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Comparative Assessment of the Vertebral Left Atrial Size in Healthy Adult Dogs

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Abstract Vertebral left atrial size can be used as a radiographic tool to evaluate left atrial size in dogs. Vertebral left atrial size has been studied in dogs; however, few studies have been conducted on breed-specific differences in healthy dogs. To study the median vertebral left atrial size differences by breed and to investigate the association between age, sex, body condition score, thoracic depth-to-width ratio, and vertebral left atrial size. A total of 220 dogs of the following breeds: Maltese (n = 73), Beagle (n = 30), Poodle (n = 41), Shih-tzu (n = 44), and Mongrel (n = 32) were reviewed retrospectively. Sex, body weight, age, and body condition score of each dog were collected. Thoracic radiography was conducted for dorsoventral and right/left lateral views in all dogs to measure the vertebral heart score, vertebral left atrial size, and thoracic depth-to-width ratio. No significant differences in the median vertebral left atrial size were found among the breeds. There were no effects of sex, age, body condition score, and thoracic depth-to-width ratio on vertebral left atrial size. There was a significant positive correlation between the vertebral heart score and vertebral left atrial size. Breed, age, sex, and chest conformation did not correlate with vertebral left atrial size.

Key words body condition score, dog, radiography, vertebral left atrial size.

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Introduction

Thoracic radiography is a valuable tool for cardiovascular examination (11). Radiographic evaluation of the thorax for the diagnosis of cardiac disease is based on the heart size, heart shape, condition of the pulmonary arteries and veins, and evidence of congestive heart failure. Moreover, radiography is used to measure the heart size, especially when echocardiography is not available. An increase in the left atrial size represents an increase in left atrial pressure, which is associated with the chronicity and severity of cardiac diseases (7). Therefore, the measurement of the left atrial size is an important indicator for determining the diagnosis, progression, and treatment of cardiac disease (7).

Since its introduction in 1995, the vertebral heart score (VHS) has been established as an objective method to evaluate the heart size (4,6). This method measures cardiac width and height and is corrected to the overall body size through comparison with vertebral body length, starting with T4 (4). Differences in the VHS in canine breeds have already been studied (5).

Recently, vertebral left atrial size (VLAS) has been identified as a novel radiographic tool for measuring left atrial size (12).

In one study evaluating the VLAS in healthy dogs, the reference interval for VLAS was 1.4-2.2 (14). These results were similar to those reported by Malcolm et al. (12), who described a newly reported radiographic index for evaluating left atrium (LA) enlargement. However, these studies had several limitations: they had small sample sizes, did not separate their samples by breed, and failed to consider the body condition scores (BCS), which can affect the VLAS value in dogs. Since VHS was affected by BCS in Lhasa Apso breed, VLAS also needs study on the effects of BCS by breeds (6).

The BCS system is a useful method to indirectly estimate dog and cat obesity levels by palpation and visual observation of fat under the skin (5). The most used BCS system is the 9-point-scale (8,9). A BCS score of 4 or 5 represents the ideal weight in dogs, while a score of 1-3 indicates an underweight stature, and 6-9 indicates obesity (9). The association between the heart size represented by the VHS and BCS was evaluated in a previous study by Jepsen-Grant et al. (6). Except for the Lhasa Apso breed, there were no significant differences in the VHS between dogs with a high and low BCS (6). However, the association between the BCS and the VLAS has not been studied in different breeds.

Therefore, the objectives of this study were as follows: 1) to evaluate the effects of sex, age, and thoracic depth-to-width ratio on the VLAS; 2) to assess the correlation between the BCS and VLAS in different breeds; and 3) to evaluate the extent to which the median VLAS differs from the total median value by breed. It was hypothesized that the VLAS would not be affected by age, sex, BCS, or chest conformation, with no differences across breeds. If true, along with other studies, this study can support that VLAS can be used as a useful diagnostic tool not affected by age, sex BCS and chest conformation to some breeds.

Materials and Methods

Animals

Medical records at the Veterinary Medical Teaching Hospital of Chungnam National University, documented from September 2016 to February 2021, were reviewed retrospectively. This study involved 220 dogs of the following breeds: Maltese, Beagle, Poodle, Shih-tzu, and Mongrel. Each owner signed an approval form indicating that they agreed to the possibility of clinical data from their pet's examination being used for veterinary medical research. The inclusion criteria for this study were: age >1 year (i.e., skeletally mature), no auscultation finding of gallop sound or heart murmur, and radiographic diagnosis of normal heart shape and size. Exclusion criteria were subjective radiographic evidence of heart disease, congenital heart disease, cardiomyopathy, cardiac tumor, and thoracic deformities (i.e., hemivertebrae). Subjects were also excluded if thoracic radiographic abnormalities of interstitial or alveolar lung pattern, or of pleural or pericardial effusion, were confirmed. In addition, dogs with systemic diseases, such as hypovolemia and anemia, or those who were taking medications that may affect the heart size, such as diuretics, were excluded. To collect information on sex, body weight, age, and the BCS, medical records at the time of thoracic radiographic evaluation of each dog were used.

Thoracic radiography

Thoracic radiography was conducted to obtain dorsoventral views and right and left lateral views of all the dogs in this study. Thoracic depth-to-width ratios, VHS, and VLAS values were measured. Both the VLAS and VHS were measured using a digital caliper in the right lateral inspiratory thoracic radiographic view. A digital radiographic system was used to acquire radiographs of the thorax (MDXP-40TG, Medien International Co., Gyeonggi-do, Republic of Korea). A digital radiographic viewing software was used to analyze and measure the radiographic images. (ZeTTA PACS Viewer, TY Soft, Gyeonggi-do, Republic of Korea).

The VLAS was measured as previously described by Malcolm et al. (12). A line was drawn using a digital caliper from the ventral center of the mainstem bronchus carina to the

point where the left atrial margin met with the dorsal section of the caudal vena cava. Starting at T4, a line of equal length was drawn to the vertebrae, and the number of vertebrae corresponding to that line was estimated to the nearest 0.1 vertebrae (14). The investigator was blinded to the information on the samples.

The VHS was measured as previously described by Buchanan et al. (4). A single veterinarian measured VHS values. To determine the long axis, we drew a line from the carina of the mainstem bronchus to the apex. To determine the short axis, we drew a perpendicular line that widened the heart. Radiographic fat opacity was not observed. Then, starting with T4, the number of vertebrae corresponding to the long and short axes was expressed in 0.1 vertebrae (4).

The thoracic depth-to-width ratio was measured to determine the dog's thoracic form (6). Depth was measured on the radiographic right lateral view. Starting from the xiphoid process, a line was drawn to the vertebrae. The width was assessed on the radiographic dorsoventral view. This was the length between the pair of 8th ribs. Dogs with a thoracic depth-to-width ratio <0.75 were considered barrel-chested dogs, and dogs with a ratio >1.25 were considered deep-chested dogs (6).

Body condition score (BCS)

In this study, a 9-point BCS scale was used. BCS was measured by each veterinarian at the time of thoracic radiography. It was based on illustrations and descriptions from the World Small Animal Veterinary Association (WSAVA). The BCS is classified into 3 categories. Dogs with a BCS of 1-3 had visible ribs that were palpable without difficulty and little or no fat. Additionally, the abdominal trunk was easily identified when viewed from above. Dogs with a BCS of 4 or 5 had ribs with proper abdominal trunk and fat cover. Dogs with a BCS of 6-9 had ribs that were not easily palpable and excessive fat (5,9).

Statistical analysis

In this study, non-parametric tests were conducted because the data did not satisfy the assumption of normality, and the specific analysis methods are as follows. First, frequency, ratio, median, interquartile range, etc. were calculated to identify sex, age, weight, BCS, and VLAS distributions according to breed. Second, Kruskal-Wallis test was performed to determine the median VLAS difference depending on the BCS population for each breed. Third, Mann-Whitney U test was conducted to determine the median VLAS difference by sex for each breed. Fourth, Spearman's rank correlation coefficient was evaluated to determine the correlations between age, VLAS, and VHS. Fifth, frequency, ratio, median, interquartile range, etc. were calculated to determine the distribution of the thoracic depth-to-width ratio. Sixth, Spearman's rank correlation coefficient was also calculated to determine the association between the thoracic depth-to-width ratio and VLAS. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using a commercial computer-based software program (SPSS 23.0; IBM SPSS statistics, Armonk, NY, U.S.A) and Reference Value Adviser V2.1.

Results

The clinical data for age, sex, body weight, BCS, and VLAS distribution are summarized in Table 1. The sample population of 220 dogs was classified according to the following breeds: Maltese (n = 73), Beagle (n = 30), Poodle (n = 41), Shih-tzu (n = 44), and Mongrel (n = 32). The median and standard deviation values for the VLAS of each breed were calculated (Table 1). No significant differences in the median VLAS were found across breeds.

The median VLAS difference between the BCS groups ac-

Table 1. Characteristic data, median and interquartile range of VLAS, and comparisons of mean VLAS between total population and each breed group

Breed	Sex F/M (n)	Age (yr) (Median) (IQR)	Weight (kg) (Median) (IQR)	BCS 1-3/4-5/6-9 (n)	VLAS (Median) (IQR)
Maltese	40/33	8.00 (5.00-11.00)	3.30 (2.48-4.05)	18/31/24	1.90* (1.70-2.00)
Beagle	12/18	6.50 (2.00-10.00)	12.80 (9.15-13.66)	8/5/17	1.80* (1.60-2.00)
Poodle	26/15	7.00 (3.00-10.50)	4.50 (3.65-5.25)	8/21/12	1.80* (1.55-2.00)
Shih-tzu	23/21	11.00 (7.00-13.00)	6.00 (4.45-7.26)	6/20/18	1.80* (1.60-1.98)
Mongrel	15/17	8.00 (5.00-10.00)	6.17 (4.56-10.36)	7/17/8	1.75* (1.60-2.00)
Total	104/116	8.00 (5.00-11.00)	4.60 (3.44-7.20)	49/94/79	1.80* (1.60-2.00)

*No statistically significant differences compared to total median VLAS ($p > 0.05$).
F, females; M, males; N, number of dogs; BCS, body condition score; VLAS, vertebral left atrial size; IQR, interquartile range.

Table 2. Descriptive data of correlation between median VLAS and BCS group according to breeds

Breed	BCS 1-3		BCS 4-5		BCS 6-9		p-value
	n	Median (IQR)	n	Median (IQR)	n	Median (IQR)	
Maltese	18	1.85 (1.60-2.00)	31	2.00 (1.70-2.00)	24	1.95 (1.73-2.00)	.387
Beagle	8	1.85 (1.53-1.98)	5	1.70 (1.60-1.75)	17	1.90 (1.65-2.00)	.161
Poodle	8	1.85 (1.73-1.98)	21	1.80 (1.55-2.00)	12	1.80 (1.43-2.00)	.954
Shih-tzu	6	1.60 (1.25-1.88)	20	1.90 (1.70-2.00)	18	1.75 (1.50-1.90)	.061
Mongrel	7	1.60 (1.50-2.00)	17	1.70 (1.55-1.95)	8	1.80 (1.73-2.00)	.265
Total	47	1.80 (1.60-2.00)	94	1.85 (1.70-2.00)	79	1.90 (1.70-2.00)	.333

No significant difference in mean VLAS by BCS group for each breed ($p > 0.05$).
N, number of dogs with BCS group according to breed; IQR, interquartile range.

Table 3. Comparison between median VLAS and sex within each breed group

Breed	Male		Female		p-value
	n	Median (IQR)	n	Median (IQR)	
Maltese	33	1.90 (1.70-2.00)	40	2.00 (1.70-2.00)	.300
Beagle	18	1.75 (1.60-2.00)	12	1.90 (1.65-2.00)	.441
Poodle	15	1.80 (1.50-2.00)	26	1.85 (1.58-2.00)	.639
Shih-tzu	21	1.70 (1.50-1.95)	23	1.80 (1.60-2.00)	.314
Mongrel	17	1.70 (1.65-2.00)	15	1.80 (1.60-2.00)	.894
Total	104	1.80 (1.60-2.00)	116	1.90 (1.63-2.00)	.147

No significant difference in median VLAS by BCS group for each breed ($p > 0.05$).
N, number.

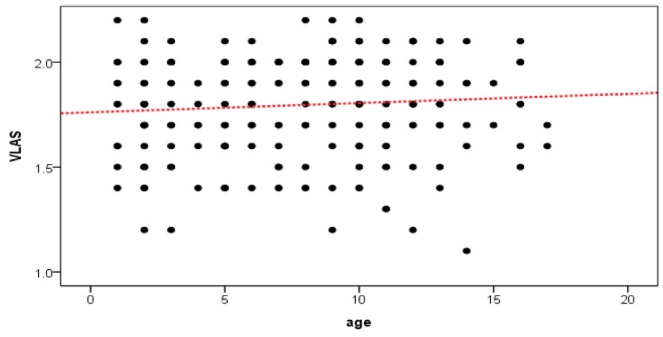

Fig. 1. Graph illustration of no significant correlation between age and VLAS in all dogs (Spearman's rank correlation coefficient = 0.085; $p > 0.05$).

cording to breed is shown in Table 2. The median VLAS was not significantly different across the BCS groups. Within each breed, the dogs were then classified by sex. The median VLAS for each dog breed and sex are presented in Table 3. The median VLAS was not significantly different between the sexes.

The relationship between age and VLAS was investigated in all dogs (Fig. 1). Since the Spearman's correlation coefficient between age and VLAS is 0.085 ($p > 0.05$), there was no significant correlation between age and VLAS.

The relationship between the thoracic depth-to-width ratio distribution and VLAS according to breed is shown in Table 4. The differences were not statistically significant for each breed. The percentage of barrel chest conformation (ratio <0.75) for each breed was as follows: Shih-tzu (45.5%), Maltese (49.3%), Mongrel (21.9%), Poodle (17.1%), and Beagle (3.3%). Deep-chested dogs (ratio <1.25) were not found in this study. There was a significant positive correlation between VLAS and VHS in all dogs (Spearman's correlation coefficient = 0.273, $p < 0.001$) (Fig. 2).

Discussion

In this study, we compared breed-specific differences in the median VLAS of healthy adult dogs. We also evaluated the effect of sex, age, BCS, and thoracic depth-to-width ratio on the VLAS, as our findings would help to apply this tool as an index of left atrial enlargement in thoracic radiography. To date, several studies have evaluated the VLAS in healthy dogs (10,12,14).

Radiography is a valuable diagnostic tool for the screening and monitoring of cardiac enlargement (1). As the VHS has

Table 4. Description of thoracic depth-to-width ratio and number of dogs for each breed satisfying to have barrel chest (ratio <0.75)

Breed	n	Median (IQR)	Ratio <0.75		Correlation between VLAS	
			n	%	r†	p-value
Maltese	73	0.75 (0.70-0.82)	36	49.3%	.004	.971
Beagle	30	0.82 (0.79-0.90)	1	3.3%	−.074	.698
Poodle	41	0.83 (0.77-0.88)	7	17.1%	−.102	.527
Shih-tzu	44	0.76 (0.70-0.83)	20	45.5%	.055	.721
Mongrel	32	0.85 (0.76-0.91)	7	21.9%	.003	.987
Total	220	0.79 (0.72-0.86)	71	32.3%	−.042	.531

†Spearman's rank correlation coefficient.
N, number of dogs in each breed group; SD, standard deviation.

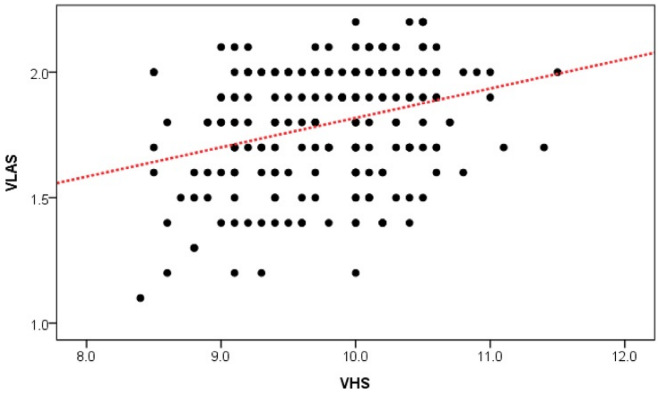

Fig. 2. Graph illustration of positive correlation between VHS and VLAS in all dogs (Spearman's rank correlation coefficient = 0.273; p < 0.001).

been used previously to measure overall heart size, a recent study by Malcolm et al. (12) proposed that VLAS be used to measure left atrial size in dogs as well. Related studies suggested that the VLAS may be useful as an indicator of left atrial enlargement along with VHS (10,12,14).

However, VHS has several limitations. A previous study identified that VHS varies between breeds (6). The study evaluated the distribution of VHS in dogs of eight breeds and found that in four groups, Pug, Pomeranian, Bulldog, and Boston Terrier, the VHS value was much larger than the reference value. Therefore, it is difficult to apply the reference value uniformly because of the large variation across breeds (6).

In addition, in the aforementioned study, the relationship between the BCS and VHS was evaluated to assess the likelihood that the presence of pericardial fat would affect VHS measurements (6). No correlation was identified for the other breeds, but a positive correlation was identified in the Lhasa Apso breed group (6). Because the VHS measures the short and long axes for the entire heat margin, VHS can overestimate the heart size (6). Therefore, VLAS, which measures the size of the left atrium, may not have a significant interobserver error (14).

In addition, the effects of the cardiac cycles were also considered. The VLAS may be more useful than VHS in terms of not being affected by the cardiac cycle (2). According to a study using fluoroscopy by Brown et al. (3), significant differences in VHS were found between systole and diastole, but no significant differences in the VLAS were found.

A recent study by Vezzosi et al. (14) reported a median VLAS of 1.9 (reference interval: 1.4-2.2) in healthy dogs. They also reported that body weight, sex, and age were not correlated with the VLAS. Therefore, to expand on these results, our study investigated whether the median VLAS differed by breed in healthy dogs. In addition, we evaluated the effect of the BCS and thoracic depth-to-width ratio on the VLAS.

In a recent study of VHS and VLAS in healthy Chihuahua breed, VLAS was not influenced by sex and BCS as in this study (13). Also, there was a recent study of VHS and VLAS in healthy Maltese dogs (2). The median and interquartile range (IQR) for VLAS was 2 (IQR, 1.8-2.1).

This study also examined the correlation of VLAS with age and sex. Consistent with the findings of Vezzosi et al. (14), we found that the VLAS was not affected by age or sex.

Jepsen-Grant et al. (6) reported a correlation between the VHS and BCS. BCS did not correlate with VHS in that study except for the Lhasa Apso breed group. In this study, the dogs were divided into three groups according to their BCS (BCS 1-3, BCS 4 or 5, BCS 6-9). The VLAS was not affected by the BCS.

Additionally, we evaluated the association between VLAS and thoracic depth-to-width ratio to determine whether chest conformation affected VLAS in each breed. No significant association was found between VLAS and the thoracic depth-to-width ratio in this study. Therefore, VLAS was not affected by chest conformation.

A limitation of this study is that not all samples were able to

rule out heart disease through echocardiography. Some samples were ruled out for heart disease through history taking, clinical signs, cardiac auscultation and thoracic radiography.

In conclusion, this study indicates that when using VLAS in several small-breed dogs, we do not need to consider VLAS by breed. In addition, age, sex, BCS, and chest conformation did not correlate with the VLAS. Therefore, VLAS can be used alongside VHS to measure heart size.

Conflicts of Interest

The authors have no conflicting interests.

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