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Research Article

The objectivity of vertebral heart scale: Comparison of detailed radiographic findings with vertebral heart scale in symptomatic dogs with cardiac failure

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Abstract

The current study aimed to evaluate the objectivity of the vertebral heart scale in the right, left, and generalized cardiomegaly. The correlation between vertebral heart scale and cardiomegaly was determined by conventional methods using a detailed evaluation form of vertebral heart scale and main stem bronchus spine distance measurements and radiographic findings. For this reason, a detailed radiographic evaluation form, including cardiac shape alterations, tracheal displacement, the ratio of the width of the heart to the thorax, and effusive findings due to cardiac failure, was compiled to provide gradation and detection of both-sided alterations in latero-lateral and dorso-ventral view. X-rays of 189 symptomatic dogs with cardiac disorders were included in the study and evaluated by experienced staff. X-ray findings were classified as left-right and both-sided enlargement and graded as mild, moderate, or severe enlargement. Using statistical analysis, the vertebral heart scale method was found to be correlated with findings of left and generalized enlargement, and a significant difference was found between the moderate and severe class (respectively $P<0.001$ and $P<0.000$); whereas no significance was found in the group or intergroup findings in right-sided enlargements. Accordingly, apart from left-sided and generalized cardiomegaly, the vertebral heart scale measurements were found within normal limits in the dogs with right-sided enlargement.

Keywords: Canine, Cardiac Enlargement, Radiography, Vertebral heart scale

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Introduction

Cardiac disorders can be detected in the absence of cardiomegaly. However, cardiac enlargement can mostly occur due to cardiac diseases (Fox et al., 1999). Thus, thoracic radiography is one of the main diagnostic tools in assessing cardiopulmonary disease (Fox et al., 1999; Spasojevic et al., 2007). Primarily, the diagnostic value depends on the information regarding cardiac size and enlargement, alterations in lung parenchyma and pleural spaces, circulation status, and non-cardiac conditions. Cardiac enlargement can be assessed using subjective methods such as; a rounder heart shape, tracheal displacement, ratio of the maximal transverse width of the heart to the maximal width of thorax, differentiation in the dorsoventral (DV) view, and the current objective method of vertebral heart scale (VHS) (Buchanan and Bücheler, 1995; Fox et al., 1999).

VHS is a more objective radiographic measurement method for heart diseases in different animal species developed by Buchanan and Bucheler (Buchanan and Bücheler, 1995). This method was found to be independent from the veterinarian's experience, however, individual differences in the selection of the points may still cause to obtain different results (Hansson et al., 2005). Furthermore, despite its limitations, this objective method is largely used as a practical tool in cardiology clinics to evaluate the heart size of dogs (Guglielmini et al., 2009). However, disagreements have been found in subjective evaluations in research (Ruehl and Thrall, 1981; Lombard and Spencer, 1985; Lamb and Boswood, 2002).

The VHS measurements are found to be most accurate in mitral insufficiency which leads to an apparent increase in the left atrial shape (Lamb and Boswood, 2002). We hypothesized that VHS measurements are found to be more accurate in demonstrating left-sided cardiac expansions than right-sided expansions when compared with conventional radiographic evaluations. Our primary goal in this study was to investigate the compatibility of VHS with cardiac enlargement detected by conventional radiographical methods. In this context, a detailed X-ray examination was compiled to

Table 1: X-ray evaluation form. All cases according to the positivity of the X-ray findings were divided into right, left and generalized. If patient's X-ray findings of both sided enlargements were present, then the patient was included in generalised class.

View	X-ray no.	Mild (3-4p)	Moderate (5-7p)	Severe (8-10p)
Left	Flattening of left atrial border in LL view (1-2p)	✓	✓	✓
	Convexity of cardiac apex in LL and DV views (0-1p)	✓	✓	✓
	Left auricular enlargement in DV view (0-1p)	✓	✓	✓
	Pulmonary venous congestion (0-2p)	✓	✓	✓
	Pulmonary edema (0-2p)	-	✓	✓
	Dorsal displacement of carina (1-2p)	✓	✓	✓
Right	Increased sternal contact of right heart border in LL view (1-2p)	✓	✓	✓
	Dorsal elevation of cranial lobar pulmonary vessels (0-1p)	✓	✓	✓
	Enlargement of pulmonary arteries in DV view (0-1p)	-	✓	✓
	Loss of cranial cardiac waist (0-1p)	✓	✓	✓
	Reverse D heart shape in DV view (1-2p)	✓	✓	✓
	Abdominal effusion (1p)	-	-	✓

demonstrate cardiac shape alterations and the severity of the cardiac failure.

Material and methods

Sample collection

X-rays with abnormal findings of 189 symptomatic dogs admitted to the Animal Hospital Clinic at the Faculty of Veterinary Medicine, Istanbul University-Cerrahpasa were included in the study. Symptomatic dogs suffering from coughing, syncope, dyspnoea, and ascites were included and were grouped according to the intensity of the X-ray findings. X-rays of dogs with non-cardiac illnesses, giant breeds, and breeds with a round chest were excluded from the study. Cavalier King Charles, labrador retrievers and hound (e.g. whippet and greyhound) breed dogs were excluded from the study. X-rays with normal findings were also excluded.

X-ray reception

Radiographic shots for the cardiology clinic were taken under the standard procedure. The films were exposed at the moment of full inspiration. The animals were placed in right recumbency for the lateral view and sternal recumbency for the dorsoventral view while pulling the forelimbs forward and hindlimbs backward.

Preparation of X-ray evaluation form

The X-ray evaluation form is given in Table 1. According to the assessment forms, X-rays were evaluated as latero-lateral (LL) (Figure 1) and DV view (Figure 2) and then were further divided into sub-groups of right-sided, left-sided, and generalized patterns.

The presence of noticeable left atrial and ventricular enlargement without apparent effusion finding allowed the inclusion of a mild class of left-sided enlargement. The presence of congestion and effusion were considered moderate and severe enlargement signs. Left atrial bulging, severe pulmonary oedema, and course of trachea almost parallel to the spine were regarded as signs of the severe class. While evaluating the right-sided enlargement, only the findings of right atrial and ventricular enlargements were mildly graded. Obvious findings of enlargement of right compartments were moderately graded. To separate between the moderate and severe types, the presence of abdominal effusion was used. If findings of both-sided enlargements were present, then the X-ray was included in the generalized class. The ratio of the width of the heart to the width of the thorax was also classified. The normal size was accepted as 2/3.

Vertebral heart scale measurements

Measurements were made on LL views by the method described by Buchanan and Bücheler (1995). Accordingly, the long axis was drawn starting from the ventral border of the carina point to the cardiac apex, and the short axis was determined at the widest part of the cardiac silhouette perpendicular to the long axis under the ventral border of vena cava caudalis (Figure 3). The long and short axis measurements were then repositioned over the thoracal spine starting from the cranial edge of the 4^{th} thoracal vertebrae and counted in the terms of vertebrae caudally. Also, the distance between the main stem bronchus and the spine (Br-Sp) was measured on the lateral view.

Observation

The study was conducted by three observers (two Ph.D. students and two professors) who evaluated the X-ray images. The observers were aware that the dogs were having cardiac problems at different stages but were non-aware of the cardiac status of each dog.

Table 2: Results of vertebral heart scale (VHS) according to severity and enlargements of chamber size. (Min: minimum, Max: maximum, M: mean, SD: Standard deviation, N.S.:Non-significant). Lowercase letters are symbolized the significance in a row. *** p<0.001, N.S.: p<0.05.

View		Vertebral heart scale (VHS)			p-value
		Mild	Moderate	Severe	
Left	No.	5	23	27	0.001^{***}
	M.±SD	10.34 ± 0.46^{b}	10.40 ± 0.19^{b}	$11.7\pm0.25^{a***}$	
	Min-Max	9.2-12	9-12.3	9.5-14	
Right	No.	6	14	11	N.S.
	M.±SD	9.40±0.66	9.96±0.26	10.0±0.26	
	Min-Max	8.5-10.7	7.5-11.7	9.4-10.5	
Generalized (LR)	No.	0	33	70	0.000^{***}
	M.±SD	-	10.33 ± 0.14^{b}	$11.75\pm0.17^{a***}$	
	Min-Max	-	9.1-13	8.4-15.7	
p-value		N.S.	N.S.	N.S.	

Therefore, the major value of the observers was taken into account. The average value was taken into account when three different results were obtained.

Statistical analysis

SPSS used for the statistical analysis (IBM SPSS Statistics 2019 v26). A statistical method of analysis of variance (ANOVA) was used to determine the significance in groups and inter groups, and Student-Test was used for analyses of mild groups of left and right-sided enlargements in Br-Sp measurements.

Results

According to the X-ray evaluation form, 55 X-rays were included in the left chamber enlargement, 31 X-rays in the right chamber enlargement, and 103 X-rays were found to be generalized cardiac enlargements. The numbers of X-rays classified according to severity are given in Table 2. By statistical analysis (ANOVA), the vertebral heart scale method was found to be correlated with findings of left and generalized enlargement.

A significant difference was found between moderate and severe classes (respectively; p<0.001 and p<0.000); whereas no significance difference was found in group or intergroup findings in right-sided enlargements (Table 2). In all cases of generalized and especially left-sided cardiomegaly, the distance of Br-Sp had decreased in direct proportion to the severity of the cardiomegaly (respectively; p<0.05, p<0.001), also there was a significant difference between the moderate class of right and generalized groups (p<0.05) in Br-Sp measurements (Table 3).

Discussion

Thoracic radiography is a commonly used valid method in the evaluation of heart diseases (Spasojevic et al., 2007). VHS measurement, which was first developed by Buchanan and Bücheler (1995), is a practical method used in clinical practice (Hansson et al., 2005; Spasojevic et al., 2007). In practice, the objectivity of VHS measurement has overtaken conventional thoracic X-ray evaluation methods (e.g. presence of a bulge, sternal contact) (Nakayama et al., 2001). Determining the ventral border of the carina can be easy, but detection of the left ventricular apex point may vary (Nakayama et al., 2001), and there may be problems in determining the cardiac base (Hansson, 2004). However, in cases where the measurement of VHS is not equal to whole vertebrae, individual factors may vary when producing an estimate.

Likewise, the point where the short axis is placed is another factor that may vary according to individual differences (Spasojevic et al., 2007). In recent times many studies have been carried out on the effectiveness of VHS in the evaluation of heart disease (Hansson, 2004; Hansson et al., 2005; Spasojevic et al., 2007; Greco et al., 2008). In this study, we aimed to assess the correlation between VHS and cardiomegaly findings determined by conventional methods and enable a detailed assessment tool based on a combination of VHS and Br-Sp measurements and radiographic findings.

Previous studies have demonstrated that the breed factor also significantly impacts the VHS (Bavegems et al., 2005; Marin et al., 2007; Spasojevic et al., 2007; Birks et al., 2017; Zahabpour et al., 2017). Considering that there is more sternal contact in deep or barrel-chested dogs in the lateral position (Ware, 2003), barrel-chested dogs were excluded from the study. Research has identified, in particular, the Cavalier King Charles spaniel (10.6±0.5 v), Labrador Retriever (10.8±0.6 v) and Boxer (11.6±0.8 v), Whippet (11±0.5 v), and Greyhound (10.5±0.1 v) breeds on VHS measurements as higher than the normal reference range (Lamb et al., 2001; Bavegems et al., 2005; Marin et al., 2007). Therefore, Labrador retrievers and hound (e.g. whippet and greyhound) breed dogs were not included in this study. It has also been demonstrated that the differences between right-side and left-side recumbency

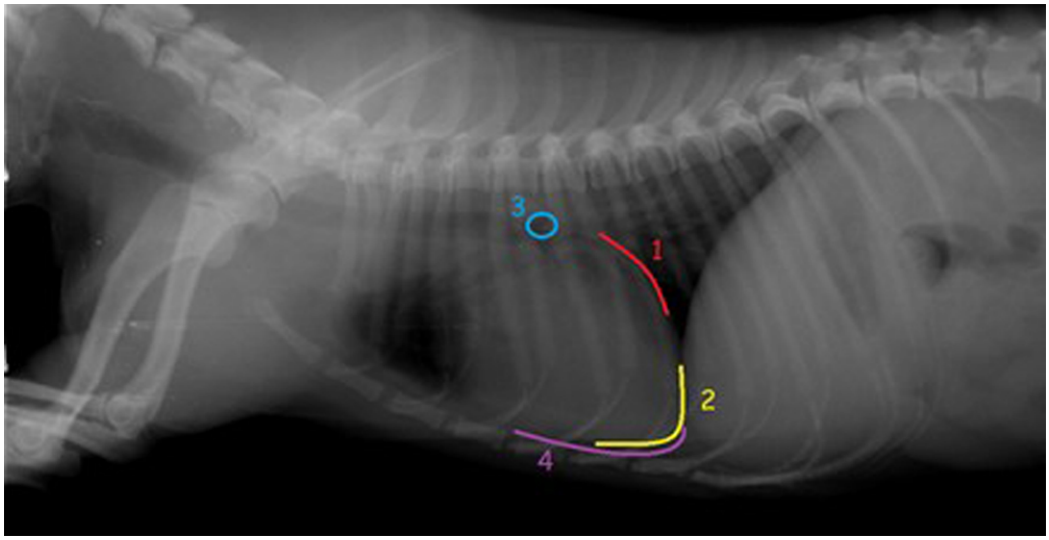

Figure 1: Assessment of latero-lateral view. 1: Left atrial border. 2: Cardiac apex. 3: Carina. 4: Right ventricle sternal contact.

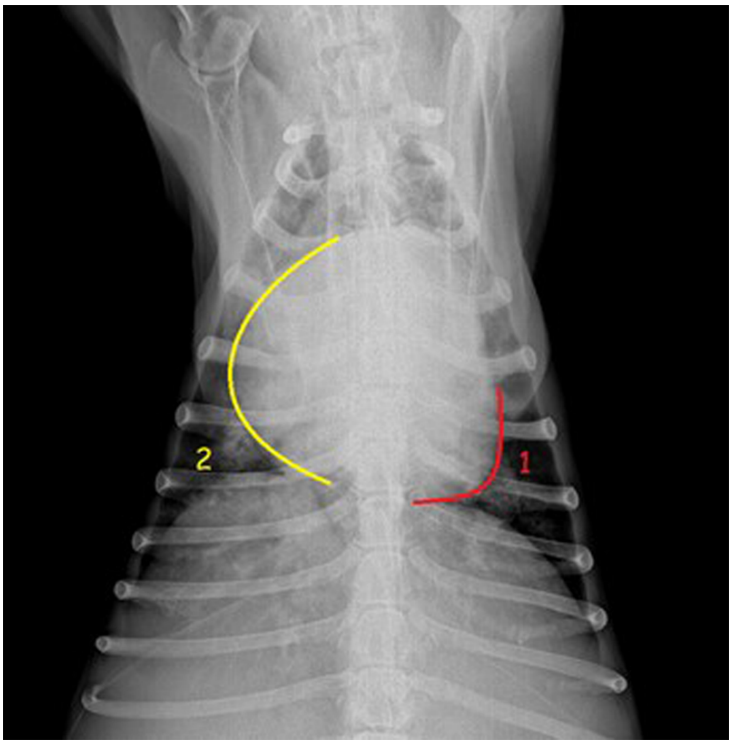

Figure 2: Assessment of dorso-ventral view. 1: Convexity of cardiac apex. 2: Reverse D heart shape.

Table 3: Distance between main bronchus and spine (Br-Sp) according to severity and enlargements of chamber size. (Min: minimum, Max: maximum, M: mean, SD: Standard deviation, N.S.:Non-significant). Uppercase letters are symbolized the significance in a column, lowercase letters are symbolized the significance in a row. * p<0.05, ***p<0.001, N.S.: p>0.05.

View		**Distance between main bronchus and spine (Br-Sp)**			**p-value**
		Mild	Moderate	Severe	
Left	No.	5	23	27	0.001^{***}
	M.±SD	1.73 ± 0.20^{a}	1.48 ± 0.45^{aAB}	1.0 ± 0.37^{bB}	
	Min-Max	1-3	1.1-3	1.4-2.3	
Right	No.	6	14	11	N.S.
	M.±SD	2.0±0.57	1.95 ± 0.16^{A}	1.77 ± 0.22^{A}	
	Min-Max	1-3	1.1-3	1.4-2.3	
Generalized (LR)	No.	0	33	70	0.01^{*}
	M.±SD	-	1.47 ± 0.37^{aB}	1.19 ± 0.50^{bB}	
	Min-Max	-	0.7-1.9	0.2-1.5	
p-value		N.S.	0.05^{*}	0.02^{*}	

may cause a disparity in VHS measurements (Greco et al., 2008). Therefore, to minimize individual differences, all X-rays in this study were taken in right lateral recumbency during full inspiration and assessed by veterinary surgeons experienced in cardiology.

In recent years, many studies have been performed on the effectiveness of VHS (Nakayama et al., 2001; Hansson et al., 2005; Spasojevic et al., 2007; Sánchez et al., 2012; Jepsen-Grant et al., 2013). However, studies comparing VHS in left or right-side cardiomegaly are not exiciting. Mitral valve degeneration is a common disease in dogs and causes left atrial and ventricular dilatation and hypertrophy (Carlsson et al., 2009). In a study on dogs with mitral regurgitation, right heart chamber sizes of dogs were measured by radiographically and no significant dilation findings were observed (Carlsson et al., 2009). Nevertheless, X-ray findings regarding the right side of the heart can be considered as specific for right heart failure. In this study, the highest Br-Sp value was determined in the group of the right side heart failure. The result showed that the carina point had not changed in the right heart dilation group and, significantly, this was reflected in VHS measurements.

In a previous study, two dogs had an accentuated right heart border on X-rays, while VHS findings were normal, although the echocardiographic and electrocardiographic examinations have shown that one of them had concentric hypertrophy (Spasojevic et al., 2007). In our study, the VHS was normal (9.4-10.5) according to the X-ray evaluation form, even in dogs with severe right failure findings. This group also had hydrops-ascites results related to cardiac failure. Although X-rays with a high VHS threshold limit (11.7) were detected in dogs with moderate right failure symptoms, an average VHS value was still within the normal range (9.96±0.26). As demonstrated in Table 2, mild cases were not observed in generalized dilation. As previously mentioned (Atkins, 1991), it can be considered that this is because left-sided enlargement may have caused right-sided enlargement. According to the authors, in cases where both chambers are affected, moderate to severe congestive heart failure can arise, and the symptoms can be classified in the moderate to severe enlargement category during assessment.

Mitral valve disease in dogs leads to a significant dilation in the left atrium (Lamb and Boswood, 2002). In the present study, the maximum value measured in the VHS with left heart failure was detected by X-rays, from mild to severe, such as found in relatively high values up to 12-14. The VHS measurement method has been reported to be more reliable in small breed dogs with mitral insufficiency, which results in severe cardiac eccentric hypertrophy and dilatation (Lamb and Boswood, 2002). As a result of atrial enlargement, Br-Sp distance is reduced. In this study, especially in the group of dogs with left side heart failure, the Br-Sp distance had dropped to the lowest value (1.0±0.37). Also in dogs with generalised severe class, Br-Sp distance was found to be higher at a certain ratio (1.19±0.50).

Tracheal dislocation, which leads to more significant changes to the VHS value, is more evident, especially in left side heart failure. Coughing is an important clinical sign of mitral valve disease (Buchanan, 1992). In a study on the cough findings of 69 dogs, VHS findings were found to be increased (12.8±1) in dogs with coughing of cardiac origin. In dogs with a higher than 11.4 VHS score, the beginning of coughing signs of cardiac origin was detected at 92% sensitivity and 75% specificity (Guglielmini et al., 2009). In the present study, the mean VHS value was found to be 11.7±0.25 in patients with clinical signs of pulmonary oedema and venous congestion in the severe left heart failure group. A significant correlation was found between VHS and LA: AO ratio in a study comparing

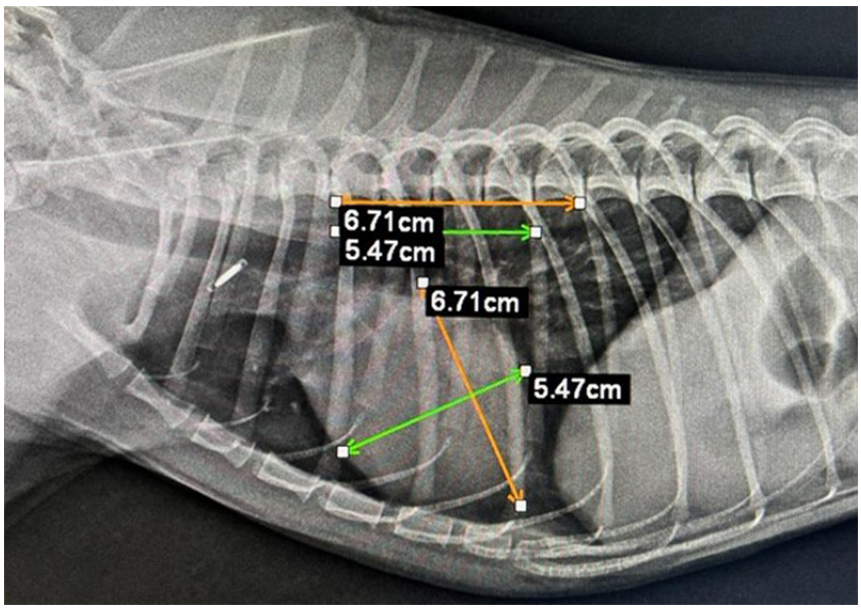

Figure 3: The long axis (orange line) was drawn starting from the ventral border of carina point to the cardiac apex. The short axis (green line) was determined at the widest part of cardiac silhouette perpendicular to the long axis under the ventral border of V.cava caudalis. Then all the lines re-positioned over the thoracal spine starting from the cranial edge of 4th thoracal vertebrae and counted in the terms of vertebrae caudally.

the echocardiography and electrocardiography findings. The researchers expected these results since the left atrium is a component of the short axis (Nakayama et al., 2001). Thus it can be concluded that left compartment enlargements are more effective on the short and long axis.

The radiograph survey plays an important tool in determining congestive heart failure (Lamb and Boswood, 2002). The X-ray evaluation form shown in Table 1, designed according to conventional X-ray evaluation findings, also allows classifying heart failure from mild to severe according to congestion findings. In a study where a subjective evaluation method was developed for dogs with mitral valve disease, 16 observers agreed on only one-third of the X-ray parameters (Lamb and Boswood, 2002). According to the golden standards determined by cardiologists, it is recorded that the observers have a fallibility rate of 18% (Hansson, 2004). This study aimed not to determine the differences between the observers; however, there was no X-ray in which all observers agreed, as only X-rays belonging to patients with cardiac symptoms were included in the study. Moreover, it can be because of using observers experienced in cardiology.

Many factors that affect the VHS measurement evaluations are accepted to be an objective evaluation method (Buchanan and Bücheler, 1995), and there may be differences among the implementers (Hansson et al., 2005). Still, using VHS assessment methods by combining with subjective methods will further increase accuracy (Hansson, 2004). Accordingly, although it is known to be a sensitive method for left growths associated with mitral valve failure which is common in dogs. It is worth mentioning that, there is not a sufficient number of studies for its sensitivity in cases of the right side compartment enlargement. It is thought that the evaluation form which was prepared based on many known radiographic criteria (Table 1), is more qualified in the subjective assessments. In this study, the VHS assessment method was found to be sensitive, particularly in left compartment enlargements and generalized enlargements, however, it was detected among the reference ranges in cardiomegalies associated with right compartment enlargements.

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Conflict of Interest. The authors have no conflict of interest to declare.

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