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Computed Radiographic (CR) assessment of cardiac size in German shepherd dogs

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Thoracic radiography is a very useful diagnostic technique, which allows a fast and non-invasive assessment to obtain valuable information on the cardiac silhouette. Objective assessment of different cardiac parameters can be helpful for diagnosing cardiac disorders in canines where echocardiography is not readily available. So, the present study was designed for objective assessment of cardiac parameters, and their correlation with age and body weight in German shepherd dogs using Computed Radiography. Different cardiac parameters viz. vertebral heart score, cardio-thoracic ratio, cardiac sphericity index, vertebral left atrial size, radiographic left atrial dimension, and manubrium heart score were measured radiographically in client owned 30 healthy German shepherd dogs in right and left lateral recumbency using standard procedures. Reference values of various cardiac parameters were recorded and correlated with age and body weight. Alteration in these reference values has the future scope for utility in diagnosis of cardiac affections in German shepherd dogs.

Key words: *Cardiac size, Computerized radiography (CR), German shepherd dog.*

Vertebral heart score (VHS) measurement is frequently used method to measure the cardiac size and objective assessment of cardiomegaly in dogs (Lamb *et al.*, 2000). The cardiothoracic ratio (CTR) is considered as a classic index of cardiac functions and increased CTR in thoracic radiographs is associated with poor prognosis, which suggests the importance and necessity of early diagnosis (Monfared *et al.*, 2015). Manubrium heart score (MHS) eliminates some of the problems allied with the VHS and CTR (Mostafa and Berry, 2017). Cardiac sphericity index (CSI) is ratio of cardiac long-axis length and cardiac short-axis length, calculated to objectively evaluate the roundness of the cardiac silhouette and modified from the lateral sphericity index (Mostafa *et al.*, 2020). Vertebral left atrial size (VLAS) and radiographic left atrial dimension (RLAD) are new methods to estimate the left atrium (LA) size and are reliable and useful for the prediction of LA enlargement in dogs with myxomatous mitral valve disease (MMVD) (Malcolm *et al.*, 2018; Salguero *et al.*, 2019).

These measurements are likely to be useful for diagnosis of the cardiac pathology, only when the normal reference range for the same are available for different breeds. Hence, the present study was designed for objective assessment of normal cardiac parameters and their correlation with age and body weight using Computed Radiography (CR) in German shepherd dogs (GSD).

Materials and Methods

The present study was conducted on 30 client owned healthy German shepherd dogs free from cardiothoracic diseases. Dogs having normal physiological parameters viz., rectal temperature (°F), respiratory rate (breaths/min), heart rate (beats/min) and haematological parameters viz., Hb (g%), PCV (%), RBC (10^6/ìL), WBC (10^3/ìL) and DLC (%) were considered healthy and selected for the study. The selected animals were divided into two groups based on the age and body weight containing 15 animals each. Mean±SE body weight for group I was 10.58±1.06 kg (< 12 months) and in group II was 20.94±0.93 kg (> 12 months). Inspiratory radiographs were taken in ventro-dorsal (VD), right lateral (RL) and left lateral (LL) positions as described by Torad and Hassan (2014).

Vertebral heart score (VHS) was measured by using the method described by Buchanan and Bucheler (1995) in nearest 0.1 vertebral body length using right and left lateral thoracic radiographs. Cardio-thoracic ratio (CTR) was measured using two different methods: comparing the greatest width of the heart silhouette and the distance between the thoracic walls at the level of the 8th thoracic vertebrae in ventro-dorsal view (Fig. 1), and comparing the cardiac and thoracic areas in both lateral and ventro-dorsal views (Figs. 2A & B). Vertebral left atrial size (VLAS) and right left atrial dimension (RLAD) were measured as per the procedure described by (Malcolm *et al.*, 2018) (Fig. 3) and (Salguero *et al.*, 2019) (Fig. 4). Manubrium heart score (MHS) was calculated using maximum manubrium length (ML), cardiac short length (SAL) and long axis length (LAL) (Fig. 5). The cardiac sphericity index (CSI) was measured by calculating the SAL:LAL ratio to evaluate the roundness of the cardiac silhouette**.** The results of different parameters were analyzed by SPSS

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statistics. Independent samples t-test was used for comparison between groups (I & II) and radiographic views. The Bivariate Pearson's correlation coefficient (r) was used to determine the correlation of each parameter with age and body weight.

Results and Discussion

Different cardiac parameters and their correlation with age and body weight in German shepherd dogs using Computed Radiography are:

1. Vertebral heart scale (VHS) and cardiothoracic CTR

Different parameters were measured by different standard methods which have been described previously by different researchers in different breeds of dog and cat and mean values were drawn. No

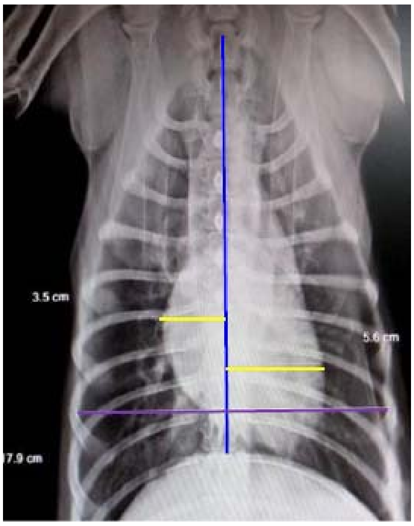

Fig. 1: Ventro-dorsal thoracic radiograph showing thoracic cavity length, measurement land mark of maximum right distance (X), maximum left distance (Y) and maximum thoracic diameter (Z); at the level of 8th thoracic vertebrae. CTR = X + Y/Z (linear measurement)

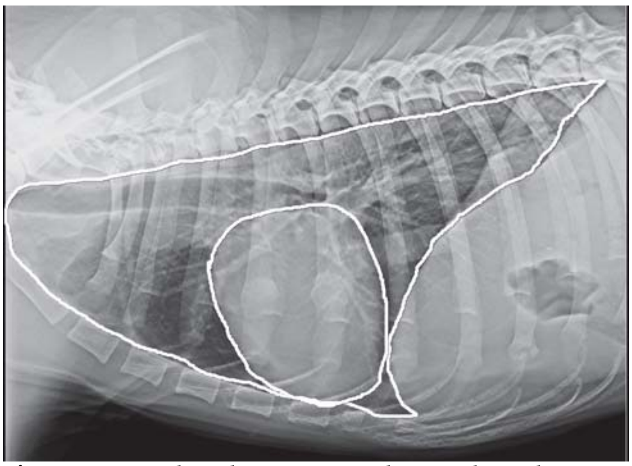

Fig. 2A: Lateral thoracic radiograph showing measurement land mark of cardiac area (A) and thoracic area (B) is according to Method II. CTR calculated by equation cardiac area/thoracic area (area measurement).

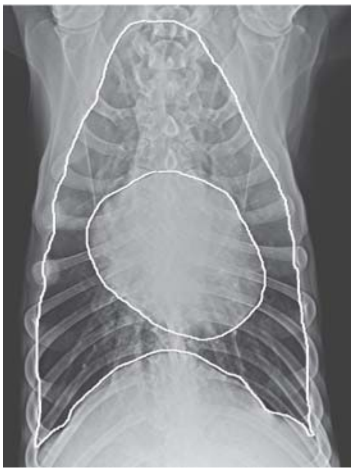

Fig. 2B: Ventro-dorsal thoracic radiograph showing measurement land mark of cardiac area (A) and thoracic area (B) according to Method II. CTR calculated by equation cardiac area/thoracic area (area measurement).

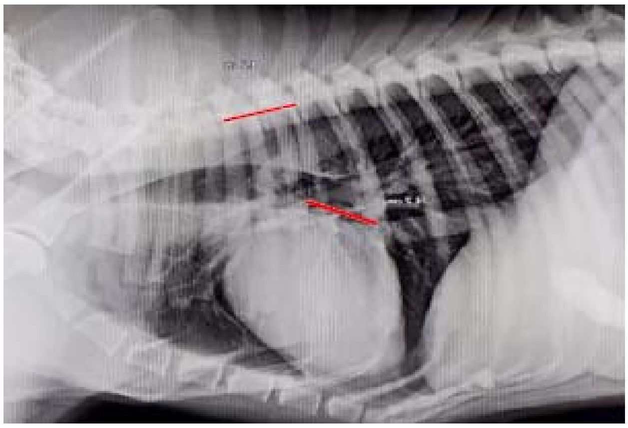

Fig. 3: Lateral thoracic radiographic projection of vertebral left atrial size (VLAS) expressed in vertebral body units to the nearest 0.1 vertebra. Line drawn and measured from the centre of the most ventral aspect of the carina to the most caudal aspect of the left atrium where it intersected with the dorsal border of the caudal vena cava.

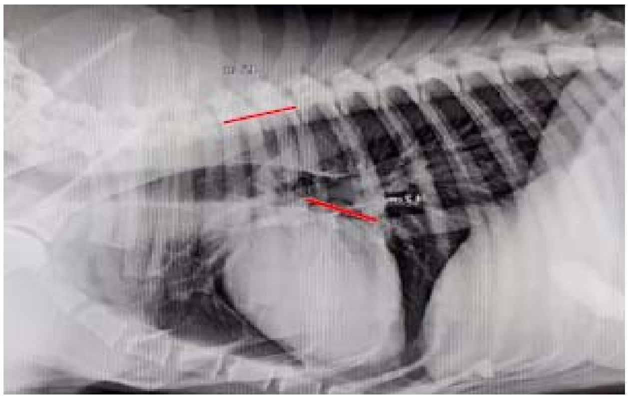

Fig. 4: Lateral thoracic radiograph showing measurement landmark of radiographic left atrial dimension (RLAD) by a line bisecting the 90° angle formed by intersection of the VHS long axis and short axis was drawn from this point to the left atrium and ensure 45° angle between this line and intersection of long axis and short axis.

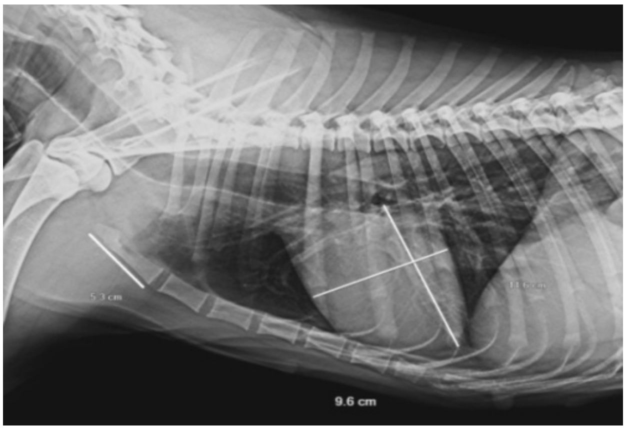

Fig. 5: Lateral thoracic radiographic view showing measurement of ML (manubrium length), Short MHS was calculated by ratio of SAL:ML and long MHS was calculated by ratio of LAL:ML. Sum of SAL and LAL to ML was provided the overall-MHS [SAL; short axis length & LAL; long axis length]

Table 1.1: Mean ±SE of VHS and CTR in lateral thoracic radiographs of groups I and II.

Parameter	Right	Left
Group I		
VHS ^{NS}	9.41±0.09v	9.29±0.09v
CTR Lateral^{NS}	0.41±0.01	0.40±0.01
Group II		
VHS^{NS}	9.37±0.11v	9.13±0.14v
CTR Lateral^{NS}	0.42±0.01	0.40±0.01

The superscript (NS) showed no significant (P≥0.05) difference between right and left lateral view; **whereas 'v'indicates ????**

Table 1.2: Mean±SE of CTR in ventro-dorsal thoracic radiographs of groups I and II.

CTR (VD)	Group I	Group II
Method I/		
Schillaci *et al.* (2009)	0.53±0.01	0.53±0.01
Method II/		
Torad and Hassan (2014)	0.44±0.01	0.43±0.01

**Mean value is significant at the P≥0.01 level (Where is **?)

significant changes were observed in the values of VHS in right and left lateral recumbency as well as between both the groups but slight increased values were seen in the right lateral radiographs. Increased and significant values of VHS in right lateral recumbency has been reported in many studies, but the level of significance was found to be low (Kraetschmer *et al.*, 2008). Significant VHS values in right lateral recumbency were also reported in dogs by Ghadiri *et al.* (2010). Hence, recumbency can be considered while evaluating the VHS in dogs (Azevedo *et al.*, 2016). In right lateral recumbency distance from the cassette to heart might be the reason for increased values (Greco *et al.*, 2008).

German shepherd dogs' hearts were measured in one study using various techniques, and the results showed no significant differences between any of the methods used (Ljubica *et al.*, 2007); nevertheless, the majority of clinicians and researchers use the approach outlined by Buchanan and Bucheler (1995), used in this study.

There was negative correlation with age and body weight with VHS values in this study. There are different studies on VHS calculation available based on sex, breed, thoracic conformation and size of animals and radiographic diagnosis of cardiac diseases (Jepsen-Grant *et. al.*, 2013), but literature is scarce about the age wise differences and correlation of age and body weight in measurement of VHS. The VHS values in the two groups were not significantly different, might be due to the relationship between the size of the cardiac silhouette and changes in vertebral length (Sleeper and Buchanan, 2001). Breed or body conformation also should be considered while measuring the VHS (Marin *et. al.*, 2007).

There was significant difference in the CTR between the groups using the two approaches at the ventro-dorsal position. The measurement methods, which were linear measurement in Method I and area wise measurement in Method II, can be used to explain the highly significant variation. In the second way of measurement, there was no discernible difference between the two groups in either lateral recumbency, albeit there was a minor rise in values in the right lateral views. This indicates that the cardiac and thoracic areas grow in proportion to age and body weight. According to Torad and Hassan's second technique, CTR values in the ventro-dorsal position were higher in both cases compared to the right and left lateral recumbency positions. A study of the cardiothoracic ratio (CTR) measured for the Poodle breed by linear method showed mean values of 0.48±0.05 for male and 0.50±0.03 for female, and has demonstrated the strong positive correlation of CTR and VHS, which strongly support the use of CTR on a large scale. However, normal values of CTR in veterinary medicine for different breeds are not available (Azevedo *et al.*, 2016).

There was no significant difference in the CTR values between the groups and these values were negatively correlated with age and body weight in GSD. Similar findings were reported in non-human primates but the differences between different species of macaques were significant (Schillaci *et al.*, 2009). Although CTR has been widely used to describe heart size and associated prognosis in human medicine (Monfared *et al.*, 2015) but it is not as well-known and reliable in veterinary medicine as VHS. So a thorough study is required to establish the standard CTR values for healthy dogs of various breeds in order to check its reliability. Atrial size on the vertebral scale has been quantitatively assessed by two new techniques, VLAS and RLAD. These techniques could be useful for the veterinary field, where echocardiography is not easily accessible and VLAS e" 2.3v considered as

Table 1.3: Correlation of VHS and CTR with age and body weight in group 1 and II.

Parameter	Group I (Mean±SE)	Group II (Mean±SE)	Correlation with age	Correlation with body wt.
Right VHS^{NS}	9.41±0.09v	9.37±0.11v	-.092	-.114
Left VHS ^{NS}	9.29±0.09v	9.13±0.14v	-.195	-.198
CTR VD ^{NS} (Method I)	0.53±0.01	0.53±0.01	-.205	-.203
CTR VD ^{NS} (Method II)	0.44±0.01	0.43±0.01	-.055	-.058
Right CTR^{NS} (Method II)	0.41±0.01	0.40±0.01	.019	-.055
Left CTR^{NS} (Method II)	0.40±0.01	0.40±0.01	-.210	—.089

The superscript (NS) showed no significant difference (P≥0.05) between Mean±SE value of group I and group II

Table 2: Mean±SE of MHS, VLAS, RLAD and CSI in lateral thoracic radiographs of groups I and II.

Table 2.1: Manubrium heart Score (MHS)

Parameter	Right	Left
Group I		
ML^{NS} (mm)	28.87±2.11	28.67±2.03
SMHS^{NS}	2.96±0.16	2.98±16
LMHS^{NS}	3.53±0.20	3.40±0.18
Over all MHS^{NS}	6.48±0.36	6.37±0.33
Group II		
ML^{NS} (mm)	43.73±1.60	43.47±1.58
SMHS^{NS}	2.21±0.08	2.19±0.07
LMHS^{NS}	2.73±0.10	2.69±0.10
Over all MHS^{NS}	4.92±0.18	4.86±0.17

Table 2.2: Vertebral left atrial size (VLAS) and Radiographic left atrial dimension (RLAD)

Parameter	Right	Left
Group I		
VLAS^{NS}	1.56±0.07 v	1.70±0.07 v
RLAD^{NS}	1.56±0.05 v	1.57±0.05 v
Group II		
VLAS^{NS}	1.70±0.06 v	1.75±0.07 v
RLAD^{NS}	1.71±0.06 v	1.58±0.08 v

Table 2.3: Cardiac Sphericity Index (CSI); Parameter (%)

Parameter	Right	Left
Group I		
SAL/Cardiac dia.^{NS} (mm)	81.33±2.82	81.53±2.71
LAL/Cardiac length^{NS} (mm)	97.07±4.01	93.13±3.39
CSI^{NS} (%)	84.48±1.83	87.80±1.05
Group II		
SAL/Cardiac dia.^{NS} (mm)	95.27±1.84	94.80±1.76
LAL/Cardiac length^{NS}(mm)	117.73±2.33	113.40±2.80
CSI^{NS} (%)	80.99±1.05	83.73±1.10

The superscript (NS) showed no significant (P≤0.05) difference between right and left lateral view.

a useful indicator of enlargement of left atrium. (Malcolm *et al.*, 2018; Salguero *et al.*, 2019).

Previously quantitative evaluation of the tracheal bifurcation angle was used to distinguish between dogs with normal and enlarged left atriums. Significant differences between the two groups of dogs were found, but the measurement's low sensitivity rendered it ineffective for diagnosing left atrial enlargement (Le Roux *et al.*, 2012).

When the vertebral left atrial size (VLAS) was measured, there was no significant difference between the right and left lateral recumbency in either group, but higher values were discovered in the left lateral recumbency group. This finding suggests a positive but insignificant correlation between the VLAS and age and body weight, and this correlation may be caused by the enlarged heart shape with age and body weight. Slight increased values in left lateral recumbency have the probability of increased distance of carina to the caudal vena cava in left lateral radiographs.

Although all of the values in the recumbency and between the groups were non-significant, the results of the RLAD values could not be used to draw a specific pattern of normal values. Since the dorsolateral boundary of the left atrium was obscured by overlapping bronchioles and vascular structures in this investigation, there is a chance that the variation in the measurement of RLAD in both the recumbency and groups was inaccurate.

MHS showed a highly significant difference between the groups and highly significant negative correlation was also found with age and body weight in lateral recumbency. Manubrium length (ML) showed the highly positive correlation with age and body weight. Short MHS and long MHS showed the highly negative correlation with age and body weight hence overall MHS also showed the highly negative correlation. Previously the MHS has been calculated for cardiac diseases in comparison to control group of dogs (Mostafa *et al.*, 2020). Manubrium is a prominent and elongated bone segment that can be easily identified on lateral thoracic radiograph rarely affected by disease as intervertebral disc and congenital anomalies makes the inaccurate calculation of VHS (Jepsen-Grant *et al.*, 2013). So manubrium length is a useful reference point to measure the cardiac short and long axis in dogs (Mostafa and Berry, 2017)

Cardiac sphericity index (CSI) differed significantly in both groups. Cardiac short axis length and long axis length were highly positively correlated

Table 3: Correlation of MHS, VLAS, RLAD and CSI with age and body weight in group 1 and II.

Table 3.1: Manubrium heart Score (MHS)

Parameter	Group I (Mean±SE)	Group II (Mean±SE)	Correlation with Age	Correlation with body wt.
Right ML** (mm)	28.87±2.11	43.73±1.60	.661**	.743**
Right short MHS**	2.96±0.16	2.21±0.08	-.594**	-.604**
Right long MHS **	3.53±0.20	2.73±0.10	-.557**	-.593**
Right over all MHS**	6.48±0.36	4.92±0.18	-.577**	-.591**
Left ML** (mm)	28.67±2.03	43.47±1.58	.683**	.745**
Left short MHS**	2.98±16	2.19±0.07	-.605**	-.587**
Left long MHS**	3.40±0.18	2.69±0.10	-.549**	-.507**
Left over all MHS**	6.37±0.33	4.86±0.17	-.578**	-.575**

Table 3.2: Vertebral left atrial size (VLAS) and radiographic left atrial dimension (RLAD

Parameter	Group I (Mean±SE)	Group II (Mean±SE)	Correlation with Age	Correlation with body wt.
Right VLAS^NS	1.56±0.07	1.70±0.06	.015	.100
LEFT VLAS^NS	1.70±0.07	1.75±0.07	.012	.002
Right RLAD^NS	1.56±0.05	1.71±0.06	.064	.214
Left RLAD^NS	1.57±0.05	1.58±0.08	.219	-.115

Table 3.3: Cardiac Sphericity Index (CSI)

Parameter	Group I (Mean±SE)	Group II (Mean±SE)	Correlation with Age	Correlation with body wt.
SAL / Cardiac dia. ** (mm)	81.33±2.82	95.27±1.84	0.481**	0.799**
LAL / Cardiac length**(mm)	97.07±4.01	117.73±2.33	0.462*	0.657**
Right CSI*(%)	84.48±1.83	80.99±1.05	-0.157	-0.009
SAL / Cardiac dia. ** (mm)	81.53±2.71	94.80±1.76	0.507**	0.798**
LAL / Cardiac length**(mm)	93.13±3.39	113.40±2.80	0.544**	0.752**
Left CSI * (%)	87.80±1.05	83.73±1.10	-0.304	-0.228

**Correlation is significant at the P≤0.01 level. *Correlation is significant at the ≤0.05 level, mean value **is significant at the P≤0.01 level, **mean value is significant at the ≤0.05 level. The superscript (NS) showed no significant (P≤0.05) difference between Mean±SE value of group-I and group-II

with age and body weight in both groups. In contrast to that negative correlation was observed for CSI value suggesting that proportionate increase in cardiac long axis is more proportion as compared to short axis. Cardiac sphericity index (CSI) has been calculated earlier and recommended that MHSs values could be added for screening of cardiac diseases (Mostafa *et al.*, 2020).

To conclude, the reference values of various cardiac parameters were established and correlated with age and body weight in German shepherd dogs. These parameters are useful to evaluate the cardiac size for the veterinary field where echocardiography is not easily accessible. Further research may strengthen this study and will be highly useful in diagnosis and prognosis of cardiac disorders in dogs.

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