Indirect Measurement of Systemic Blood Pressure in Conscious Dogs in a Clinical Setting

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ABSTRACT. The present study compared 2 indirect methods, Doppler sphygmomanometry and oscillometry, for measurement of the systemic blood pressure level in 100 conscious, client-owned dogs in a clinical setting on 2 separate occasions. The mean systemic blood pressure values, measured by Doppler sphygmomanometry on 2 separate occasions, were 156 ± 38.2 mmHg and 150 ± 34.1 mmHg, respectively. Using oscillometry, the mean systolic blood pressure values were 138 ± 36.9 mm Hg and 133 ± 33.5 mm Hg on 2 separate occasions. There were significant differences between the systemic blood pressure readings for both methods on the same occasion (P<0.001). The coefficients of variance from 5 consecutive measurements in the same dog obtained by Doppler sphygmomanometry on the 2 separate occasions were 4.1 ± 3.2% and 3.1 ± 1.7%; that of the oscillometric method on the 2 separate occasions were 18.7 ± 11.3% and 17.2 ± 12.5%. The coefficients of variance of these 2 methods were statistically different on each occasion (P<0.001). Five consecutive systemic blood pressure readings were obtained for each dog within 6 min on both occasions using Doppler sphygmomanometry. More than 15 min was required to complete 5 consecutive systemic blood pressure readings by oscillometric sphygmomanometry for all dogs on each occasion. The results of this study indicate that Doppler sphygmomanometry provides more efficient and precise measurements of the systemic blood pressure level than oscillometric testing in conscious dogs in a clinical setting.

KEY WORDS: conscious dog, Doppler sphygmomanometry, oscillometric method, systemic blood pressure.

FULL PAPER

Systemic blood pressure level is a reference for diagnosis, treatment and clinical research in veterinary medicine and is used extensively in veterinary patients as a part of clinical assessment. Hypertension is associated with causative underlying diseases, such as hyperadrenocorticism and chronic renal failure. Sustained hypertension causes irreversible tissue damage in the target organs, including left ventricular hypertrophy and hypertensive retinopathy. Anti-hypertensive treatment is required to prevent this damage [18]. Blood pressure measurement is also a vital factor in anesthetic management of critical patients.

The systemic blood pressure value can be determined by either a direct (invasive) or indirect (noninvasive) method [3, 4, 6, 10, 15, 17, 19]. The direct method has been considered the gold standard for clinical measurement of systemic blood pressure in veterinary medicine [3, 6, 19], but the pain it causes prevents its use in the clinical setting. Indirect methods, such as Doppler sphygmomanometry and oscillometry, have been evaluated in small animals over the last decade [2, 5, 7, 9, 11, 12, 20, 21]. The accuracy of indirect methods is still controversial [3–7, 10]. However, it is generally agreed that, in anesthetized dogs, the systemic blood pressure value correlates well with that obtained via an invasive method if it is averaged from sequential readings obtained by an oscillometric technique [3, 7, 10, 19]. Despite the fact that only a limited number of studies have addressed the precision of indirect methods, indirect blood pressure measurement has been the focus of increasing attention and is extensively used in the clinical setting. The aim of this study was to evaluate the precision and efficiency of 2 indirect methods of systemic blood pressure measurement in conscious dogs in a clinical setting.

MATERIALS AND METHODS

One hundred client-owned dogs at the National Taiwan University Veterinary Hospital were enrolled in this study. All dogs had been admitted for treatment of various medical problems and were conditionally selected; anxious or excited dogs were excluded from the study. The nature of the disorders, such as heart failure or chronic renal failure that might affect blood pressure, was considered to be irrelevant to this study. Informed consent was obtained from all owners before the study was initiated.

The breeds represented in this study are shown in Table 1. Of the 100 dogs, 31 were intact females, 21 were spayed females, 39 were intact males and 9 were castrated males. The mean age was 10.7 years (standard deviation (SD): 2.8 years, with a range of 2–16 years), and the mean body weight was 7.3 kg (SD: 6.3 kg, with a range of 2.0–39.4 kg).

The systemic blood pressure values of the dogs were evaluated by the same protocol in which the following 2 indirect methods were used:

Doppler sphygmomanometry: a Doppler Ultrasonic Flow Detector (Model 811-B, Parks Medical Electronics, Inc., Aloha, OR, U.S.A.) with an inflatable cuff width of 1.9, 2.5, 3, 4 or 5 cm (depending on the circumference of the antecubital) was used [10, 15]. The cuff was wrapped around
the middle part of the antebrachium, and a Doppler probe coated with ultrasonic transmission gel was positioned over the palmar area to detect blood flow from the arteria digitalis palmaris communis. The cuff was then inflated and deflated to obtain a systemic blood pressure reading via an aneroid pressure gauge. During systemic blood pressure measurement, the antebrachium was maintained at the level of the heart. A series of 5 readings (with 10 to 20 sec between consecutive measurements) was obtained for each dog, and all measurements were completed within 6 min. The final systemic blood pressure value was calculated as the mean of 5 readings. The heart rate was manually recorded by pulse Doppler ultrasound detection over a period of 20 sec before and after the systemic blood pressure value was measured.

Oscillometric method: an oscillometric device (Model 740–1, CAS Medical System Inc., Branford, CT, U.S.A.) was used with an inflatable cuff width of 1.9, 2.5, 3, 4 or 5 cm, depending on the circumference of the antebrachium. The cuff was wrapped around the middle part of the antebrachium and was then inflated and deflated to obtain the SBP reading. During systemic blood pressure measurement, the antebrachium was maintained at the level of the heart. The systemic blood pressure value was provided automatically by the device. A series of 5 readings (with 10 to 20 sec between consecutive measurements) was obtained for each dog. The final systemic blood pressure value was calculated as the mean of the readings. The heart rate was displayed automatically by the device while the systemic blood pressure was being measured. In this study, the heart rates were recorded and presented as the average of the first and fifth measurements.

To minimize procedural stress, all dogs were allowed to assume a comfortable position with only gentle restraint by their owners. The dogs remained in the same position throughout systemic blood pressure measurement. For each dog, the systemic blood pressure readings were obtained for both methods using the same antebrachium, and the same protocol of systemic blood pressure measurement was repeated 1 to 2 weeks later. Throughout the study, the same oscillometric device, Doppler flow detector, and aneroid pressure gauge were used, and blood pressure measurement was conducted by the same investigator (Hsiang) in all cases.

The statistical analyses were conducted using statistical software (SAS/STAT version 8.02, SAS Institute, Inc., Cary, NC, U.S.A.). Agreement between the results of the 2 methods was assessed by Bland-Altman plots. Precision estimates were examined for both methods. A comparison of the systemic blood pressure mean readings, coefficients of variance of measurements and heart rates obtained by Doppler sphygmomanometry or oscillometry on 2 separate occasions was performed with repeated measures analysis of variance. The values are represented as means ± SD. For all analyses, a P value of <0.05 was considered statistically significant.

RESULTS

Agreement between the two methods: The mean systemic blood pressure values measured by Doppler sphygmomanometry on 2 separate occasions were 156 ± 38.2 mmHg and 150 ± 34.1 mmHg (Table 2); no statistically significant differences were found between the 2 separate occasions (P = 0.09). The mean systemic blood pressure values obtained by oscillometry on 2 separate occasions were 138 ± 36.9 mmHg and 133 ± 33.5 mmHg (Table 2), and no statistically significant differences were found between the 2 separate occasions (P = 0.09). The systemic blood pressure readings measured by both methods on the same occasion were significantly different (P < 0.001). Agreement between the measurements from the 2 methods was assessed using Bland-Altman plots by plotting the mean systemic blood pressure readings of Doppler sphygmomanometry measurement on the x-axis and the differences in the systemic blood pressure values between the results of the 2 methods on the y-axis (Fig. 1 for the first occasion, and Fig. 2 for the second occasion).

The heart rates recorded with the Doppler flow detector and oscillometric device are shown in Table 3. There were no differences in heart rate (pulse) measured by Doppler flow detector or oscillometric device on the 2 separate occasions (P = 0.20 and P = 0.94, respectively). The heart rates obtained by the 2 methods on the same occasion were significantly different (P < 0.001).

Measurement precision: The coefficients of variation from 5 consecutive measurements obtained by Doppler sphygmomanometry on the 2 separate occasions were 4.1 ± 3.2% and 3.1 ± 1.7% (Table 4). The coefficients of variance from 5 consecutive measurements obtained by Doppler sphygmomanometry were statistically different between the 2 separate occasions (P = 0.006). The coefficients of variance from 5 consecutive measurements obtained by the oscillometric method on 2 separate occasions were 18.7 ± 11.3% and 17.2 ± 12.5% (Table 4); no significantly differ-

Table 1. Study Subject Breeds

<table>
<thead>
<tr>
<th>Breed</th>
<th>Number of dogs</th>
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<tbody>
<tr>
<td>Beagle</td>
<td>1</td>
</tr>
<tr>
<td>Cocker spaniel</td>
<td>2</td>
</tr>
<tr>
<td>Golden retriever</td>
<td>2</td>
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<tr>
<td>Lhasa apso</td>
<td>1</td>
</tr>
<tr>
<td>Maltese</td>
<td>20</td>
</tr>
<tr>
<td>Miniature pinscher</td>
<td>3</td>
</tr>
<tr>
<td>Miniature schnauzer</td>
<td>5</td>
</tr>
<tr>
<td>Mongrel</td>
<td>22</td>
</tr>
<tr>
<td>Papillon</td>
<td>1</td>
</tr>
<tr>
<td>Pekingese</td>
<td>1</td>
</tr>
<tr>
<td>Pomeranian</td>
<td>9</td>
</tr>
<tr>
<td>Poodle</td>
<td>10</td>
</tr>
<tr>
<td>Pug</td>
<td>1</td>
</tr>
<tr>
<td>Shetland sheepdog</td>
<td>1</td>
</tr>
<tr>
<td>Shih tzu</td>
<td>5</td>
</tr>
<tr>
<td>Yorkshire terrier</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>
ences were found between the 2 separate occasions ($P=0.32$). The coefficients of variance of the 2 methods were significantly different on the same occasion ($P<0.001$).

**Time required for systemic blood pressure measurement:**

For all dogs, 5 consecutive systemic blood pressure readings were obtained by Doppler sphygmomanometry within 6 min on both occasions. More than 15 min was required to complete the 5 consecutive systemic blood pressure readings by oscillometric sphygmomanometry for all dogs on each occasion.

**DISCUSSION**

With the increasing use of the systemic blood pressure value during diagnosis, treatment and clinical research in veterinary medicine, the use of direct or invasive methods in determining the value has become inevitable. In this study, systemic blood pressure measurements were performed via 2 indirect methods, sphygmomanometry Doppler and oscillometry, in 100 dogs in a clinical setting on 2 separate occasions. The systemic blood pressure measurements were obtained by the same investigator to minimize measurement technique inconsistencies [14, 15, 17].

The systemic blood pressure readings provided by the 2 indirect devices were statistically different ($P<0.001$). The systemic blood pressure values obtained by Doppler sphygmomanometry were statistically significantly higher than those obtained by the oscillometric device [1, 8]. A similar finding has also been reported in cats. It has been suggested that a different reference range should be established for each device [8]. In this study, agreement between the results of the 2 methods of testing was assessed using Bland-Altman plots, which indicated that the 2 methods were negatively correlated. This finding was consistent on both occasions. This suggests that the oscillometric device might underestimate increasing blood pressure levels. A similar finding has also been reported in other studies in which dogs and cats served as the subjects [1, 3]. The limited ability of the transducer to detect systolic pulses might have caused the negative correlation [1].

In this study, both Doppler sphygmomanometry and oscillometry delivered higher systemic blood pressure readings on the first occasion than on the second occasion. However, the difference was not statistically significant ($P =0.09$). The blood pressure value can be affected by the surroundings and the ‘white coat effect’. In dogs, the white
coat effect can be minimized by familiarizing the subjects with the procedure for obtaining the systemic blood pressure value [13, 16]. It is generally believed that use of an automated systemic blood pressure measurement device can also minimize the white coat effect [13]. However, artifacts related to patient motion remain the primary challenge. Systemic blood pressure readings obtained during artifact-creating events may result in inaccurate values. Oscillometric devices may detect artifact signals instead of actual blood pressure readings [13, 14, 17]. In this study, tremors and movement of the antebrachium during systemic blood pressure measurement were the most frequent events that caused artifacts. This was the reason for which the oscillometric device required more time than did Doppler sphygmomanometry to complete 5 consecutive systemic blood pressure measurements. For each dog, at least 8 attempts were required to complete 5 consecutive readings. More time or attempts might be required to complete 5 consecutive systemic blood pressure measurements in anxious or excited dogs.

The heart rates recorded by Doppler ultrasound flow detection and oscillometry were significant different (P<0.001). This significant difference suggests that the sympathetic tone might be higher in dogs with pulse Doppler ultrasound detection than with an oscillometric device. In this study, the coefficients of variation from the 5 consecutive systemic blood pressure measurements for the 2 methods were significantly different (P<0.001). This finding suggests that Doppler sphygmomanometry is more precise than oscillometry in determining the systemic blood pressure value. Similar results have been reported in other studies [5, 8]. The coefficient of variation of the systemic blood pressure measurements obtained by Doppler sphygmomanometry on the second occasion was significantly lower than that on the first occasion in this study (P=0.006). The past experience of the individuals and dogs involved in this procedure might explain the difference.

Doppler sphygmomanometry is generally labor intensive, but systemic blood pressure measurement can be performed efficiently by trained personnel. The results of our study indicate that Doppler sphygmomanometry provides more efficient and more precise measurements of the systemic blood pressure values than an oscillometric device in conscious dogs in a clinical setting.

REFERENCES


