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Evaluation of Electrocardiographic Parameters, Thoracic Morphometry and Vertebral Heart Size in Clinically Normal Dogs

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ABSTRACT

***Background*:** The Vertebral Heart Size (VHS) method sets standards for the evaluation of dog's heart size from the comparison of the cardiac dimension with the length of the thoracic vertebrae through radiographic study. Electrocardiogram (ECG) is widely used in veterinary medicine for the evaluation of electrical conduction system of the heart; however, the increase of duration and amplitude of the ECG waves can suggest the increase of cardiac chambers in dogs. The scientific literature presents electrocardiographic and VHS values for dogs of different breeds and sizes; however, there is little information on the correlation of these parameters. Therefore, the aim of this study was to evaluate the amplitude and duration of ECG waves, thoracic morphometry and VHS values, in order to correlate these parameters in clinically normal dogs.
***Materials, Methods & Results*:** Twenty healthy dogs (11 females and 9 males), without breed distinction, medium sized (14.46 ± 2.92 kg) and aged between 1 and 8 years, were evaluated through physical examination, digital ECG (frontal and precordial leads) and thorax X-ray in right lateral (RL), left lateral (LL) and ventrodorsal (VD) projections. Thoracic morphometry and VHS measurements were determined as previously described. Clinical and ECG parameters were compatible with the references in all dogs evaluated. Dogs presented thorax intermediate (75%) with the depth and width ratio (D/W ratio) > 1.0. Some individual VHS values were higher than the references and the mean VHS values in VD projection was higher than in RL and LL projections (n = 20; $P < 0.05$). Female and male dogs did not differ among the evaluated parameters. A positive correlation was observed between thoracic morphometry and body weight ($r \geq +0.70$; $P < 0.001$) and a negative correlation was found between the D/W ratio and VD VHS ($r = -0.62$; $P < 0.05$). No significant correlations were observed between the age, ECG parameters, thoracic morphometry and VHS measurements.
***Discussion*:** The majority of dogs presented intermediate thorax, a common characteristic for healthy dogs of different breeds. Some dogs had higher VHS values in different projections, when compared to references. The same has been reported by others authors for diferent breeds. However, there is no consensus about VHS values for all sexes, breeds and physical conformations in dogs. In agreement with other authors, the mean value of VD VHS was higher in relation to RL and LL VHS; however, RL and LL VHS did not differ. Positive and significative correlations were observed between body weight and thorax depth, and between body weight and thorax width, confirming that larger dogs had greater thoracic measurements. The thorax type could influence the VHS, when this parameter is determined by VD projection, because was observed a negative and significative correlation between the D/W ratio and VD VHS. So, the dogs with a deeper thorax may have lower VHS values. The correlation between VHS measurements and duration and amplitude of the ECG waves was weak, possibly because the dogs evaluated had no clinical and radiographic signs of cardiomegaly. The results of this work indicated that dogs of medium size, without signs of cardiovascular or pulmonary disease, may have higher values for VHS; besides that, thoracic morphometry may alter VHS measurement obtained from the VD projection. In addition, ECG parameters were not influenced by thoracic morphometry and had no correlation with VHS measurements.

Keywords: small animals, ECG, types of thorax, VHS.

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INTRODUCTION

The Vertebral Heart Size (VHS) method determines the cardiac dimensions relatives to length of thoracic vertebrae, using right lateral (RL), left lateral (LL) and ventrodorsal (VD) radiographic projections [6]. It's a quantitative method that establishes a good correlation between heart size and body length in dogs [5].

The ECG is a graphical record of electrical activity generated by the heart during the phases of cardiac cycle [21]. The ECG tracing is obtained by the standardized positioning of the electrodes on the dog's limbs (frontal leads) and thorax (precordial leads) [23].

In dogs, the enlargement of the cardiac chambers may produce an increase in amplitude (in millivolts) and/or duration (in seconds) of the ECG waves, in addition to the reference values for this species. In this sense, the wider and broader P-wave and QRS complex are suggestive of atrial and ventricular enlargement, respectively [3,23].

A positive correlation between VHS measurements and the duration of the P wave and QRS complex have been demonstrated in dogs with ventricular pacing-induced cardiomegaly [19]. So, the VHS method could help in the interpretation of the ECG of dogs with different thoracic conformations. The scientific literature presents the ECG [12,18,24] and VHS [7,8] values in dog of different breeds and sizes; however, there is little information about the correlation of these parameters in healthy dogs.

Therefore, the aim of this study was to evaluate the amplitude and duration of ECG waves, thoracic morphometry (depth and width) and cardiac dimensions using VHS, in order to correlate these parameters in clinically normal dogs.

MATERIALS AND METHODS

Animals

Twenty healthy dogs (11 females and 9 males) without breed distinction, of medium size, without accumulation of body fat and age between 1 and 8 years, were evaluated. These criteria were established because the cardiac diseases, such as valvular degeneration and cardiomyopathies, are frequently reported at extremes, that is, in small and large dogs [9], older than 8 years [17].

The dogs were evaluated through the general physical examination and ECG. Those considered clinically normal were submitted to radiographic examination of the thorax.

Electrocardiographic and X-ray examination

Computerized ECG were recorded in all dogs with a speed of 25mm/s, and calibration set at 10mm/mV (EDAN SE digital)[1]. The following leads were recorded: LI, LII, LIII, aVR, aVL, aVF, V1, V2, V3 and V10, from the electrodes placement on the body surface [23].

ECG interpretation included the determination of mean electrical axis; rhythm; heart rate; P-wave and QRS duration; P-wave and QRS amplitude, PR and QT intervals duration, using Smart ECG ViewerV2.42® software[1].

The radiographs were performed using the Altus ST SAWAE® digital X-ray (630 Ma, 125 kV)[2]. Dogs were positioned in: 1) right and left lateral recumbencies, with neck extended, thoracic limbs pulled cranially and parallel to each other to record of the RL and LL projections and 2) dorsal recumbency, with each thoracic limb taped separately and pulled cranially to record of the VD projection [14].

Depth and width of the dogs' thorax were determined according to literature recommendations [5]. In the RL projection, thorax depth (D) was measured considering the distance between the cranial border of the xiphoid process and the ventral border of the vertebral column, with a line drawn perpendicular to the vertebral column (Figure 1A). In the VD projection, thorax width (W) was determined from the distance between the medial edges of the octave ribs, along with the more lateral curvatures (Figure 1B). The thorax depth and width were made using an adjustable caliper, which was placed on a metric ruler to obtain the values in millimeters, with the aid of SE Media Viewer® software[3]. The ratio between depth and width (D/W ratio) was used to determine the type of thorax: < 0.75 = broad; between 0.75 and 1.0 = intermediate and > 1.0 = deep [7].

VHS was determined in RL, LL and VD projections, according to previously describe [4, 6]. In lateral projections, the long axis of the heart (S1) was obtained from the ventral border of the main bronchus to the most distant ventral contour of the cardiac apex (Figure 2). The short axis of the heart (S2) was determined by drawing a perpendicular line to the long axis (S1), at the height of the middle third of the heart (Figure 2).

In the VD projection, the measurements were obtained by drawing a line from the base's most extreme point to the limit of the cardiac apex, to determine the long axis of the heart (S1) and then another line, perpendicular to the long axis, between the points of greater cardiac diameter, to determine the short axis of the heart (S2) [Figure 3].

S1 and S2 measurements were made using an adjustable caliper which were repositioned along the vertebral column, starting at the cranial border of the fourth thoracic vertebra (T4, Figures 2 & 3), to obtain the number of vertebrae, with 0.1 vertebra approximation. S1 and S2 were then added to the calculation of VHS in all projections [4,6,8].

In dogs, the normal values of VHS for heart size are between 8.5 and 10.5 vertebrae in the lateral projection, and between 9.4 and 11.0 vertebrae in the VD projection [5,10].

Statistical analysis

Age, weight, amplitude and duration of the ECG waves, depth and width of thorax, and VHS values were submitted to descriptive statistical analysis, to calculate the mean value and the standard deviation. The mean VHS values in the three projections were submitted to ANOVA and compared by Bonferroni test. The comparisons between two groups (female and male) were made by unpaired t test ($P < 0.05$). Correlations between age, body weight, ECG measurements, thoracic morphometry and VHS were evaluated by the Pearson coefficient. All statistical analyzes were performed using PRISM package[4].

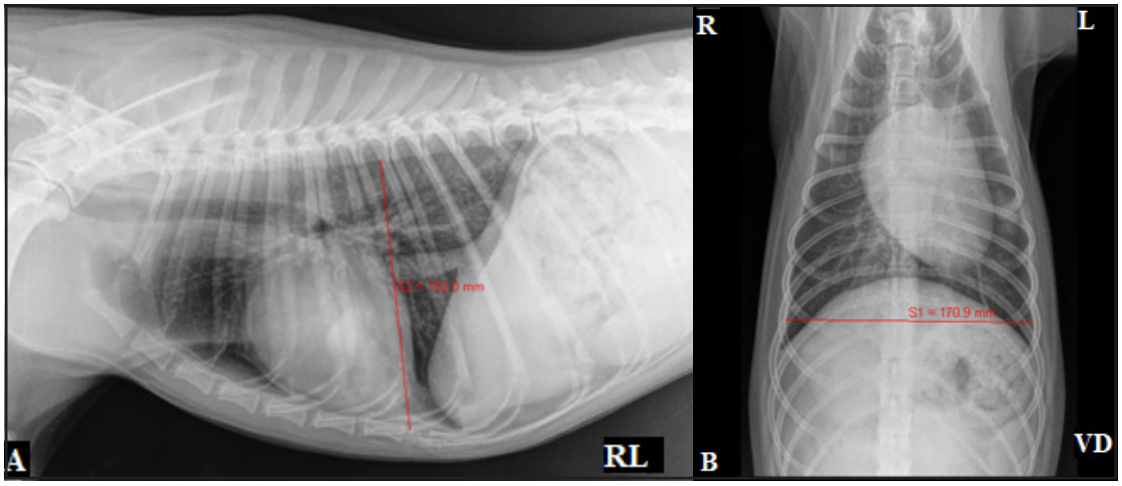

Figure 1. A- Thorax depth in dogs (= 152 mm), determined from the xiphoid process and perpendicular to vertebral column, in the right lateral projection (RL). B- Thorax width in dogs (= 170.9 mm), from the distance between the octave ribs, in ventrodorsal projection (VD). R: right. L: left. Source: Elaborated by the authors, according to Buchanan and Bücheler [5].

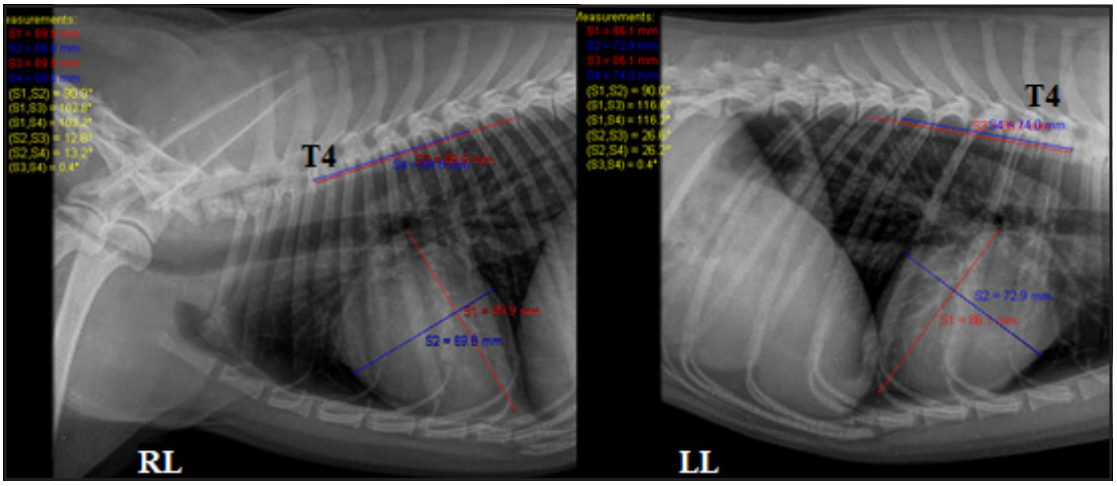

Figure 2. Vertebral Heart Size (VHS) measurement, using X-ray lateral projections. S1: long axis of the heart. S2: short axis of the heart. T4: fourth thoracic vertebra. RL: right lateral. LL: left lateral. Source: Elaborated by the authors, according to Buchanan and Bücheler [5].

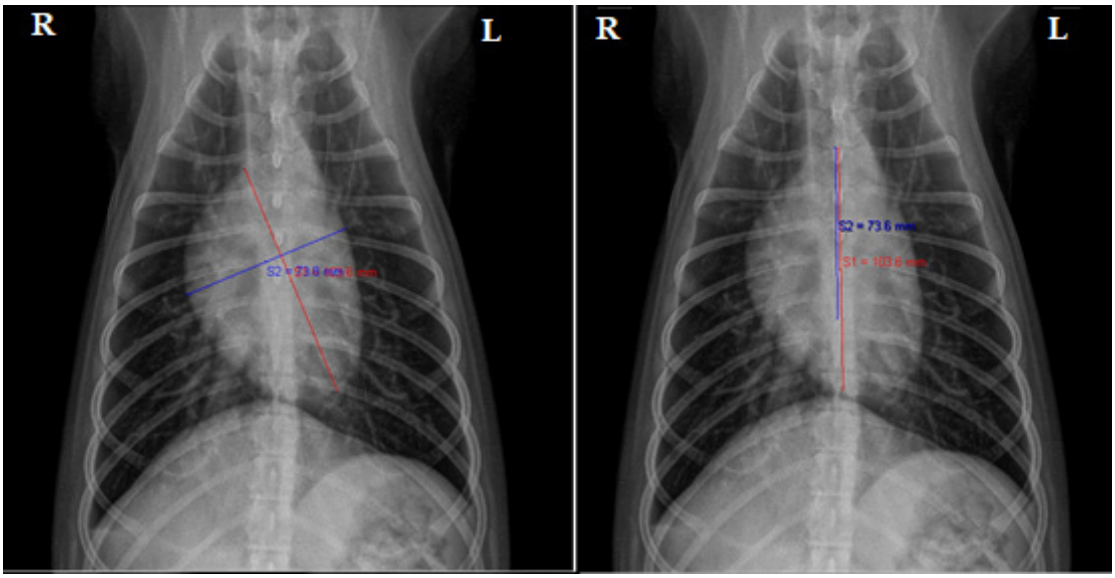

Figure 3. Vertebral Heart Size (VHS) measurement, using X-ray ventrodorsal projection. S1: long axis of the heart. S2: short axis of the heart. R: right. L: left. Source: Elaborated by the authors, according to Buchanan and Bücheler [5].

RESULTS

All dogs presented normal parameters in the clinical evaluation, without clinical and radiological signs of cardiovascular or pulmonary disease. The mean values of age (4.29 ± 2.36 years versus 4.22 ± 1.86 years) and body weight (14.40 ± 3.31 kg versus 14.53 ± 2.58 kg) did not differ between the groups of female (n = 11) and male (n = 9) dogs ($P > 0.05$). The experimental group was formed by the following dog breeds: Border Collie (1), Australian Cattle Dog (2), English Cocker Spaniel (2) and mixed breed (15).

ECG parameters were considered normal in all dogs evaluated. The mean ECG parameters values are shown in Table 1 and no differences were found between the groups of female and male dogs ($P > 0.05$).

Regarding thoracic morphometry, the individual thorax depth and width and D/W ratio values are shown in Table 2. Most of the evaluated dogs (75%) had the intermediate thorax. No differences were observed between the thoracic measurements of female and male groups.

The individual and mean values of VHS in RL, LL and VD projections are shown in Table 3. Higher values were found on RL VHS (30%), LL VHS (30%) and VD VHS (35%), when compared to normal values. Mean VD VHS value was higher in comparison to RL VHS and LL VHS values ($P < 0.02$). RL VHS and LL VHS values did not differ from each other ($P = 0.783$). The mean VHS values in the 3 projections did not differ between female and male groups.

Moderate and positive correlations were observed between body weight and thorax depth (r = +0.70; $P < 0.001$), and between body weight and thorax width (r = +0.74; $P < 0.001$). Besides that, a moderate and negative correlation (r = -0.62; $P < 0.05$) was found between the D/W ratio and VD VHS ($P < 0.05$). No significant correlations were found between the age, parameters of ECG, thoracic morphometry and VHS measurements.

Table 1. Mean values of electrocardiographic parameters (n= 20 dogs).

Parameter	Results
HR (bpm)	115.25 ± 19.85
Mean electrical axis (degrees)	+70 ± 14.68
LII P (s)	0.038 ± 0.002
LII P (mV)	0.18 ± 0.046
LII PR interval (s)	0.10 ± 0.012
LII QRS (s)	0.05 ± 0.006
LII QRS (mV)	1.78 ± 0.48
LII QT interval (s)	0.18 ± 0.02
V1 R(mV)	1.51 ± 0.50
V1 S(mV)	0.62 ± 0.33
V2 R (mV)	1.97 ± 0.18
V2 S (mV)	0.25 ± 0.18
V3 R (mV)	1.65 ± 0.51
V3 S (mV)	0.12 ± 0.17

±: standard deviation; HR: heart rate; bpm: beats per minute; LII: lead II; s: seconds; mV: millivolts; V1, V2, V3: precordial leads.

Table 2. Individual values of thoracic measurements and classification of thorax type.

Dog	Thorax Depth (mm)	Thorax Width (mm)	D/W	Thorax Type
Female 1	143.6	188.1	0.76	Intermediate
Female 2	156.7	185.2	0.85	Intermediate
Female 3	131.2	148.4	0.88	Intermediate
Female 4	146.5	171.6	0.85	Intermediate
Female 5	137.1	155.0	0.88	Intermediate
Female 6	129.5	143.9	0.90	Intermediate
Female 7	154.8	179.9	0.86	Intermediate
Female 8	124.3	168.2	0.74	Wide
Female 9	137.6	168.2	0.82	Intermediate
Female 10	126.8	151.3	0.84	Intermediate
Male 11	139.6	134.0	1.04	Deep
Male 12	146.5	171.7	0.85	Intermediate
Male 13	166.3	170.3	0.99	Intermediate
Male 14	112.8	159.2	0.71	Wide
Male 15	132.2	164.0	0.81	Intermediate
Male 16	127.1	161.4	0.79	Intermediate
Male 17	151.9	145.2	1.05	Deep
Male 18	129.3	175.6	0.74	Wide
Male 19	136.4	149.2	0.91	Intermediate
Male 20	157.4	173.7	0.91	Intermediate

D/W: thorax depth and width ratio.

Table 3. Individual values of Vertebral Heart Size (VHS) in the three projections. Measured in vertebrae.

Dog	VHS (RL projection)	VHS (LL projection)	VHS (VD projection)
Female 1	10.1	10.4	10.5
Female 2	**11.0**	10.1	**12.0**
Female 3	10.2	10.4	10.1
Female 4	10.2	**11.2**	10.7
Female 5	**10.9**	10.5	10.8
Female 6	10.3	10.5	10.4
Female 7	9.6	9.7	11.0
Female 8	9.5	9.4	10.6
Female 9	9.9	9.7	10.6
Female 10	**10.8**	**10.8**	**11.5**
Male 11	10.5	**10.6**	9.7
Male 12	**10.9**	10.0	**11.6**
Male 13	10.3	10.0	10.0
Male 14	10.5	**10.8**	**11.8**
Male 15	**11.2**	**10.7**	**11.4**
Male 16	10.2	10.4	**11.1**
Male 17	10.4	10.5	10.2
Male 18	10.0	9.9	**11.1**
Male 19	10.3	10.3	10.6
Male 20	**10.8**	**10.9**	10.4
Mean ± SD	10.38 ± 0.46	10.34 ± 0.46	10.81 ± 0.62*

In bold, VHS values higher than the references: 8.5 to 10.5 vertebrae (lateral projection) and 9.4 to 11.0 (ventrodorsal projection) [4,9]; RL: right lateral-lateral; LL: left lateral-lateral; VD: ventrodorsal; SD: standard deviation. *$P < 0.02$ versus RL VHS and LL VHS.

DISCUSSION

The ECG parameters were compatible with the references [23,25]. In relation to thoracic morphometry, most of dogs presented thorax intermediate, a common characteristic for healthy dogs of different breeds [7,20].

Some dogs (females and males) presented higher values for RL VHS, LL VHS and VD VHS in comparison to references (Table 3) [5,10]. The same was reported in Spitz, Labrador Retriever and mixed breed [4], Poodles [20] and Australian Cattle Dog [16]. However, there is no consensus on VHS values for all dog sexes, breeds and physical conformations.

Mean values of VD VHS were higher in comparison to RL VHS and LL VHS. The RL VHS and LL VHS did not differ from each other. Similar results were obtained in a study that evaluated 100 dogs (males and females, of all sizes, between 2 and 75 kg) and did not observed differences between RL VHS and LL VHS, but a higher value was found for VD VHS [6]. In the VD projection, the heart acquires a more globalized shape [22], a fact that can influence VHS measurement.

In a study where the VHS measurements of small, medium and large dogs were jointly evaluated, the authors observed that RL VHS was higher than LL VHS; however, this difference was not maintained when the dogs were divided in groups according to size [11]. On the other hand, recent studies evaluated the VHS between dogs of the same breed, i.e, Spitz, Labrador retriever [4], Dachshund [2] and Australian Cattle Dog [16]. These authors reported that RL VHS was higher than LL VHS in these breeds. In the present study, the means values of RL VHS and LL VHS did not differ in dog of different breeds, but of the similar size.

The mean VHS values in the three projections did not differ between females and males. According to this result, some studies did not shown differences between sexes for VHS values in several dog breeds [1,4,13,15]. However, in a study with Dachshund the VHS values were higher in females than in males [2].

Positive and significative correlations were observed between body weight and thorax depth, and between body weight and thorax width, confirming that larger dogs had greater thoracic measurements. Moreover, a negative and significative correlation was found between the D/W ratio and VD VHS, suggesting that dogs with a deeper than wider thorax (with higher D/W ratio values) presented lower VHS values. Therefore, the thorax type could influence the VHS when this parameter is determined by VD projection.

Female and male dogs did not differ in relation to age and body weight and the most had intermediate thorax. Possibly, due to these similarities, the means values of ECG parameters and VHS measurements were not different between sexes.

In the present study, the correlation between VHS measurements and duration and amplitude of the ECG waves was weak, possibly because the dogs evaluated had no clinical and radiographic signs of cardiomegaly. Already in large dogs with induced cardiomegaly, a progressive increase in VHS was observed, which also resulted in increased P-wave and QRS duration [19]. Since most of the dogs presented the intermediate type thorax, that is, neither very deep nor very wide, the thoracic morphometry also did not influence ECG recording.

CONCLUSIONS

The results of this work indicated that in medium size dogs, without signs of cardiovascular or pulmonary disease: 1) may have higher values for VHS; 2) VD VHS may be greater than RL VHS and LL VHS; 3) thoracic morphometry did not influence ECG waveform recording, but may alter VHS measurement obtained from the VD projection and 4) ECG parameters were not influenced by thoracic morphometry and had no correlation with VHS measurements.

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Ethical approval. This experiment was approved by the Ethics Committee for Animal Use of Faculty of Animal Science and Food Engineering of the University of São Paulo (protocol number: 4.226.070.416).

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Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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