;4- Cão
INTRODUCTION

Recognition of the relevance of arterial hypertension in small animals and its correlation with systemic diseases has demonstrated the importance of standardized and adequate measurement of blood pressure in the veterinary medical clinic routine (ACIERNO et al., 2018). Blood pressure can be measured invasively or by the non-invasive method, with advantages and disadvantages in both methods (STEPIEN, 2000). The invasive form is the gold standard method of measurement, due to its greater accuracy in obtaining the values derived from the puncture in the dorsal and femoral podal arteries. However, there are risks of contamination, bleeding or embolism (WADDELL, 2000). The non-invasive technique is the most used in veterinary clinical routine due to its greater practicality (BOSIACK et al., 2010) and the availability of quality devices available on the market, represented by oscillometric methods and ultrasonic Doppler.

In the oscillometric method, systolic (SBP), diastolic (DBP) and mean (MAP) blood pressure is measured, with the cuff inflated until reaching the systolic pressure and then gradually deflated. Its measurement is performed using a microprocessor that captures the amplitudes of the oscillations exerted by the blood flow on the arteries when the cuff is deflated, thus estimating the SBP, MAP, DBP (CARR, 2001). In the ultrasonic Doppler method, the measurement of blood pressure is obtained through the sounds emitted by the arterial blood flow. For the measurement, the cuff is inflated until the sounds are not audible and when it is slowly deflated, the device captures and amplifies the sound generated by the return of arterial blood flow, characteristic during systole. With the aid of the sphygmomanometer, we identified the value of systolic blood pressure (PAS) (HENIK & BROWN, 2008).

Comparing these indirect methods in healthy non-anesthetized dogs, Chetboul et al. (2010) demonstrated that, despite the greater ease of handling the oscillometric device, it presented similar values to the ultrasonic doppler method, being recommended in the measurement of SBP in healthy dogs. Previous study, Haberman et al. (2006) comparing the indirect methods with the direct, showed that the oscillometric device and the ultrasonic Doppler can underestimate SBP, with the Doppler method showing more reliable values. Pereira-Neto et al. (2014) described similar results when they studied obese dogs and defined a greater precision in the measurement of SBP by the ultrasonic doppler method when compared to the oscillometric method.
In addition to the different measurement methods, external factors can underestimate or overestimate blood pressure values in dogs and cats. According to Garcia (2011) and Rondeau et al. (2013), for an accurate reading, it is important that the limb used is at the level of the heart with the patient in lateral or sternal decubitus. If the distance between the cuff and the base of the heart is greater than 10 cm, it is recommended to apply a correction factor of +0.8 mmHg/cm (ACIERNO et al., 2018). According to Henik et al. (2005), the position of the animal must allow the cuff to be at the same level as the right atrium, highlighting that the blood flow of the median artery between the carpus and the metacarpal is a recommended place for measuring blood pressure. Haberman et al. (2006) concluded that SBP values by the Doppler method are more accurate when measured in the metatarsal artery, with the oscillometric method, and its use in the coccygeal artery is recommended.

Cuff selection is a fundamental step to ensure a minimally reliable result. (DURHAM, 2019). The ratio of limb circumference to cuff size has been the main observation described in the literature, in which the cuff size should correspond to 30% to 40% of the circumference of the measured site (ACIERNO et al., 2018). Smaller cuffs overestimate the pressure value as the opposite is also observed (STEPIEN, 2000). It is known that the placement of the cuff in joint regions prevents the total occlusion of blood flow, as well as the laxity of the cuff in the chosen limb (DURHAM, 2019). Although the guideline, published by ACIERNO et al. (2018), recommend the correct measurement of the cuff, it is known that due to the diversity of brands, the correct measurement due to the busy daily routine of the veterinary clinic, variations in values may occur. Thus, in order to prove the possible variations in relation to the cuff used, the present study aims to evaluate the influence of cuff numbering in the determination of blood pressure by comparing two non-invasive methods: ultrasonic doppler and oscillometric device.

**MATERIALS AND METHODS**

The Animal Ethics and Experimentation Committee (CEUA) approved the present work under protocol 0005/2020. Eighteen male and female dogs were used, aged between 1 and 14 years, of different breeds and sizes, submitted to elective surgical procedures at the animal surgery department of the university veterinary hospital. Before being included in the present study, the dogs underwent a complete pre-anesthetic clinical
evaluation, with laboratory tests, electrocardiography, chest radiography and blood pressure measurement. Dogs that were hypotensive (SBP < 90 mmHg), hypertensive (SBP > 180 mmHg) and/or that required emergency surgical procedures were excluded.

To measure blood pressure, a portable ultrasonic Doppler device from the brand MEDMEGA - model “DV 610” plus a sphygmomanometer was used. The high-definition oscillometric device was branded InPulse Animal Health - BpScan. New veterinary cuffs, in sizes no. 1 (2.5 cm), no. 2 (3.0 cm), no. 3 (4.0 cm), no. 4 (5.0 cm) and no. 5 (6.0 cm), were used in all appliances and dogs evaluated (Figure 1). First, the ideal size of the cuff for each animal was defined according to the guidelines of the guideline for the management of systemic hypertension in dogs and cats (ACIERNO et al., 2018). The cuff should have a width of 30% to 40% of the left anterior limb, measured with a flexible measuring tape and positioned in the medial region of the radius. Trichotomy in the metacarpal region was performed to identify the arterial pulse.

In order to rule out other external factors that could alter the value obtained, the measurements were performed with the animal anesthetized. The anesthetic protocol was defined according to the surgical procedure performed by the responsible professionals. As it is a comparative study between measurement methods and cuff size, the protocol used did not interfere with the results.

With the animal in the anesthetic plane, systolic pressures were obtained with the ultrasonic Doppler device initially and later with the oscillometric device, with the cuff always attached to the left forelimb in the medial portion of the radius. In addition, in all measurements, the animal was positioned in the supine position, keeping the left forelimb at the same level as the heart. In both devices, the first measurements of SBP values were performed with the ideal-sized cuff. Next, the cuff with a higher number than the ideal was used and later with the cuff with a lower number. Both measurements were repeated five times. Emphasizing that the SBP measurements were performed following the protocol determined in the guidelines published by ACVIM for the identification, assessment and management of systemic hypertension in dogs and cats (ACIERNO et al., 2018).

After obtaining the values in both devices, the animals were separated into three groups, according to the ideal cuff established, as shown below:
• Group 1 (G1) = dogs with ideal cuff no. 2, superior no. 3 and inferior no. 1 (n = 8);
• Group 2 (G2) = dogs with ideal cuff no. 3, superior no. 4 and inferior no. 2 (n= 5)
• Group 3 (G3) = dogs with ideal cuff no. 4, superior no. 5 and inferior no. 3 (n = 5)

In each group (G1, G2 and G3) the mean SBP values obtained by the cuffs considered ideal, upper and lower numbering, were established. Based on the mean values and standard deviation of both cuffs, they were compared using analysis of variance. The assumptions of analysis of variance, homogeneity of residuals and variances were checked using the normality test and homoscedasticity using the Kolmogorov-smirnov test and the Bartlett test. In the presence of a significant effect of ANOVA, the means were compared by the Tuckey test. To compare the values obtained by Doppler and oscillometric, the Student t-test was used, with those considered significant at 5% probability.

RESULTS

The 18 dogs used in the present study had a mean age of 6,8±4,5 years, being 12 females and 6 males, of different breeds such as Blue Heeler (n=1), Boxer (n=1), Cocker Spaniel (n=2), Daschund (n=1), Maltese (n=1), American Pitbull (n=1), Poodle (n=2), Sharpei (n=1) and mixed breed (n=8). The average body weight was 12,8±11,4 and diameter of the circumference of the left forelimb was between 7 to 16 cm.

Table 1 exemplifies and demonstrates the differences in SBP values obtained in the same dog, according to the studied group, in relation to the measured limb circumference, cuffs and measurement methods used (Doppler and oscillometric - Figure 1).
Table 1. Systolic blood pressure (SBP) values obtained in a dog of the respective studied group, according to EAC circumferences, cuff number and measurement methods.

<table>
<thead>
<tr>
<th>Dog</th>
<th>Group</th>
<th>Limb circumference</th>
<th>Cuff</th>
<th>SBP (mmHg) Doppler</th>
<th>SBP (mmHg) Oscillometric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal 1 G1</td>
<td>7 cm</td>
<td>Ideal (no. 2)</td>
<td>99,6</td>
<td>116,6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 cm</td>
<td>Superior (no. 3)</td>
<td>70</td>
<td>107,4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 cm</td>
<td>Inferior (no. 1)</td>
<td>NM*</td>
<td>NM*</td>
<td></td>
</tr>
<tr>
<td>Animal 9 G2</td>
<td>10 cm</td>
<td>Ideal (no. 3)</td>
<td>110</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 cm</td>
<td>Superior (no. 4)</td>
<td>78,4</td>
<td>80,6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 cm</td>
<td>Inferior (no. 2)</td>
<td>NM*</td>
<td>93,4</td>
<td></td>
</tr>
<tr>
<td>Animal 14 G3</td>
<td>13 cm</td>
<td>Ideal (no. 4)</td>
<td>100</td>
<td>1055,6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13 cm</td>
<td>Superior (no. 5)</td>
<td>90</td>
<td>93,8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13 cm</td>
<td>Inferior (no. 3)</td>
<td>102</td>
<td>96,2</td>
<td></td>
</tr>
</tbody>
</table>

* NM= Value not measured due to non-fixation of the cuff in relation to the circumference of the limb.

Franco, 2023
Table 3 shows the results of SBP values obtained in all evaluated dogs (n=18), not subdivided into groups, according to the proposed indirect measurement methods, in which no statistical differences were observed between the mean values measured, regardless of the cuff numbering. However, when the mean SBP values were compared according to the numbering of the cuffs used by the same method, the results differed statistically. However, the SBP values obtained in the ideal-sized cuff compared to the upper one do not differ statistically, but when compared to the lower-numbered cuff, the values were significantly overestimated.

Table 3. Mean values and standard deviation of SBP of 18 dogs evaluated by ultrasonic and high-definition oscillometric Doppler methods using ideal, superior and inferior cuffs.

<table>
<thead>
<tr>
<th>Method</th>
<th>Ideal cuff</th>
<th>Superior cuff</th>
<th>Inferior cuff</th>
<th>p-value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General (n=18)</td>
<td>Doppler</td>
<td>110,9±17,9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>94,7±14,4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>142,08±23,2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oscillometric</td>
<td>101,76±17,2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>97,5±17,4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>126,52±20,5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0,02101*</td>
</tr>
</tbody>
</table>

Averages followed by distinct lowercase letters on the line differ from each other (P ≤ 0,05). * p ≤ 0,05 indicate a significant difference between cuff sizes; * p value (t-test) ≤ 0,05 indicate statistical inequality between the indirect methods of measuring SBP.

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Regarding the data statistically analyzed according to the studied groups (G1, G2, G3) described in Table 4, there were no significant differences in the mean SBP values in relation to the measurement method used and the number of the cuff. However, in the G1 group, it was not possible to measure SBP with the smaller size cuff (no.1) due to incompatibility in the size of the circumference of the limb. In groups G2 and G3, when the values between the cuffs used were compared, the mean SBP values of the upper numbered cuff were significantly higher in relation to the values obtained in the ideal numbered cuff.
Table 4. Mean SBP values and standard deviation obtained in the groups evaluated according to the ideal cuff size, by the ultrasonic and high-definition oscillometric Doppler measurement methods.

<table>
<thead>
<tr>
<th>Group</th>
<th>Method</th>
<th>Ideal cuff</th>
<th>Superior cuff</th>
<th>Inferior cuff</th>
<th>p-value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>Doppler</td>
<td>111.2±21\text{a}</td>
<td>94.6±19.2\text{a}</td>
<td>-</td>
<td>0.121</td>
</tr>
<tr>
<td>(n=8)</td>
<td>Oscillometric</td>
<td>101.6±14.1\text{a}</td>
<td>97.2±19.7\text{a}</td>
<td>-</td>
<td>0.612</td>
</tr>
<tr>
<td></td>
<td>p-value (t-test)</td>
<td>0.386</td>
<td>0.791</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>Doppler</td>
<td>106.32±6.4\text{ab}</td>
<td>97.129.8±\text{b}</td>
<td>136.8±40.1\text{a}</td>
<td>0.040*</td>
</tr>
<tr>
<td>(n=5)</td>
<td>Oscillometric</td>
<td>109.32±29.7\text{a}</td>
<td>106.36±19.7\text{a}</td>
<td>130.6±52.6\text{a}</td>
<td>0.062*</td>
</tr>
<tr>
<td></td>
<td>p-value (t-test)</td>
<td>0.805</td>
<td>0.481</td>
<td>0.609</td>
<td></td>
</tr>
<tr>
<td>G3</td>
<td>Doppler</td>
<td>115.08±25.1\text{ab}</td>
<td>92.64±11.1\text{b}</td>
<td>145.6±31.8\text{a}</td>
<td>0.045*</td>
</tr>
<tr>
<td>(n=5)</td>
<td>Oscillometric</td>
<td>94.36±4.9\text{b}</td>
<td>89.16±5.35\text{b}</td>
<td>123.8±24.4\text{a}</td>
<td>0.006*</td>
</tr>
<tr>
<td></td>
<td>p-value (t-test)</td>
<td>0.147</td>
<td>0.465</td>
<td>0.233</td>
<td></td>
</tr>
</tbody>
</table>

Averages followed by distinct lowercase letters on the line differ from each other (P ≤ 0.05). * p (anova) ≤ 0.05 indicate a significant difference between cuff sizes; * p (t-test) ≤ 0.05 indicate statistical inequality between the indirect methods of measuring SBP; G1 – ideal cuff dogs no. 2; G2 – ideal cuff dogs no. 3; G3 – ideal cuff dogs no. 4.

Franco, 2023

DISCUSSION

The measurement of systolic blood pressure (SBP) is a very important parameter in the routine of the veterinary clinic, in the diagnosis of systemic arterial hypertension and in the clinical monitoring of patients; aiding in the diagnosis and prognosis of systemic diseases. The standardized measurement of blood pressure is of paramount importance in obtaining reliable values (ACIERNO et al., 2018). There are numerous factors that can alter the SBP values, such as the chosen measurement method (CHETBOUL et al., 2010), the positions of the patient (RONDEAUL et al., 2013), the anatomical site of measurement (HABERMAN et al., 2006; OLIVEIRA et al. 2021) and cuff size (VALTONEN & ERIKSSON, 1970). These factors considered and preserved in the present study, confirming the changes in the values in relation to the numbering of the cuff.

In addition, factors such as breed, age and sex can also contribute to changes in the SBP values obtained. As for the breed, it is known that the result can be interfered depending on the anatomical aspect of the limb, as found in dogs of the breeds Basset Hund and Daschund, because of the shorter limbs (DURHAM, 2019). With regard to
age, it was evidenced that there is an increase of 1 to 3 mmHg per year as the animals grow (ACIERNO et al., 2018). But Wagner et al., (2003) reported that regardless of age, all animals are subject to SBP changes when anesthetized. Regarding sex, most studies did not point to differences in SBP between males and females (ACIERNO et al., 2018). In the present study, when we compared the measurement methods and cuff size, the presence of age, breed and sex diversity did not interfere with the results obtained in relation to SBP values.

Comparing the SBP values obtained according to the indirect methods used, ultrasonic and oscillometric Doppler, it can be seen that there were no statistical differences between the methods. These results, which corroborated the data described by Chetboul et al. (2010) where when comparing the SBP values in healthy dogs obtained through the methods used here, they found similar and reliable values. Previously Haberman et al. (2006) compared indirect methods with invasive blood pressure measurement, obtaining more reliable values with the invasive method compared to indirect methods. In addition, they mentioned that the ultrasonic and oscillometric Doppler methods found similar results, both being considered adequate for SBP measurement. Recently, Bala et al. (2021) studied the effectiveness of high-definition oscillometric Doppler in normal dogs, revealing the good quality of measurement of the equipment associated with the importance of the parameter in the clinical routine. In the aforementioned study, 170 dogs were evaluated with an established end-organ risk categorization, with 42.35% of the dogs with mild risk of SAH, demonstrating the effectiveness and quality of the measurement method. Similar data were obtained and identified in the present study, in relation to the absence of significant differences in SBP values when comparing a high-definition oscillometric device to the Doppler method.

As previously mentioned, blood pressure values in small animals are subject to a wide variation in values, due to several influencing factors, such as the selection of the cuff and its position on the limb, patient stress, measurement environment, quality and handling of equipment. However, cuff selection is a critical step to ensure a legitimate result (VALTONEN & ERIKSSON, 1970). The results obtained in the present study confirmed that cuffs with lower than ideal numbers overestimated the SBP values, regardless of the method used. This fact reaffirms the need for standardization and execution of the technique in the measurement of SBP, especially in the choice of cuff, as mentioned by Acierno et al., (2018) and Bala et al., (2021) aiming to obtain more
reliable values and minimizing the factors that may interfere with the values at the time of measurement. Stressing the importance of cuff location, Oliveira et al. (2021) studied the measurement of SBP in anesthetized dogs using indirect methods, similar to the present study, reported the agreement of values between the devices. However, the cuff positioned proximal to the carpus showed good agreement in the measurement of SBP, its use at the base of the tail is not recommended for SBP monitoring in dogs.

Regarding the handling of the cuff Durham (2019) reported that it is essential to check the cuff, because if it is damaged, it may present an unreliable record due to rapid deflation when deflating. He also stressed that the cuff should not be placed over joints, as it prevents the occlusion of arterial flow. In addition, the cuff must be placed comfortably around the limb without being too loose to avoid an erroneous SBP reading (STEPIEN, 2000). However, the SBP measurements in the present study were performed following the norms of the guidelines determined by the ACVIM for the identification, assessment and management of systemic hypertension in dogs and cats (ACIERNO et al., 2018). The handling of the cuffs was performed correctly in relation to the measurement of the circumference of the left anterior limb used; location of the cuff in the medial region of the radius, stress was minimized due to the anesthetic procedure in all dogs of the evaluated groups. The care with measurement can also evidence the quality of the devices used, mainly emphasizing the high-precision oscillometric method, with SBP values below 10 mmHg when compared to the Doppler method, as mentioned by Wernick et al. (2010) when they studied the oscillometric method in anesthetized dogs. Posteriorly, Seliskar et al. (2012) evaluated oscillometric and Doppler ultrasonic devices to measure blood pressure in anesthetized dogs, with results evidencing the quality of the oscillometric method in measuring mean pressures (MAP) in comparison with the results obtained by the invasive method.

An important fact, cited in the current guidelines (ACIERNO et al., 2018), recommend that a correction factor of +0.8 mmHg/cm be applied if the distance between the cuff and the base of the heart is greater than 10 cm. Factor not used in the present study, due to the dogs being standardized in the left lateral decubitus position and properly anesthetized, with the measurement performed in the same cardiac plane.

Regarding the size of the chosen cuff, according to the guidelines (ACIERNO et al., 2018) the ideal cuff should have a width of 30% to 40% of the limb used. According to Valtonen & Eriksson (1970) when evaluating the effect of cuff width on the accuracy
of SBP measurement in dogs, they observed that larger cuffs had very low SBP values, being considered unreliable. In the present study, no statistical differences were found between the SBP values obtained by the cuffs considered ideal and the one with the highest number. However, the same authors (Valtonen & Eriksson, 1970) also observed that cuffs with less than ideal width lead to higher SBP values, which corroborates the results obtained in the present study, regardless of the measurement method used.

Variations in SBP values in relation to cuffs have also been documented in human patients. According to the recommendations for measuring blood pressure in humans from the American Heart Association (AHA), the use of inappropriately sized cuffs is one of the most frequent errors in SBP measurement, and may considerably overestimate the values if the cuff is too small (SMITH, 2005). In addition, in a study carried out with 530 people, the use of cuffs considered smaller than ideal led to the misdiagnosis of systemic arterial hypertension, allowing the introduction of wrong therapy (ARCURY et al., 2007). These situations can occur in veterinary medicine in dogs and cats, when we do not standardize the method of measuring blood pressure. Thus, evidencing the importance of the present study along with the care with the measurement and choice of the cuff in the measurement of SBP, using the indirect methods studied here.

**CONCLUSION**

Through the present study it was possible to conclude that the indirect methods, ultrasonic Doppler and high precision oscillometric, did not show differentiated SBP values when used in anesthetized dogs. In addition, the use of a cuff with a lower than ideal number overestimates the values, regardless of the method used to measure SBP.
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