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RADIOGRAPHIC ASSESSMENT OF HEART SIZES IN DOG: RETROSPECTIVE EVALUATION OF SELECTED CASES

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Abstract:

Radiographs of thoracic cavity are useful as a diagnostic modality to detect heart diseases and have a potential to provide information equivalent to other cardiac diagnostic modalities. Radiographic interpretation can be by gross examination or by using different measurements like, relationship with inter-costal spaces or vertebral heart score. A specification of 2.5 to 3.5 inter-costal spaces had been introduced in veterinary medicine as an indicator of normal heart size in lateral radiographic views for dogs, but due to some limitations, use of these techniques has been supplanted by another cardiac measurement technique called the vertebral heart score, in which the heart length and width on the thoracic radiograph is compared with the vertebral length. The objective of the present study was to compare the vertebral heart scale (VHS) and the intercostal space (ICS) to assess changes in the size of the cardiac silhouette of ten healthy dogs. It shows that there is no statistically significant difference between the VHS and ICS method in diagnosing the presence or absence of cardiomegaly in the evaluated radiographs. Both methods are sufficient for diagnosis however the VHS appears to be more objective and sensitive because it allows for a baseline comparison with a relatively independent structure (vertebral bodies).

This study is a retrospective case review of selected thoracic radiographs of dogs from radiograph archives. It does not reflect the heart sizes of dogs’ resident in Maiduguri

but would serve to assist in the selection of cardiac silhouette measurement method for daily clinical use. Findings from this study would be reflective of the heart sizes of other species of animal while comparisons are made only with the ability of each method to agree on cardiomegaly.

Key words: Cardiac Silhouette, Inter Costal Space, Thoracograph, Vertebral Heart Score/Scale,

INTRODUCTION

Detailed Clinical assessment of the heart is gaining a lot of attention in routine small clinical practice (Bavegemset *et al*., 2005). Conditions of the heart ranging from dilated cardiomyopathies to septal defects are frequently picked up routinely in recent times (Bavegemset *et al*., 2005). Thus, advances in veterinary cardiology research and investigations, most notably in the areas of diagnostic imaging and cardiovascular therapeutics, have considerably added to the understanding and awareness of cardiac pathologies (Bavegemset *et al*., 2005) as a vital aspect of general health examination in small animals (Bavegemset *et al*., 2005). Increased attention given to the evaluation of cardiac conditions of both cats and dogs has been a subject of academic discourse and research (Root and Bahr., 2002). Despite the availability of other cardiac evaluation techniques, thoracic radiography remains an integral part of the diagnosis and management of cardiac disease (Root and Bahr., 2002). Radiographs are generally used to evaluate clinical response to therapy or progression of disease in a general sense (Thrall., 2007).

Thoracic radiography is one of the most commonly performed diagnostic tests in small animal practice (Gugjoo *et al*., 2013; Olatunji *et al*., 2015). The indication for such radiograph is often to assess the size of the heart in order to relate findings with observed clinical signs (Gugjoo *et al*., 2013). Radiographic interpretation of heart sizes can be done by subjective assessment of the cardiac silhouette or by using objective measurement methods such as the cardiothoracic ratio (Gugjoo *et al*., 2013), relationship of the cardiac silhouette with the intercostal spaces (Kealy *et al*., 1989), and the measurement of the dimensions of the cardiac silhouette in relation to the thoracic vertebral bodies otherwise referred to as Vertebral Heart Score (VHS) method. The VHS has been adjudged to be useful in assessing changes in heart size over time as it provides a good correlation between the growth of visceral organs, including the heart, and vertebral body length (Church., 2011). These assessments are comparable to electrocardiographic and echocardiographic parameters (Nakayama *et al.*, 2001: Gugjoo *et al.*, 2013).

The canine heart is ovoid. Its long axis forms an angle of 45° with the sternum; the base thus faces craniodorsally and the blunt apex lies near the junction of the sternum and the diaphragm, a little to the left of the midline (Dyce *et al*., 2010). Nevertheless, the heart in the dog is located between the third rib and the sixth intercostal spaces. The left ventricles occupy most of the left side of the heart, but because of the way in which the heart is positioned in the thoracic cavity, the anterior part of the right ventricle, the left atrium and the pulmonary trunk are also on this side (Joanna *et al*., 2014).

The angle between the axis of the heart and the sternum and the space between the apex and diaphragm vary both more considerably than many accounts suggest. The angle is greater and the shape of the heart more conical in deep chested breeds (figure 1).

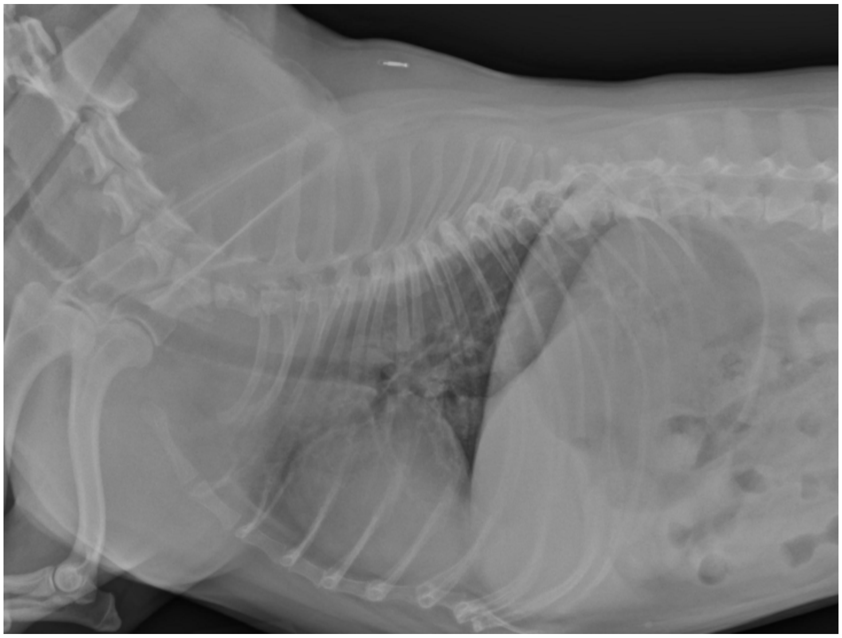

Figure 1: Canine thoracograph showing outlines of internal organs

Because the position of the heart is biased, a thinner layer of lung tissue intervenes between the heart and the left thoracic wall, resulting in the heart sound being more pronounced on the left side. On the right side, the ventricles occupy the majority of the area with a small portion of left ventricle caudoventrally and right atrium dorsally (Dyce *et al*., 2010). There are more variations in the normal canine heart than in any other organ, and the heart is inherently variable in size because of its contractility during the cardiac cycle. Additionally, there is considerable breed variation with regards to normal heart size and shape in different species (Bavegems *et al*., 2005).

The heart has four chambers, two upper atria, the receiving chambers, and two lower ventricles, the discharging chambers. The atria open into the ventricles via the atrioventricular valves, present in the atrioventricular septum. This distinction is visible also on the surface of the heart as the coronary sulcus, *(Susan et al., 2008*). The heart contributes about 0.7% of the body weight on average (Dyce *et al*., 2010).

Radiographs allow for evaluation of heart size and shape, pulmonary parenchymal pattern and pulmonary vasculature. No other single diagnostic modality allows simultaneous evaluation of all three of these parameters (Oyama, 2013). Knowledge of the heart size for a specific body weight can help to indicate the degree and direction of the change from normal when evaluating for cardiac diseases (Muzzi *et al*., 2006; Ghadiri *et al.*, 2008).

The thoracic radiography is one of the most commonly performed radiographic examinations in small animal practice (Dark *et al*., 1996). Determination of heart size is important in evaluating patients with heart disease, because an enlarged cardiac silhouette in radiographs is a reliable indication of pathologic cardiac changes (Buchanan and Bucheler, 1995). Follow up radiographs are used to evaluate clinical response to therapy or progression of disease (Thrall., 2007). Thoracic radiography is an essential part of evaluating the patient, allowing determination of heart size via the Vertebral Heart Score [VHS] assessment (Buchanan *et al*., 1995) and scrutiny of pulmonary vasculature and parenchyma for evidence of pulmonary infiltrates and vascular engorgement typical of Congestive Heart Failure (Lord *et al.*, 2010). In the patient without clinical signs, the size of the heart, assessed over time can be used to estimate the likelihood of Congestive Heart Failure development in the near future (Reynold *et al*., 2012).

Cardiac silhouette size can be measured by:

- intercostal space method; a guideline of 2.5 to 3.5 intercostal spaces for dogs was introduced in 1968 and is still used in veterinary medicine. In general, the height of the heart on the lateral projection is two-thirds the height of the chest (Figure 1). The width of the heart is between 2.5 and 3 intercostal spaces (Figure 1). Limitations of this method include variations of the heart size and shape, conformation of the thorax, phase of respiration, superimposition of ribs, and imprecise measurement points (Lamb, C.R., year; Boswood *et al*.,2002).

- vertebral heart score method; a system of cardiac measurement was designed to take into account the inherent variation between breeds in cardiac size. The system is called the vertebral heart scale or size (VHS) and has been investigated in dogs, normal and obese cats, and ferrets by several authors. It uses the sum of the length and width of the cardiac silhouette, which is then translated into the total units of thoracic vertebral length to the nearest 0.1 vertebra (Buchanan and Bucheler, 1995; Buchanan, 2000; Litster and Buchanan, 2000; Litster and Buchanan *et al*., 2000; Sleeper and Buchanan, 2001; Stepien, 1999).

The VHS may be useful in assessing change in heart size over time as there is good correlation between the growth of visceral organs, including the heart and vertebral body length (Church., 2011). It is reported that electrocardiographic and echocardiographic parameters provide findings comparable to VHS for evaluation of heart size (Nakayama *et al.*, 2001; Gugjoo *et al*., 2013). Accuracy of the VHS in the diagnosis of cardiac disease was first evaluated by Lamb *et al*., (2001).

The mean VHS reported by Buchanan and Bucheler (1995) was 9.7±0.5 and 10.2±0.83 vertebrae in lateral and ventrodorsal radiographs respectively of different dog breeds. Also, the VHS values in lateral radiographs were unaffected by the depth or broadness of the chest of dogs which is in contrast to intercostal space method where such variation does occur as reported by Jepsen-Grant *et al.*, 2013. However, slightly higher values were observed in right lateral recumbency (Gugjoo *et al*., 2013).

The higher VHS in right recumbency could be explained by the fact that divergence of X-ray beam and more distance of the heart from the cassette occurs in right lateral recumbency which leads to image magnification. In contrast to above reports, findings on mixed breed and native dogs of Iran showed non-significant difference in VHS when taken in right or left lateral recumbency (Ghadiri *et al*., 2010). VHS has been reported to be fairly accurate for exclusion of coughs of cardiac origin in dogs with mitral valve disease (MVD) (Guglielmini *et al*., 2009). In another report on congestive heart failure (CHF) due to mitral valve regurgitation, VHS was found to be useful for detecting onset of CHF in Cavalier King Charles Spaniels with mitral regurgitation (Gugjoo *et al*., 2013).

VHS has been found as the most accurate radiographic index for identifying dogs with pericardial effusion (PE) and also to differentiate it from other cardiac diseases (Guglielmini *et al*., 2012; Gugjoo *et al*., 2013). The normal range of the vertebral heart sum in dogs is 8.5 to 10.5. Vertebral heart sums greater than 10.5 may indicate cardiomegaly due to cardiac disease. The cavalier King Charles spaniel's upper limit of normal is about 11.7 (Hansson *et al*., 2005). An enlarged silhouette warrants further investigation with the use of echocardiography (Buchanan *et al*., 2000).

MATERIALS AND METHODS

Thoracic radiographs of ten (10) adult mongrel dogs of the same weight that underwent routine radiographic cardiac size examination were sourced from the archives. Recorded history of these dogs revealed no evidence of clinical signs of cardiovascular or respiratory disease. Physical examination, complete blood count and serum chemistry all revealed normal (within physiological range) parameters.

Records revealed that all examinations were performed with manual restraint of the animals and radiographic technique was of right lateral thoracic view using pre-set technique chart for the Shimadzu X-ray Machine® (Japan) located at the Faculty of Veterinary Medicine, Universiti Putra Malaysia.

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All radiographs were taken at the time of full inspiration. An attempt was made to keep the chest of animal as close to the film as possible, to include all the thoracic vertebrae in radiographs and to avoid any rotation of the body of animal via mechanical restraint. The radiographs were evaluated qualitatively to exclude animals that presented any radiographic change. Radiographs with motion blurs or expiratory radiographs were excluded from the study.

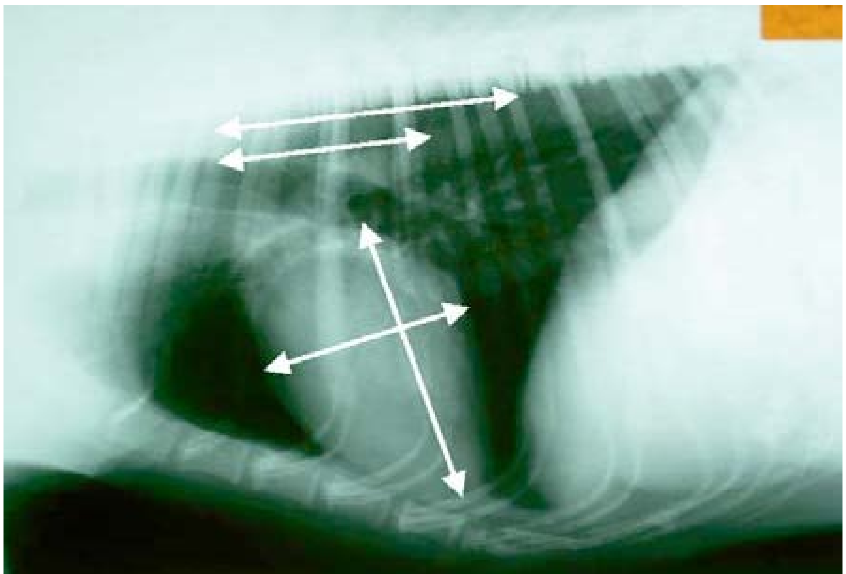

Figure 2a: Dimension of the cardiac silhouette on thoracograph

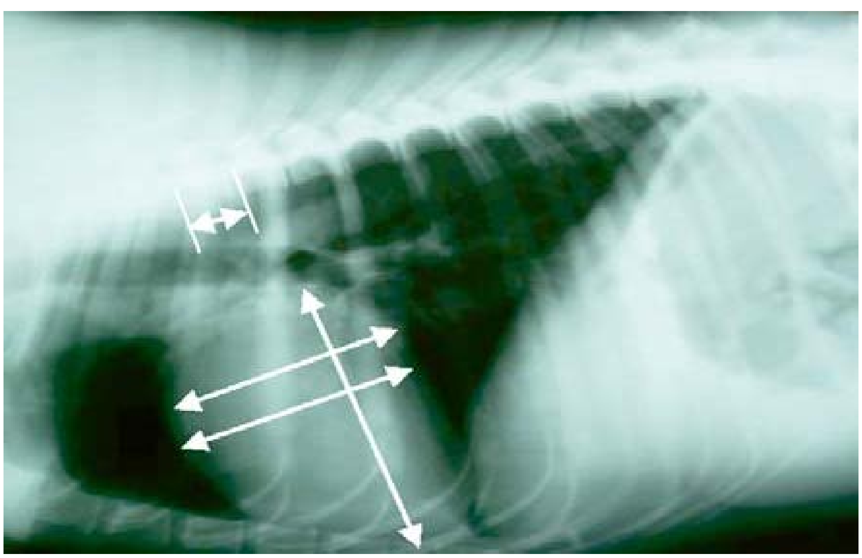

Figure 2b: Dimension of the cardiac silhouette on thoracograph

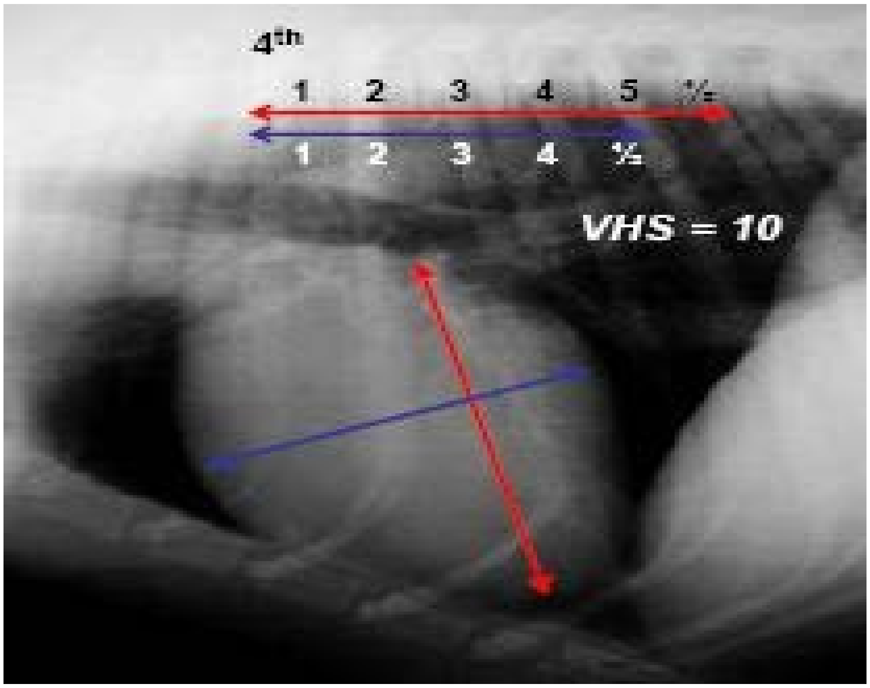

Figure 3: VHS method on the thoracograph (length and width)

The length of the heart is measured from the ventral border of the carina to the cardiac apex. The width of the heart is measured perpendicular to the long axis across the widest portion of the heart. The length and width (figure 3).

Quantitative evaluation of the radiographs was performed by measuring vertebral heart score (VHS) using the method described by Buchanan and Bucheler *et al.*, 1995. In lateral thoracic radiographs, LA of heart was measured from the ventral border of the largest main stem bronchus seen in cross section to the most distant ventral contour of the cardiac apex using an adjustable caliper. The caliper was then repositioned over the thoracic vertebrae beginning with the cranial edge of the fourth thoracic vertebrae (T4). Distance spanned by the caliper was estimated to the nearest 0.1 vertebral body length. The caliper was then placed on a metric ruler, and the interval was recorded to the nearest millimeter to obtain more precise measurements for statistical analysis. Care was taken not to measure any distance that had the radiographic opacity of fat. The SA of heart was measured in the central third region (from the cranial to caudal border of the widest portion of the heart), perpendicular to the LA and the number of vertebrae was calculated in the same manner as for LA. The LA and SA dimensions of the heart were then added to obtain a vertebrae or heart sum that indicated the heart size relative to body length. The heart size and vertebral length were also determined in millimeters, (Bodh *et al*., 2016).

VHS (vertebral heart scale) method was used, described by Buchanan and Bucheler (1995), which involves measuring the long axis (L-representing the distance from the carina to the cardiac apex) and short axis (l - representing the maximum diameter perpendicular on the axis of the heart term) in cm and their sum was compared with the length of thoracic vertebrae (v), from cranial edge of thoracic vertebra 4 (T4) from right side incidence. Average and standard deviation were calculated.

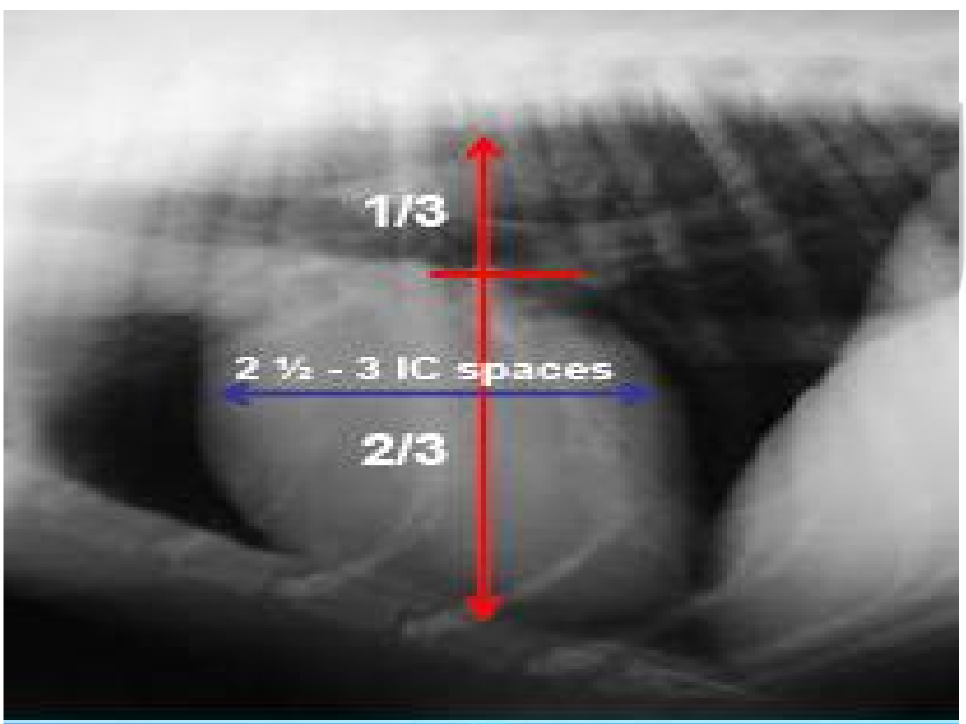

Figure 4: ICS Method on the thoracograph

In general, the height of the heart on the lateral projection is two-thirds the height of the chest (Figure 4). The width of the heart is between 2.5 and 3 intercostal spaces (Figure 4).

RESULTS AND DISCUSSION

Table 1: Comparison between VHS* and ICS using right lateral radiographic view**

SAMPLE	PARAMETERS			
	Long axis	**Short axis**	**VHS***	**ICS****
Dog 1	5.5	4.5	10.0	3.5
Dog 2	5.5	4.6	10.1	3.5
Dog 3	5.6	4.5	10.1	3.5
Dog 4	5.7	4.9	10.6	3.5
Dog 5	5.2	4.6	9.8	3.0
Dog 6	5.3	4.4	9.7	3.5
Dog 7	6.1	4.9	11.0	3.5
Dog 8	5.6	4.5	10.1	3.5
Dog 9	5.4	4.4	9.8	3.5
Dog 10	5.2	4.3	9.5	3.5

Table 2: Showing cardiomegaly dog when VHS is used

SAMPLE	PARAMETERS		
	Long axis	**Short axis**	**VHS**
Dog 4	5.7	4.9	10.6
Dog 7	6.1	4.9	11.0

Table 3: Showing marginal cardiomegaly when ICS is used

SAMPLE	PARAMETER; ICS
Dog 1	3.5
Dog 2	3.5
Dog 3	3.5
Dog 4	3.5
Dog 6	3.5
Dog 7	3.5
Dog 8	3.5
Dog 9	3.5
Dog 10	3.5

VHS* VERTEBRAL HEART SCORE
ICS** INTERCOSTAL SPACE

Chi-square Test

The two-sided P value is 0.5312, considered not significant.

Calculation details:

Chi-square statistic (with Yates correction) = 0.3922

Degrees of freedom = 1

Relative Risk

Relative risk = 0.8889

95% Confidence Interval: 0.6124 to 1.290

(using the approximation of Katz.)

Difference between the two proportions

Top row (VHS):

Fraction in the left column: 0.8000

Bottom row (ICS):

Fraction in the left column: 0.9000

Difference:

Difference between the fractions: 0.1000

The standard error and the confidence interval of the difference between proportions can only be calculated when each cell is greater than five.

Data analyzed

	Normal	**Abnormal**	**Total**
VHS	8	2	10
	40%	10%	50%
ICS	9	1	10
	45%	5%	50%

It shows that there is no statistical significant difference between the VHS and ICS method in diagnosing the presence of absence of cardiomegaly in the evaluated radiographs.

The ICS had diagnosed marginal cardiomegaly in all the 10 cases due to the external variables which can enhance contraction or relaxation of the intercostal muscles which can affect the objectivity of assessment. While VHS selected only Case 2 as being large. Cardiomegaly is a reliable sign of heart disease and it is seen in cases of hypertrophic or dilated cardiomyopathy (Litster *et al*.,2000). It has been reported that in general dilated cardiomyopathy is progressing whereas pericardial effusion, aortic stenosis and endocarditis are seen very often in large breeds like bull dogs (Hogan., 2002). Cardiomegaly can be easily determined in thorax radiographies and can be objectively measured with VHS application.

In other studies, related to VHS (Lamb *et al*., 2002) different dog breeds have been used. Because of this, many researchers have recommended comparing the radiographs of ill dogs with the radiograph of a completely healthy dog of the exact same breed and size. However, it has been emphasized that it is not always possible in practice to find a healthy dog of the exact same breed and size.

Also we think that in clinical practice the lateral radiographic position may be preferred to the Ventrodorsal position because the lateral radiographic position is more comfortable and causes less stress for the patients with suspected cardiac disease. Also, there are no differences concerning age and sex of the patients in our study (Sleeper *et al*., 2001). In general, the sizes of vertebrae and the sizes of internal organs show a parallel development. In other studies, electrocardiographic and echocardiographic parameters have shown equal results like VHS for heart size.

Therefore, it could be concluded that cardiac illnesses causing cardiomegaly can be diagnosed using lateral thorax radiography and VHS in cases with insufficient diagnostic tools. On the other hand, normal heart size does not always mean that there is no heart disease. Because of this, only determination of VHS is not sufficient for patients having heart disease symptoms. We conclude that VHS is easy to apply and objective for clinical practice in determining the heart size. Our study can be a guide in clinical practice for evaluating heart diseases in mongrel dogs.

CONCLUSION

Both methods are sufficient for diagnosis however the VHS appears to be more objective and sensitive because it allows for a baseline comparison with a relatively independent structure (vertebral bodies).

RECOMMENDATION

The increased routine evaluation of cardiac conditions in small animal clinical practice has brought into fore the value of radiographic measurement of cardiac size by radiographic means. However, the levels of agreement or disagreement in obtained diagnosis from both methods are currently underreported. Hence there is an immediate need for the adoption of a method that is consistent, pragmatic, objective and convenient to interpret among veterinary radiologists.

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