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Research Article

Examination of the Vertebral Heart Scale and Anatomical Structure of Different Dog Breeds by Computed Tomography

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Abstract

This study aims to reveal the statistical difference by measuring the vertebral heart scale and anatomical structures of the heart in different dog breeds. The vertebral heart scale (VHS) has recently been described as a method for measuring the heart silhouettes of dogs and cats. Vertebral heart scale (VHS) may vary in dog and cat breeds due to age, weight, etc. Twenty-one dogs (10 males and 11 females) of different ages and weights were used. Among the dog breeds used are the French Bulldog, Russian Poodle, Rottweiler, Jack Russell, Golden Retriever, King Charles, Pekingese, Belgian Shepherd, Husky, Chihuahua, Cocker, Terrier, Bulldog, Bouvier and Flanders breeds. Multislice detectors were scanned at 80 kV, 200 MA, 639 mGY, and 0.625 mm slice thickness. The resulting images were saved in Digital Imaging and Communications in Medicine (DICOM) format. The obtained sections were measured in 3D-Slicer software. Thoracic height (TH) and cranial vena cava (CVC) measurement parameters were statistically significant with weight ($P<0.05$). Vertebral heart scale (VHS) was not statistically significant with any parameter in the correlation analysis ($P>0.05$). At the correlation table of animal weight with the measurements, it was seen that it had a very significant positive correlation with other measurement parameters except vertebral heart score (VHS) ($P<0.01$). Vertebral heart scale was determined as 9.09±1.37 vertebrae in females and 9.50±0.52 vertebrae in males. The study aims to contribute to veterinary anatomy, surgery and internal medicine.

Keywords: Computed tomography, Dog, Vertebral heart scale

Introduction

Dogs are beings that have been in constant interaction with humans since the past. Today, dogs live in our homes like a member of the family. Apart from taking part in our lives as companions, dogs are also involved in many areas such as search and rescue work [1].

Computed tomography (CT) is the processing of cross-sectional images with high levels of ionizing radiation using X-rays and computers [2]. Computed tomography provides three-dimensional information about the structure, shape, position, and relationships of internal organs [3]. Axial, sagittal, and coronal sections obtained from CT and MR allow better evaluation of these structures. Moreover, the application of the morphometric method to these radiological images brings a new perspective to this analysis [4-6]. Since it is viewed from a single position in 2D (2D) imaging methods, it causes technical errors such as superposition and minimization. This increases the value of 3D (3D) works [7-9]. With the effect of developing technology in recent years, there are many studies in the field of anatomy with radiological, 3D modeling and different modeling techniques [10-13].

Early diagnosis of heart diseases in dogs is important for increasing the quality of life of the patient and prolonging its life. In the diagnosis of heart diseases, besides computed tomography, electrocardiography and echocardiography, biomarkers have been used recently [14,15]. Thoracic radiographs play an important role in the diagnosis of heart disease and also include prognostic information.

In particular, it contributes greatly to the subjective assessment of cardiomegaly. The wide variation in thoracic conformation among dog breeds leads to significant differences in the appearance of the heart silhouette [16,17]. Vertebral heart scale (VHS) has been described as a method to measure heart silhouettes of dogs and cats [18]. The development of the method started with the positive correlation between heart weight and body length in cats. The measurements have proven to aid in the diagnosis of heart disease in dogs [19]. It has been suggested that the vertebral heart scale may be a useful aid in cardiac assessment for inexperienced observers who may be prone to false positive interpretations in dogs, particularly when examining radiographs of puppies, brachycephalic breeds, or obese dogs [20]. The normal VHS values between 9.7 vertebrae(v), 8.7v and 10.7v in dogs are generally considered physiological [21]. Although the VHS value is high in some breeds, these values are normal for the breeds and each breed should be evaluated on its scale [19].

This study aims to reveal the statistical difference for the vertebral heart scale in dogs of different breeds and to determine whether there is a significant difference between the reference intervals of the breeds. It is also to examine the anatomical structures in the heart of dog breeds using computerized tomography images.

Material and Methods

Ethical Statement

The required ethics committee report for the study was obtained from Animal Experiments Local Ethics Committee of Istanbul University-Cerrahpaşa (Approval No: İÜC-HADYEK/29.11.2023-848033) and the Istanbul University-Cerrahpaşa, Faculty of Veterinary Medicine Ethics Committee (Report Number: 2022/38). An "Informed Consent Form" was obtained from the animal owners before to conducting tomography scans

Animals

Twenty-one dogs, which were 11 females and 10 males, were used in the study. The age ranges are between 1 and 16 years old. The weight range is between 4 and 43 kg. The dog breeds used were French Bulldog, Russian Fino, Rottweiler, Jack Russell, Golden Retriever, King Charles, Pekingese, Belgian Shepherd, Husky, Chihuahua, Cocker, Terrier, Bulldog, Bouvier, and Flanders breeds. All of the images were obtained from the archive images of Istanbul University-Cerrahpaşa Veterinary Faculty Animal Hospital. Samples were obtained from mature animals. Dogs with any evidence of pathological lesions, deformation, or other damage were excluded from this study.

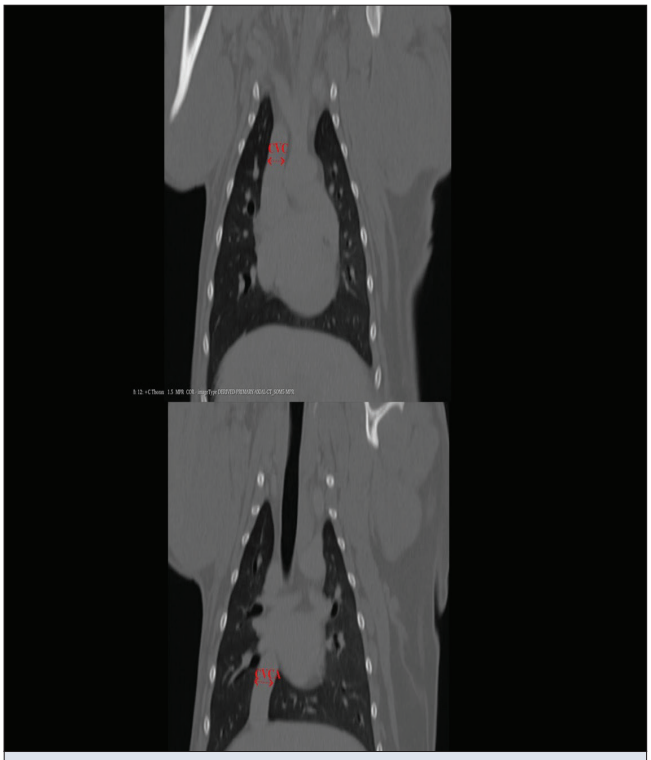

Fig 1. Measurement points of anatomical structures on the heart (CVC and CVCA)

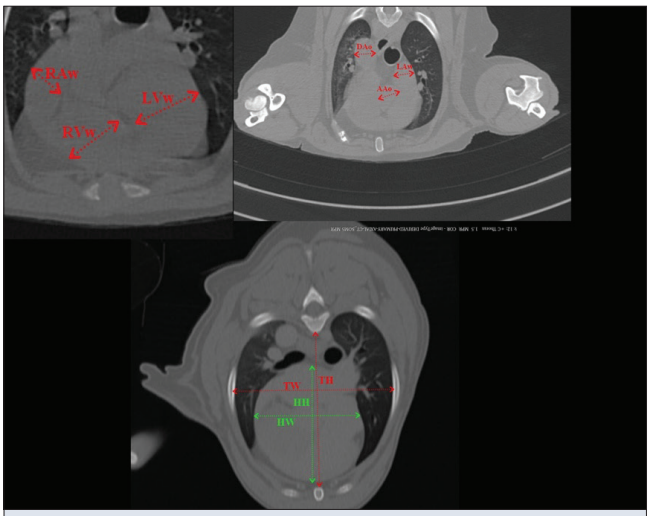

Fig 2. Measurement points of anatomical structures on the heart (TH,TW,HH,HW, Ao,AAo,and DAo)

Computed Tomography Images

Computed tomography images were scanned with 64-detector multislice 80 kV, 200 MA, 639 mGY, 0.625 mm slice thickness. The resulting images were saved in DICOM format. The obtained images were measured in 3D-Slicer software. The measurement points, specified in *Table 1*, were used from the sources specified [22-24]. Measurement points taken on the heart are shown in *Fig. 1*, *Fig. 2* and *Fig. 3*.

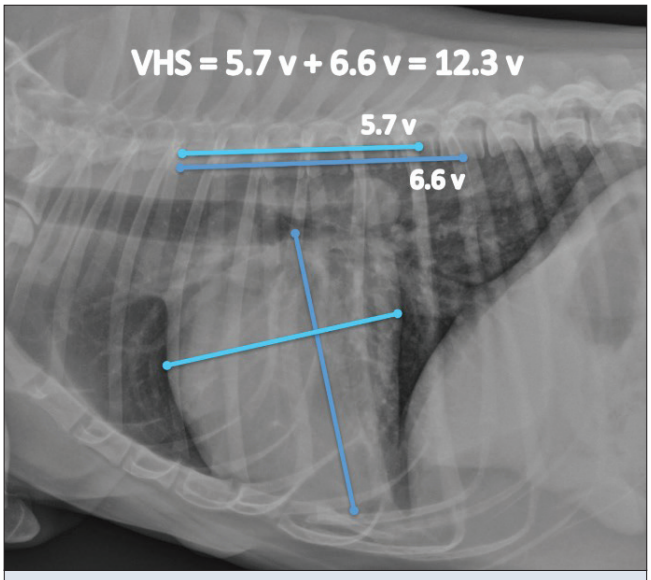

Fig 3. Vertebral heart scale measurement points

Statistical Analysis

Statistical analyses were performed in the SPSS 22.0 software program. Descriptive statistics of measurement values were used as mean, standard deviation and one-way ANOVA depending on more than one variable. The Mann-Whitney U test was used for gender comparisons according to measurements. Spearman correlation coefficient was calculated to determine the relationship between the measurements provided that they are different.

Results

The anatomical structures of the heart and VHS were measured using axial, sagittal and coronal images of the dogs participating in the study. The statistical comparison of the measurements made in our study with the measurements of age, gender and weight on the anatomical structures of the heart is given in *Table 1*. It

Table 1. *Descriptive statistics of measurements of anatomical structures of the heart in dogs by sex, age, and weight*

Parameters	Gender	N	Mean	Std. Deviation	P Value for Age	P Value for Weight	P Value for Gender
TH	Male	10	96.33	16.00	NS	*	NS
	Female	11	93.79	18.78			
TW	Male	10	102.57	25.67	NS	NS	NS
	Female	11	104.77	25.02			
HH	Male	10	63.72	11.63	NS	NS	NS
	Female	11	61.11	9.72			
HW	Male	10	71.87	16.21	NS	NS	NS
	Female	11	59.76	21.56			
Ao	Male	10	17.29	6.10	NS	NS	NS
	Female	11	15.33	5.77			
AAo	Male	10	18.91	6.35	NS	NS	NS
	Female	11	15.72	5.82			
DAo	Male	10	14.96	4.41	NS	NS	NS
	Female	11	13.72	3.84			
LVw	Male	10	32.35	8.23	NS	NS	NS
	Female	11	29.80	10.62			
LAw	Male	10	20.17	6.29	NS	NS	NS
	Female	11	17.41	5.91			
CVC	Male	10	13.36	3.38	NS	*	NS
	Female	11	11.05	3.28			
CVCA	Male	10	13.41	3.27	NS	NS	NS
	Female	11	10.90	3.50			
RVw	Male	10	22.49	6.05	NS	NS	NS
	Female	11	19.97	6.31			
RAw	Male	10	13.95	4.87	NS	NS	NS
	Female	11	13.24	4.75			
VHS	Male	10	9.50	0.52	NS	NS	NS
	Female	11	9.09	1.37			

TH: *Thoracic high,* ***TW:*** *Thoracic width,* ***HH:*** *Hearth high,* ***HW****: Hearth width,* ***Ao:*** *Aorta,* ***AAo:*** *Ascendens aorta,* ***DAo:*** *Descendens aorta,* ***LVw:*** *Left ventricular width,* ***LAw:*** *Left atrium width,* ***CVC:*** *Cranial vena cava,* ***CVCA:*** *Caudal vena cava,* ***RVw:*** *Right ventricular width,* ***RAw:*** *Right atrium width,* ***VHS:*** *Vertebral high scale*

Table 2. *Correlation between measurements of anatomical structures of the heart in dogs by age and weight (Green: P<0.01; Yellow: P<0.05; Red: P>0.05)*

Items	Age	Weight	TH	TW	HH	HW	Ao	AAo	DAO	LV	LA	CVC	CVCA	RV	RA	VHS
Age	1															
Weight	0.279	1														
TH	0.28	.721(**)	1													
TW	.462(*)	.738(**)	.649(**)	1												
HH	0.261	.675(**)	.686(**)	.858(**)	1											
HW	.455(*)	.820(**)	.568(**)	.697(**)	.687(**)	1										
Ao	0.389	.819(**)	.751(**)	.770(**)	.732(**)	.804(**)	1									
AAo	0.229	.879(**)	.769(**)	.700(**)	.649(**)	.799(**)	.901(**)	1								
DAO	0.218	.870(**)	.609(**)	.656(**)	.617(**)	.813(**)	.822(**)	.873(**)	1							
LV	0.368	.755(**)	.466(*)	.665(**)	.551(**)	.795(**)	.869(**)	.781(**)	.839(**)	1						
LA	0.255	.825(**)	.571(**)	.688(**)	.562(**)	.739(**)	.922(**)	.886(**)	.862(**)	.939(**)	1					
CVC	0.300	.900(**)	.488(*)	.648(**)	.631(**)	.899(**)	.791(**)	.817(**)	.881(**)	.862(**)	.849(**)	1				
CVCA	0.315	.825(**)	0.401	.605(**)	.587(**)	.875(**)	.791(**)	.778(**)	.883(**)	.871(**)	.834(**)	.958(**)	1			
RV	0.367	.854(**)	.517(*)	.714(**)	.599(**)	.813(**)	.796(**)	.731(**)	.843(**)	.878(**)	.843(**)	.875(**)	.845(**)	1		
RA	0.344	.804(**)	0.23	.658(**)	.473(*)	.770(**)	.668(**)	.674(**)	.806(**)	.856(**)	.799(**)	.887(**)	.860(**)	.895(**)	1	
VHS	-0.418	-0.25	-0.328	-0.183	-0.068	-0.206	-0.408	-0.289	-0.296	-0.285	-0.32	-0.189	-0.225	-0,143	-0,131	1

was determined that age and gender were not statistically significant in the measurements (P>0.05). Anatomical structures of the heart were found to be statistically significant with the weight of dogs only with thoracic height (TH) and cranial vena cava (CVC) (P<0.05). Vertebral heart scale (VHS) males are larger than females. Only thoracic width (TW) females were found to be larger than males in the measurements obtained. The correlation of measurements of age, weight and anatomical structures is given in *Table 2*. There is a significant correlation between age, thoracic width and heart width (P<0.05). It was found to be statistically insignificant with other parameters (P>0.05). Vertebral heart scale was found to be statistically insignificant with any measurement parameter (P>0.05).

Discussion

In this study, fifteen different breeds of dogs of different weights, whose CT taken in our hospital, were evaluated to determine the values of VHS and heart anatomical structures.

Vertebral heart scale has become an important marker in the diagnosis of heart diseases in cats and dogs. In clinical practice, breed-related differences in VHS value have been observed between dog breeds and accordingly weight differences. This study was conducted to determine whether the weight, age, sex and breed factor differed on the results by compiling the tomography images of the dogs brought to our hospital with different complaints.

Cardiomegaly, which is the most common heart disease, is formed in dogs with valvular diseases, dilated cardiomyopathy, congestive heart failure and congenital heart diseases [25]. The type of heart disease will affect the accuracy of a diagnosis based on measurements of the vertebral heart scale. Heart diseases can impose different loads on the heart depending on their pathophysiology and the heart's response varies according to the load [26]. Volume-loading diseases such as mitral regurgitation cause eccentric hypertrophy or enlargement of the heart chambers with a corresponding increase in the external dimensions of the heart. Diseases that exert pressure loads, such as aortic stenosis, tend to cause concentric hypertrophy, i.e. thickening of the myocardium occupying the ventricular lumen without any significant change in external dimensions. The observed inter-racial differences in the diagnostic accuracy of the vertebral heart scale are at least partly due to pathophysiological differences between the conditions to which the breeds are predisposed [19]. As Lamb et al.[19] noted, vertebral heart scale values greater than 10.4v for the Yorkshire terrier and 11.1v for the Cavalier King Charles Spaniel should provide about 80 percent accuracy in diagnosing heart disease. With these data obtained from breed-based research, the veterinarian's diagnosis of heart diseases is accelerated.

Considering that dogs being male or female may show differences in VHS measurements, the gender was also included in our study as a statistical criteria and differences were determined according to gender. The same researchers also indicated that female dogs have a lower VHS value than male dogs. According to Buchanan and Bücheler [20], there was no difference in the VHS value in dogs between males and females. The fact that the thoracic width determined in our study is greater in females and the VHS value is higher in male dogs supports the effect of gender on sizing.

Sagoglu [26] calculated the VHS value as 11v and above in dogs with mitral valve disease, dilated cardiomyopathy, congestive heart failure, congenital heart disease and developed cardiomegaly. Buchanan and Bücheler [20] reported in their study that healthy dogs have a VHS value of 10.5 and below.

The margin of error that may arise in heart score measurements using X-ray images is important during diagnosis. It is seen that many different results have been obtained in the researches. Regarding the direction of X-rays, some researchers noted that the heart silhouette appears larger than the left view because the heart is on the left side in Whippets [27]. It is also showed that a greater view on heart radiographs taken from the right view in Beagles [21]. Different notifications are also seen in studies conducted in rodents [28-30].

In the present study, VHS values were determined with many dog breeds. The values determined in dogs are equivalent to the studies performed and give results equivalent to the values obtained in healthy dogs. The VHS value increased with the size of the dog, but it was observed that the heart scale increased in dogs with heart disease, regardless of size. Mean values were calculated in our study. However, it has been detected that the Pekingese dog has a VHS of 12v. This indicates that this small-sized dog has a higher VHS value than the larger-sized dogs and it shows as cardiomegaly in a this Pekingese dog.

There is a difference between male and female VHSs. Males appeared to have a greater VHS value than females. In the data obtained from the right and left radiographs, it was observed that there was no difference between the directions of the VHS value.

Wagner et al.[23] in their study on healthy cats, they reported that chest width was higher than chest height, and heart height was higher than heart width. They also found that the parameters in the measurements of males were higher than females. In this study, thoracic width was found to be greater than thoracic height in dogs. However, it was observed that the heart width was greater than the heart height in dogs. It was determined that thoracic width was higher in females than in males.

In the measurement of the anatomical structures of the heart in dogs in this study, the measurements made from different dog breeds were similar to other studies. There were small differences on average depending on the weight of the breed type of the dogs. In studies conducted on different dog breeds, the aortic root was measured as 12.8±0.31 mm and the left atrium as 15.9±0.38 mm [26], on English Bulldogs, the left atrium as 47.57±5.26 mm and the right atrium as 31.0±96.05 mm [15], in another research the average length of the left atrium was measured as 22.56 mm and the average diameter of the right atrium was 18.00 mm [31]. Changes in these values also support the importance of breed and weight differences between dogs in the diagnosis of cardiac problems.

In conclusion, this study aimed to reveal the heart anatomical measurements and vertebral heart scales taken from different breed of dogs. This study would be a guide to the researches conducted by examining CT images of dogs of the same breed and to precise their VHS and heart anatomical structure reference values.

Declarations

Availability of Data and Materials: The authors declare that data supporting the study findings are also available to the corresponding author.

Funding Support: None.

Conflict of Interest: The authors declared that there is no conflict of interest.

Ethical Approval: The ethics committee report for the study was obtained from Animal Experiments Local Ethics Committee of Istanbul University-Cerrahpaşa (Approval No: İÜC-HADYEK/ 29.11.2023-848033) and the Istanbul University-Cerrahpaşa, Faculty of Veterinary Medicine Ethics Committee (Report Number: 2022/38).

Author Contributions: In the author's contribution to this study, BCG and EO collected CT. BCG, DOE, YA manuscript design. BCG and ÇPY Completed the article hypothesis and writing phase.

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