Acta Scientiae Veterinariae, 2022. 50: 1880.

RESEARCH ARTICLE
Pub. 1880

ISSN 1679-9216

Systolic Blood Pressure in Anesthetized Bitches Measured with Photoplethysmography

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ABSTRACT

***Background*:** Photoplethysmography is widely used in human medicine, with few studies on its use in veterinary medicine. Its sensor detects fluctuations in blood volume at the site, providing direct readings of cardiac pulse and peripheral oxygen saturation, as well as estimating cardiac output, respiratory rate and blood pressure. This study aimed to evaluate the use of photoplethysmography and compare it to vascular Doppler ultrasound as an indirect method of measuring systolic blood pressure in bitches undergoing elective ovariohysterectomy, using the invasive assessment of systolic blood pressure as a reference.

***Materials, Methods and Results*:** After clinical and laboratory evaluation, 34 healthy bitches were selected to undergo elective ovariohysterectomy. After food and water fasting, patients received pethidine hydrochloride intramuscularly as pre-anesthetic medication, followed by anesthetic induction with fentanyl citrate and propofol intravenously. General anesthesia was maintained by inhalation with isoflurane diluted in 100% oxygen. Intraoperative analgesia consisted of continuous infusion of fentanyl citrate intravenously. The animals were randomly divided into 2 groups, the thoracic limb group (TLG) and the pelvic limb group (PLG). In each patient, non-invasive blood pressure measurement was obtained simultaneously with Doppler (DOP) and photoplethysmography (PPG). The sensors of both devices were placed on the end of the same limb. The PPG sensor was positioned in the interdigital region. In patients belonging to the TLG, the Doppler sensor was placed in the ventral region of the thoracic limb, under the ulnar artery. In PLG patients, the Doppler sensor was placed in the dorsal region of the pelvic limb, over the dorsal artery of the foot. The sphygmomanometer was positioned close to the sensors. For systolic blood pressure (SBP) measurement, the cuff was inflated until the Doppler sound signal and the plethysmographic wave were lost. The cuff was then deflated until the Doppler pulse sound resumed and the photoplethysmography showed at least 2 continuous waves on a regular basis. The corresponding pressure value observed on the manometer consisted of the SBP. The same 2 evaluators performed all SBP measurements: 1 responsible for the DOP method and the other for the PPG method; both were blind to the other's findings, thus minimizing potential bias in the results. All animals underwent cannulation of the auricular artery for invasive measurement of systolic blood pressure, using a multiparameter monitor. All blood pressure measurements were performed at 5-min intervals, as well as obtaining additional parameters (heart and respiratory rate, esophageal temperature, partial tissue oxygen saturation, carbon dioxide concentration) and electrocardiographic monitoring. All parameters were documented for further statistical analysis. A strong correlation ($r^2 = 0.95$) was obtained between the DOP and PPG methods regardless of the limb on which the sensors were placed. There was a low correlation between the invasive method of measuring systolic blood pressure and the other methods. There was better agreement between the DOP and PPG methods ($r^2 = -0.0061$; $P = 0.85$) when systolic blood pressure was measured in the TLG.

***Discussion*:** In the PLG, the values obtained with the DOP and PPG methods were significantly higher than those obtained with the invasive method, while the values obtained in the TLG differed slightly. It was found that the best measurement site by non-invasive methods was the thoracic limb. It was concluded that the non-invasive methods showed a low correlation with the invasive method; however, both methods had similar characteristics and photoplethysmography can be used to replace the vascular Doppler method.

Keywords: vascular Doppler, photoplethysmographic wave, plethysmography, pulse oximetry, veterinary medicine.

DOI: 10.22456/1679-9216.124686

Received: 4 May 2022 Accepted: 28 June 2022 Published: 21 July 2022

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INTRODUCTION

Arterial cannulation is the most reliable method to measure blood pressure (BP) [8,16]. However, its disadvantages include difficulty in maintaining artery viability, risk of arterial occlusion, hematoma formation, ischemia and infection [18]. The vascular Doppler and photoplethysmography are devices available for noninvasive blood pressure (NIBP) measurement [13].

The vascular Doppler method uses ultrasound waves, detecting changes in arterial blood flow. Wave frequencies are transformed into sound signals [2,6]. The sensor of the device must be placed over the artery to be occluded, distal to an inflatable cuff with a diameter of 30-40% of the circumference of the limb, and connected to a manometer to provide systolic blood pressure (SBP) readings in mmHg.

Photoplethysmography is widely used in human medicine, with few studies on its use in veterinary medicine. It is based on the use of the pulse oximeter, whose sensor has a photo emitter and an infrared light photoreceptor to detect fluctuations in blood volume [17]. This pulsatile signal is converted into an image, resulting in the plethysmographic wave. In addition to providing information on cardiac pulse and peripheral oxygen saturation [9,17], there are studies evaluating its applicability to estimate cardiac output, respiratory rate and BP [1].

The aim of this study was to determine the reliability of this method for the measurement of SBP in anesthetized bitches instead of vascular Doppler and to observe possible differences in SBP between measurements of the thoracic or pelvic limbs.

MATERIAL AND METHODS

Animals

Thirty-four healthy bitches were included, regardless of breed, with age between 6 months and 5 years and weight between 6 and 15 kg. The criteria used to select the animals were physical evaluation; absence of estrous cycle, pregnancy, or reproductive alteration; docile temperament; and values of complete blood count, white blood count, and biochemical parameters (albumin, aspartate aminotransferase, creatinine, alkaline phosphatase, total proteins, and urea) within the normal range for the species.

Anesthetic procedure

On the day of the surgical anesthetic procedure, the animals were subjected to feed and water fasting for 8 and 4 h, respectively, and they were randomly allocated to 2 groups according to the limb in which SBP was measured, namely, the thoracic limb group (TLG) and the pelvic limb group (PLG). All animals received pethidine hydrochloride[1] [Dolosal® - 4 mg/kg, IM] as anesthetic premedication to allow hair removal in the cephalic region of the right limb for venipuncture with a 22G catheter, in the dorsal side of the ears for arterial catheterization, and in the abdominal region for the surgical procedure. Moreover, hair removal in the extremities (dorsal/ ventral and interdigital regions) of the thoracic or pelvic limb was performed to place the sensors and measure SBP, as per the experimental group.

Anesthetic induction comprised the administration of fentanyl citrate[1] [Fentanest® - 2,5 mcg/kg, IV] followed by the administration of propofol[1] [Propovan® - 4 mg/kg, IV]. After anesthetic induction, sodium cephalothin[2] [Keflin® - 30 mg/kg, IV] and dipyrone[3] [Febrax® - 25 mg/kg, IV] were administered. Orotracheal intubation was preceded by the application of lidocaine[1] [Xylestesin® - 1 mg/kg] in the glottis region and the connection of the tracheal tube to the inhalation anesthesia system with the supply of isoflurane[1] [Isoforine®] diluted in 100% oxygen. Vaporization was titrated to reduce or suppress laryngeal and eyelid reflexes and maintain corneal reflex and rostroventral rotation of the eyeball, resulting in analgesia and muscle relaxation that was sufficient to perform the surgical technique (stage III and planes 1 and 2 according to Guedel). Finally, a continuous infusion of fentanyl citrate[1] [Fentanest® - 5 mcg/kg/h, IV], diluted in sodium chloride solution[4], was administered at a total rate of fluid infusion of 5 mL/kg/h. The surgical and anesthetic procedures were standardized for all patients.

After stabilization of the anesthetic plane, additional analgesia was provided with an additional dose of fentanyl citrate[1] [Fentanest® - 2 mcg/kg, IV] if an increase of 20% in the values of 2 or more parameters (heart rate, respiratory rate, and SBP) was observed. At the end of the procedure, all patients received meloxicam[5] [Maxicam® - 0.1 mg/kg, SC] and methadone[1] [Mytedom® - 0.3 mg/kg, SC] and remained under observation until complete anesthetic recovery. They were discharged at the end of the day. The medications prescribed for the postoperative period at home were meloxicam[5] [Maxicam® - 0.1 mg/kg

SID for 3 days], dipyrone [25 mg/kg TID for 5 days] and tramadol hydrochloride[6] [Cronidor® - 4 mg/kg TID for 5 days]. Suture removal was then performed 10 days after surgery.

Blood pressure measurement

The noninvasive measurement of SBP was performed by 2 methods simultaneously: vascular Doppler[7] (DOP) and photoplethysmography (PPG) through portable pulse oximetry[8] (UT100). The sensors of both devices were placed at the end of the same limb, with the PPG sensor positioned in the interdigital region and the Doppler sensor in the ventral region (thoracic limb), under the ulnar artery or dorsal region (pelvic limb), over the dorsal artery of foot.

The sphygmomanometer[9] was positioned close to the sensors. For SBP measurement, the cuff was inflated until the Doppler sound signal and plethysmographic wave were lost. The cuff was then deflated until the pulse sound reappeared and the photoplethysmography presented at least 2 continuous waves of regular shape. The corresponding pressure value on the manometer was the SBP. The same 2 evaluators performed all SBP measurements: one being responsible for the DOP method and the other for the PPG method; both were blind to each other's findings, thus minimizing potential trends in results. Moreover, the evaluator responsible for the DOP method wore headphones.

Percutaneous puncture of the auricular artery was performed with a 24G catheter, connecting it to an invasive heparinized blood pressure monitoring system through the multiparameter monitor, which provided the values of systolic, diastolic, and mean BP. Other parameters, such as heart rate (HR), respiratory rate (f), esophageal temperature (TºC), carbon dioxide concentration at the end of exhalation ($EtCO_2$), oxygen saturation in peripheral tissues (SpO_2), and electrocardiogram tracing were observed on the same monitor. The measurements started right after the stabilization of the anesthetic plane and arterial cannulation (T0), with values recorded every 5 min for 40 min (T40).

Statistical analysis

Weight and age data were subjected to Student's *t* test of independent variables. For analyzing vital parameters (HR, *f*, SpO_2, TºC, $EtCO_2$, and SBP), one-way or two-way analysis of variance (ANOVA) with repeated measures was used, followed by the Newman-Keuls post-hoc test. Pearson's correlation was performed between the groups (TLG and PLG). The correlation values (r^2) were considered very strong (r^2 = 1.00-0.90), strong (r^2 = 0.89-0.70), moderate (r^2 = 0.69-0.40), weak (r^2 = 0.39-0.20), and very weak (r^2 = 0.19-0.00). The Bland-Altman test was used to assess agreement between the 3 methods (DOP, PPG, and IBP) for measuring SBP. Values were significant when $P < 0.05$. PRISM package[10] was used to performed the analysis.

RESULTS

The animals that had their SBP evaluated noninvasively by the vascular Doppler method did not differ in the comparison between groups regarding weight and age. The weight and age were 9.89 ± 3.00 kg and 1.56 ± 1.46 years, respectively ($P = 0.87$), in the TLG, and 9.71 ± 2.97 kg and 1.53 ± 1.07 years, respectively ($P = 0.95$), in the PLG. HR, *f*, and SpO_2 did not differ (data not shown). Only TºC and $EtCO_2$ varied during the intraoperative period (Table 1), with a reduction in body temperature and $EtCO_2$ throughout the evaluations; both were maintained within the reference values for these species. The main anesthetic complications were as follows: second-degree atrioventricular block (11.7%), bradycardia (17.6%), hypotension (14.7%), and decrease in body temperature (73.5%). Atrioventricular block and bradycardia were treated with atropine (0.022 mg/kg, IV).

Table 1. Mean and standard deviation of temperature (TºC) and concentration of carbon dioxide at the end of exhalation ($EtCO_2$).

	TºC	$EtCO_2$
T0	37.12 ± 0.53^{a}	36.00 ± 8.35^{b}
T5	37.04 ± 0.54^{b}	35.64 ± 8.71^{b}
T10	36.91 ± 0.60^{c}	35.52 ± 8.92^{b}
T15	36.75 ± 0.63^{d}	38.60 ± 9.06^{ab}
T20	36.63 ± 0.65^{and}	41.76 ± 8.32^{a}
T25	36.53 ± 0.68^{and}	40.64 ± 7.76^{a}
T30	36.39 ± 0.69^{f}	39.05 ± 7.58^{ab}
T35	36.27 ± 0.73^{f}	39.00 ± 7.94^{ab}
T40	36.14 ± 0.81^{g}	37.94 ± 8.07^{ab}

Same letters correspond to equal values and different letters indicate different values, in relation to the temporal analysis of each evaluated parameter. Values were considered significant when $P < 0.05$.

The temporal analysis of SBP (absolute values) [Table 2], comparing the results with T0 for each method showed that DOP and PPG monitoring in the TLG resulted in fluctuating values of SBP over the transoperative period. The values of Invasibe Blood Pressure (IBP) in the TLG at T10 and T15 were higher than that at T0. In the PLG, both the DOP and the PPG methods did not show temporal changes in SBP. Finally, in the PLG, values obtained at all measured times with the IBP method differed from that at T0, with an increase in SBP during the operative period.

With regard to the comparison between the methods within each group (Table 2), there were no differences in SBP values between the 3 methods (DOP, PPG, and IBP) at the same evaluation time in the TLG. IBP values differed from PPG values only at T40 but without clinical significance. However, in the PLG the IBP values differed from those obtained with the DOP and PPG methods at all time points.

The comparison of SBP between the TLG and PLG when the DOP method was used (Table 2) showed differences at T0, T5, T20, T25, T30, and T40. The results for the PPG method between the groups were similar, with the exception of T20. The use of the IBP method resulted in differences only at T0 and T35, with lower SBP values in the PLG at all time points.

With regard to the correlations (r^2) between the parameters (Figure 1), the PPG method showed a very strong correlation with the DOP method (r^2 = 0.95), regardless of the group (TLG and PLG). The correlation between DOP and IBP was moderate in the TLG (r^2 = 0.41) and weak (r^2 = 0.22) in the PLG. Moreover, the correlation between PPG and IBP was weak in the TLG (r^2 = 0.38) and very weak (r^2 = 0.17) in the PLG.

Figure 2 shows the values of agreement and bias between the 3 methods (DOP, PPG, and IBP) in both TLG and PLG. Moreover, the correlation (r^2) between the difference in SBP and the means of the evaluated methods was assessed. The bias values obtained between the DOP and PPG methods in the TLG (Figure 2A) were 0.31 mmHg (r^2 = -0.0061; P = 0.85) and 2.52 mmHg (r^2 = 0, 0014; P = 0.26) in the PLG (Figure 2D). In the comparison between DOP and IBP, the bias was 13.29 mmHg (r^2 = 0.07; P = 0.00046) in the TLG (Figure 2B) and 47.16 mmHg (r^2 = 0.39; P < 0.0001) in the PLG (Figure 2E). Finally, the comparison between PPG and IBP showed bias values of -12.87 mmHg (r^2 = 0.071; P = 0.00053) in the TLG (Figure 2C) and 44.63 mmHg (r^2 = 0, 31; P < 0.0001) in the PLG (Figure 2F).

Table 2. Comparison of systolic blood pressure (absolute values) obtained by the vascular Doppler (DOP), photoplethysmographic (PPG), and invasive blood pressure (IBP) measurement methods between the experimental groups (thoracic or pelvic limb) of bitches submitted to elective ovariohysterectomy, during the intraoperative period.

	T0	T5	T10	T15	T20	T25	T30	T35	T40
					Thoracic limb (TLG)				
DOP	$100 \pm 16.9_{b}$	$113.11 \pm 25.31_{ab}$	$126.33 \pm 34.5_{a}$	$120.77 \pm 32.7_{a}$	$117.11 \pm 31.4_{ab}$	$118.38 \pm 21.5_{ab}$	$121.38 \pm 23.0_{a}$	$123.38 \pm 28.6_{a}$	$122.52 \pm 23.3_{a}$
PPG	$101.06 \pm 16.2_{b}$	$112.38 \pm 24.9_{ab}$	$126.11 \pm 32.8_{a}$	$121.55 \pm 33.2_{ab}$	$116.5 \pm 30.9_{ab}$	$118.44 \pm 23.8_{ab}$	$123.77 \pm 28.54_{a}$	$121.94 \pm 23.15_{ab}$	$121.94 \pm 23.1_{ab}$
IBP	$90.41 \pm 18.1_{b}$	$104.5 \pm 24.4_{b}$	$111.62 \pm 23.8_{a}$	$110.94 \pm 22.8_{a}$	$104.22 \pm 22.8_{b}$	$104.44 \pm 19.6_{b}$	$108.77 \pm 20.88_{b}$	$108.55 \pm 19.83_{b}$	$105.55 \pm 15.82_{b}^{\bullet}$
					Pelvic limb (PLG)				
DOP	$121.62 \pm 20.0^{*}$	$135.5 \pm 22.9^{*}$	140.75 ± 23.5	144.56 ± 29.3	$137.5 \pm 20.0^{*}$	$142.50 \pm 23.4^{*}$	$141.68 \pm 24.7^{*}$	140.87 ± 20.8	$144.12 \pm 25.3^{*}$
PPG	$122.62 \pm 20.6^{*}$	$133.75 \pm 26.1^{*}$	136.75 ± 25.5	139.87 ± 31.3	133.00 ± 19.7	$139.12 \pm 22.1^{*}$	$140.12 \pm 23.3^{*}$	137.87 ± 20.7	$143.25 \pm 26.0^{*}$
IBP	$73.76 \pm 12.00_{b}^{*\#\bullet}$	$95.06 \pm 21.7_{a}^{\#\bullet}$	$94.37 \pm 20.0_{a}^{\#\bullet}$	$98.12 \pm 20.15_{a}^{\#\bullet}$	$91.87 \pm 14._{a}^{\#\bullet}$	$94.37 \pm 17.24_{a}^{\#\bullet}$	$93.87 \pm 16.1_{a}^{\#\bullet}$	$90.06 \pm 16.6_{a}^{*\#\bullet}$	$92.12 \pm 18.9_{a}^{\#\bullet}$

Same letters represent equal results, different letters represent different results. Symbols: (*) denotes a difference for the TLG; (#) denotes a difference for the DOP method; (●) denotes a difference for the PPG group. Values were considered significant when P < 0.05.

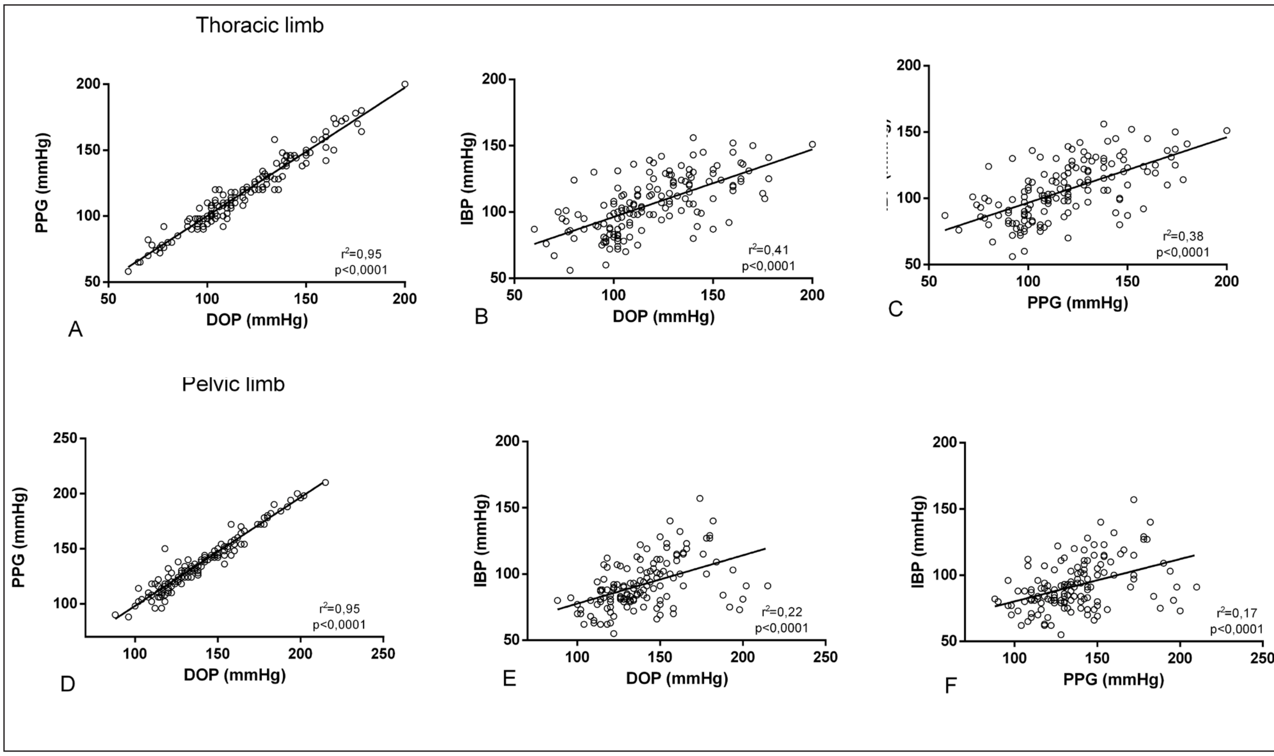

Figure 1. Correlation (r²) between the vascular Doppler (DOP), photoplethysmography (PPG), and invasive systolic blood pressure (IBP) measurement methods and between the thoracic limb (TLG) and pelvic limb (PLG) of dogs submitted to elective ovariohysterectomy. DOP *versus* PPG in the TLG (Figure 1A) and in the PLG (Figure 1D). DOP *versus* IBP in the TLG (Figure 1B) and in the PLG (Figure 1E). PPG *versus* IBP in the TLG (Figure 1C) and in the PLG (Figure 1F).

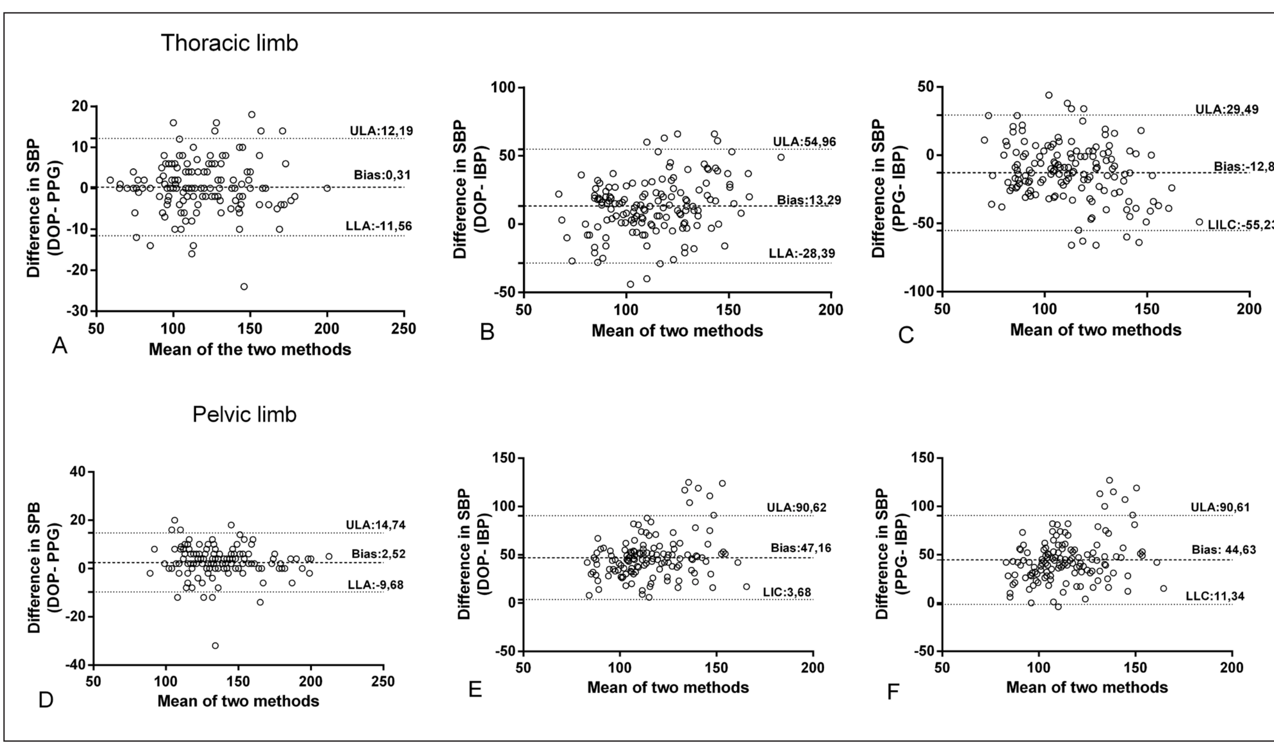

Figure 2. Bland-Altman analysis for the 3 methods (DOP, PPG, and IBP), in the different groups (thoracic and pelvic limb). [LLA: Lower limit of agreement; ULA: Upper limit of agreement].

DISCUSSION

A reduction in body temperature was the most frequent anesthetic complication in this study, which is in line with previous reports with anesthetized patients [5,15]. According to current guidelines regarding anesthesia and monitoring of small animals, a change in temperature to values below 36.7ºC is defined as hypothermia [7]. When hypothermia is severe, it can develop with arrhythmia and peripheral vasoconstriction as an attempt by the body to reduce heat loss [3,14], making it difficult to measure SBP using noninvasive methods [11] such as photoplethysmography and vascular Doppler. However, severe hypothermia was a rare event in this study and the determination of SBP values was therefore reliable by both methods.

The occurrence of arrhythmias, such as second-degree atrioventricular block (AVB), may be related to the presence of marked bradycardia [11] or the administration of full opioid agonists [11,12]. The occurrence of blocks was related to bradycardia caused by the administration of fentanyl after anesthetic induction or intraoperative rescue analgesia. A clinical relationship between bradycardia and AVB with changes in the plethysmographic wave was then observed, which proved to be flat and prolonged. However, there was no increased difference in SBP between the 2 methods (DOP and PPG) during AVB compared to the other monitoring time points.

When assessing the reliability of the use of PPG in dogs (under different levels of BP, i.e., low, normal, and high), was reports that the PPG method can be safely used to assess the trend of SBP, even under low BP values. Similarly, in this study, the presence of hypotension had no influence on the measurement and results of SBP [6]. Atropine sulfate treatment [0,022 mg/kg, IV] was instituted in patients who had multiple or isolated blocks associated with arterial hypotension, as recommended [11]. All treated cases showed a return to normal heart rhythm, correction of bradycardia and hypotension, and disappearance of AVB.

The fluctuations in SBP values over the intraoperative period observed in this study are considered normal and are attributed to events resulting from the anesthetic period, including minimal changes in the degree of anesthetic depth, intensity of surgical manipulation, and pain intensity. When an increase in SBP was detected by 1 of the noninvasive methods, it was detected by the other method. This demonstrates that both measurement methods (DOP and PPG) are adequate to assess trends in SBP behavior. Moreover, the values of SBP were higher in the PLG than in the TLG, at the same time and with the same method, which suggests a tendency to overestimate SBP in the pelvic limb, when using the same experimental design.

Furthermore, both noninvasive methods showed weak correlations and poor agreement with the IBP method, especially in the PLG, which were attributed to auricular artery cannulation to measure IBP. This choice was based on the operator’s experience in performing the technique. These findings corroborate those obtained in a study that compared 4 different arterial cannulation sites and the oscillometric method for BP measurement and demonstrated that the auricular artery had the lowest mean arterial pressure and SBP [4]. These differences are related to the smaller size of this artery compared with the other anatomical regions, which only allows puncture with low flow catheters, such as a 24G catheter.

In a pioneering study on the use of PPG in human neonates and children up to 1-year-old, there was a strong correlation ($r = 0.93$) between the DOP and PPG methods in the assessment of SBP [19]. This study corroborates these results and further demonstrates that the results are independent of the limb in which SBP is measured. It is assumed that the proximity of the 2 pressure sensors, which results in a minimal difference in perfusion between the sites, explains this fact. Moreover, note that the concomitant use of both noninvasive methods further minimizes potential disparate results, which could result from different timings of SBP measurement.

The evaluation of the photoplethysmographic wave suffers interference because of the movement of conscious patients, which produces artifacts that can become an obstacle for use in these patients [10]. In this study, interferences in the photoplethysmographic wave were observed even with the patient under general anesthesia, which were related to excessive surgical manipulation and were corrected by reducing the surgical stimulus at the time of measurement, as requested by the evaluators. This may have contributed to a stronger correlation and agreement between the DOP and PPG methods.

Although a weak correlation was observed between the noninvasive and the IBP measurement methods, there was a strong correlation and agreement between the DOP and PPG methods, with minimal or no differences in mean BP between the methods. These results reinforce the hypothesis that there is no significant difference between using Doppler or photoplethysmography in the assessment of the behavior and oscillations of SBP in anesthetized dogs, and both methods demonstrated a similar behavior of SBP, especially when it was measured in the thoracic limb. Note that this study was conducted to evaluate the reliability of using the PPG method in healthy anesthetized dogs submitted to an elective procedure. Further studies are required to establish the use of PPG in replacement of DOP in conscious or sedated patients of other species.

CONCLUSION

It was concluded that the noninvasive methods of assessing SBP showed a weak correlation with the invasive method. However, the behavior of the 2 noninvasive methods was similar and the photoplethysmographic method can thus be used in replacement of the vascular Doppler method to measure SBP in healthy dogs submitted to general anesthesia, preferably in the thoracic limb.

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***Funding*.** This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

***Ethical approval*.** This research was approved by the Ethics Committee for Animal Use of Federal University of Santa Maria (CEUA/UFSM) under protocol number 6006260819.

***Declaration of interest*.** The authors contributed equally to the manuscript. There are no conflicts of interest to declare.

REFERENCES

1 **Bartels K. & Thiele R.H. 2015.** Progrès de la photopléthysmographie: au-delà de la saturation artérielle en oxygène. *Canadian Journal of Anesthesia*. 62: 1313-1328. https://doi.org/10.1007/s12630-015-0458-0.

2 **Binns S.H., Sisson D.D., Buoscio D.A. & Schaeffer D.J. 1995.** Doppler Ultrasonographic, Oscillometric Sphygmomanometric, and Photoplethysmographic Techniques for Noninvasive Blood Pressure Measurement in Anesthetized Cats. *Journal of Veterinary Internal Medicine*. 9: 405-414. https://doi.org/10.1111/j.1939-1676.1995.tb03301.x.

3 **Brodeur, A., Annie W. & Yonaira C. 2017.** Hypothermia and Targeted Temperature Management in Cats and Dogs. *Journal of Veterinary Emergency and Critical Care.* 27(2): 151-163. https://doi.org/10.1111/vec.12572

4 **Cunha A.F., Ramos S.J., Domingues M., Shelby A., Beaufrère H., Stout R. & Acierno M.J. 2017.** Validation of noninvasive blood pressure equipment: which peripheral artery is best for comparison studies in dogs? *Veterinary Anaesthesia and Analgesia*. 44: 1068-1075. https://doi.org/10.1016/j.vaa.2017.07.002.

5 **Doyle C.R., Aarnes T.K., Ballash G.A., Wendt-Hornickle E.L., Baldo C.F., Johnson R.A., Wittum T.E. & McLoughlin M.A. 2020.** Anesthetic risk during subsequent anesthetic events in brachycephalic dogs that have undergone corrective airway surgery: 45 cases (2007-2019). *Journal of the American Veterinary Medical Association*. 257: 744-749. https://doi.org/10.2460/javma.257.7.744.

6 **Dyson D.H. 2007.** Indirect measurement of blood pressure using a pulse oximeter in isoflurane anesthetized dogs. *Journal of Veterinary Emergency and Critical Care*. 17: 135-142. https://doi.org/10.1111/j.1476-4431.2007.00226.x.

7 **Grubb T., Sager J., Gaynor J.S., Montgomery E., Parker J.A., Shafford H. & Tearney C. 2020.** AAHA Anesthesia and Monitoring Guidelines for Dogs and Cats. *Journal of the American Animal Hospital Association*. 56: 59-82. https://doi.org/10.5326/JAAHA-MS-7055.

8 **Jacobs-Fohrman Z.R., Barnes T.S., McEwen M.M. & Goodwin W.A. 2020.** Clinical evaluation of arterial blood pressure in anesthetized dogs by use of a veterinary-specific multiparameter monitor. *American Journal of Veterinary Research*. 81: 636-641. https://doi.org/10.2460/ajvr.81.8.635.

9 **Karlen W., Kobayashi K., Ansermino J.M. & Dumont G.A. 2012.** Photoplethysmogram signal quality estimation using repeated Gaussian filters and cross-correlation. *Physiological Measurement*. 33: 1617-1629. https://doi.org/10.1088/0967-3334/33/10/1617.

10 **Krishnan R., Natarajan B. & Warren S. 2010.** Two-stage approach for detection and reduction of motion artifacts in photoplethysmographic data. *IEEE Transactions on Biomedical Engineering*. 57: 1867-1876. https://doi.org/10.1109/TBME.2009.2039568

11 **Miller C. & Flaherty D. 2017.** Anaesthetic-associated cardiac arrhythmias in dogs and cats: part 1. *Companion Animal*. 22: 504-509. https://doi.org/10.12968/coan.2017.22.9.504

12 **Posner L.P., Mariani C.L., Swanson C., Asakawa M., Campbell N. & King A.S. 2014.** Perianesthetic morbidity and mortality in dogs undergoing cervical and thoracolumbar spinal surgery. *Veterinary Anaesthesia and Analgesia*. 41: 137-144. https://doi.org/10.1111/vaa.12127.

13 **Rabello T.A., Monteiro E.R., Campagnol D., Champion T., Bressan T.F. & Coelho K. 2015.** Mensuração da Pressão Arterial por Palpação Digital do Pulso Periférico em Cães Anestesiados. *Ars Veterinaria*. 31: 57. https://doi.org/10.15361/2175-0106.2015v31n1p57-62.

14 **Redondo J.I., Suesta P., Serra I., Soler C., Soler G., Gil L. & Gómez-Villamandos R.J. 2012.** Retrospective study of the prevalence of postanaesthetic hypothermia in dogs. *Veterinary Record*. 171: 374. https://doi.org/10.1136/vr.100476.

15 **Rodriguez-Diaz J.M., Hayes G.M., Boesch J., Martin-Flores M., Sumner J.P., Hayashi K., Eureka M.B. & Todhunter R.J. 2020.** Decreased incidence of perioperative inadvertent hypothermia and faster anesthesia recovery with increased environmental temperature: A nonrandomized controlled study. *Veterinary Surgery*. 49: 256-264. https://doi.org/10.1111/vsu.13328.

16 **Shih A., Robertson S., Vigani A., Cunha A., Pablo L. & Bandt C. 2010.** Evaluation of an indirect oscillometric blood pressure monitor in normotensive and hypotensive anesthetized dogs. *Journal of Veterinary Emergency and Critical Care*. 20: 313-318. https://doi.org/10.1111/j.1476-4431.2010.00536.x.

17 **Slapnicar G., Mlakar N. & Luštrek M. 2019.** Blood pressure estimation from photoplethysmogram using a spectro-temporal deep neural network. *Sensors (Basel)*.19(15): 3420. https://doi.org/10.3390/s19153420.

18 **Trim C.M., Hofmeister E.H., Quandt J.E. & Shepard M.K. 2017.** A survey of the use of arterial catheters in anesthetized dogs and cats: 267 cases. *Journal of Veterinary Emergency and Critical Care*. 27: 89-95. https://doi.org/10.1111/vec.12543.

19 **Wallace C.T., Baker J.D., Alpert C.C., Tankersley S.J., Conroy J.M. & Kerns R.E. 1987.** Comparison of blood pressure measurement by Doppler and by pulse oximetry techniques. *Anesthesia & Analgesia*. 66: 1018-1019. https://doi.org/10.1213/00000539-198710000-00019.