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Radiographic evaluation of caudal vena cava, aorta and associated ratios in apparently healthy German shepherd dogs

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Abstract
The current study was conducted for radiographic evaluation of caudal vena cava and aortic sizes of eight apparently healthy German shepherd dogs free from cardiothoracic disorders and three dogs that had cardiac problems. The course of caudal vena cava passing through abdomen into right atrium makes it visible on lateral radiograph. Thus on a lateral radiograph, the CVC to descending aorta ratio, fourth thoracic vertebra length, and fourth rib width are helpful predictors of right heart illness. To examine the caudal vena cava (CVC) and aortic (Ao) parameters, the animals were subdivided into two groups; group-I containing healthy animals and group-II contained animals with cardiac abnormalities). Mean±S.E values of body weight and age were measured 26.80±1.26 (range 22-33.2) kg and 55.00±3.62 (range 36-72) months and 36±1.53 (range 34-39) kg and 68±4.00 (range 60-72) months in animals of the group-I and II, respectively. The majority of the parameters between group I and group II animals were found to be non-significant. The goal of this study was to establish standard values (ranges) for CVC and aortic parameters.

Keywords: Cardiothoracic, caudal vena cava, aortic, dogs

Introduction
Thoracic Radiography is one of the most commonly used and easily accessible diagnostic modality for suspected cases of cardiac or respiratory illness, it is also used as a screening tool for non-specific clinical symptoms and when blood tests reveal an inflammatory process. In most species, there is a wealth of literature on the thoracic radiographic appearance. A greater grasp of normal canine thoracic radiology will allow for more accurate disease assessment. Thoracic radiographs provide valuable information related to cardiac morphometry like cardiac size, gross cardiac chamber abnormalities, alteration in the size and appearance of great vessels, distortion of the pulmonary and cardiovascular vessel size, abnormalities of the chest wall, pleural space, and the lung particularly the bronchi, interstitial spaces and alveolar tissues (Fox, 2007) [2]. Such information can help distinguish primary cardiac illness from respiratory issues in case of coughing dogs (Spier, 2011) [9] and, as a result, direct a case's therapeutic approach. Despite of the fact that echocardiography currently plays a considerable role in the diagnosis of cardiac diseases, thoracic radiography is still used to evaluate the cardiovascular system.

On a lateral thoracic radiograph, the caudal vena cava can be seen descending from the abdominal cavity to the right atrium. Although absolute CVC size comparisons across dogs are impossible, ratios of CVC size to other anatomic structures may be beneficial in providing a quantitative estimate of CVC size. The purpose of this study was to determine CVC size in dogs with and without overt heart illness, as well as dogs with cardiac disease with physical examination evidence of pressure irregularities, and to determine the mean results and suggest the range of expected normal values for radiographic parameters related to the cardiac size in German shepherd dogs.

Materials and Methods
The present research was conducted in the Teaching Veterinary Clinical Complex, Kothari Veterinary Hospital, College of Veterinary Science and Animal Husbandry, U.P. Pandit Deen Dayal Upadhyaya Pashu-Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, Mathura (U.P.).

I) Selection of animals

Present study was conducted on clinically healthy dogs. The study was carried out into two phases each containing animals with average age of 4 yrs (2-6 yrs) and average body weight of 20 kg (15-35 kg).

Phase I: Eight apparently healthy medium size German shepherd dogs (GSD) free from cardiothoracic diseases presented to the Teaching Veterinary Clinical Complex.

Phase II: The clinical cases of cardiothoracic affections diagnosed in GSD during study period of two years (Three GSD dogs).

Criteria for selection of animals

The dogs had normal physiological parameters were considered healthy and selected for the present study. Temperature (°F), Respiratory rate (breaths/min), Heart rate (beats/min), Pulse (beats/min) were recorded using a digital thermometer, observing thoracic excursions, stethoscope, auscultation using a clinical stethoscope and palpation of femoral artery respectively (Table1).

II) Radiography

The X-rays machine (Heliophos-D, Siemens Healthineers India) and computed radiography system (Regius Model 110 S with Regius direct digitizer software, Konica Minolta Healthcare, India) were used to obtained good quality radiography. Lateral radiographs were taken on fixed 90 cm focal-film distance (FFD) and 320 mA, 9.5-13 mAs and 58-63 KVP. The cassettes (14 x 17 inches) were horizontally oriented to obtain the Right lateral radiographs for complete visualization of the thorax from spine to sternum and first rib to diaphragm.

A) Length of the fourth thoracic vertebra (T_4), width of fourth rib (R_4), Caudal vena cava (CVC) diameter and aorta (AO) diameter

The length of the fourth thoracic vertebra (T4) was measured from the cranial endplate to the caudal endplate, and the width of the right fourth rib (R4) was measured directly ventral to the spine.

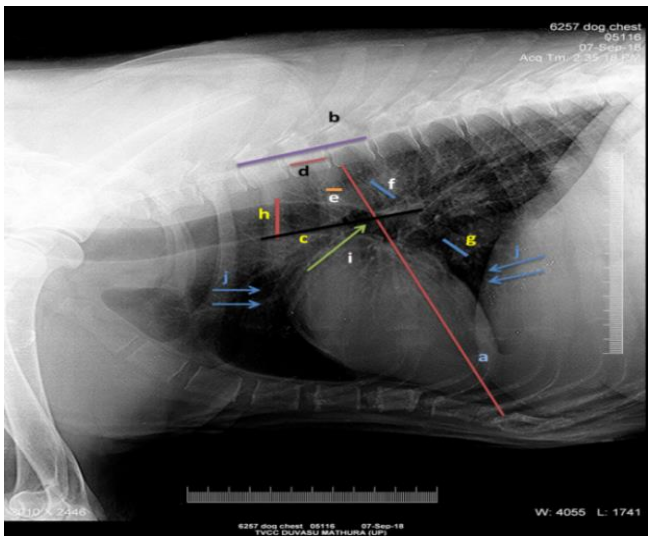

Fig 1: Right lateral thoracic radiographs showing the measurement landmarks of cardiothoracic height (a), T_3-T_5 (b), R_3-R_5 (c), T_4 (d), R_4 (e), diameter of aorta (f), diameter of caudal vena cava (g), tracheal diameter (h), location of carina (i), location of heart (j).

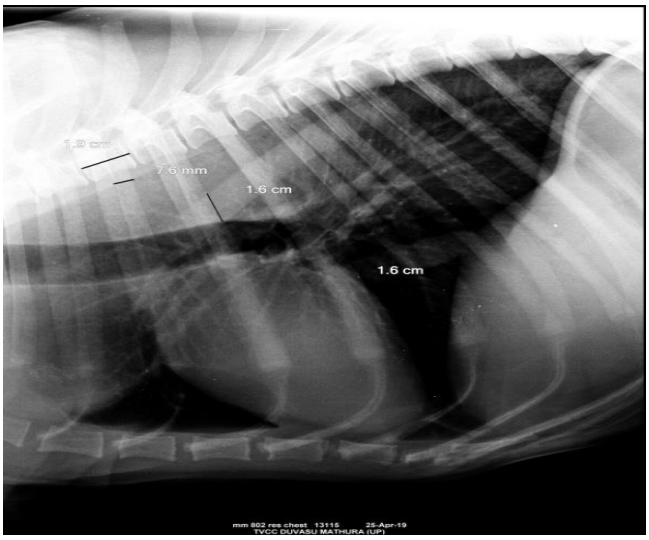

Fig 2: Right lateral thoracic radiographs showing the measurement landmarks of T_4, R_4, diameter of aorta and caudal vena cava

The diameter of the caudal vena cava was measured from ventral to dorsal boundaries at the region of greatest diameter, without overlapping the heart or diaphragm, and at the same intercostals space (5th ICS) as the caudal vena cava. (Lehmukhl *et al*., 1997) [3] (Fig.1). From these measurements the following ratios were calculated-

1. CVC/Ao
2. CVC/T_4
3. CVC/R_4
4. Ao/ T_4
5. Ao/R_4

III) Statistical analysis

The mean and standard error for each set of radiographic, electrographic and echocardiographic parameters were calculated. These parameters were compared in group-I and group-II. Bivariate Pearson's correlation test was used to establish the correlation of various radiographic, electrographic and echocardiographic parameters with body weight and age of animals (Snedecor and Cochran, 1994) [8]. The level of statistical significance was set at $p>0.05$ or $p>0.01$.

Result and Discussion

Table 2 provides the mean and range of various ratios, including CVC/AO, CVC/VL, CVC/R4, AO/VL, and AO/R4. Out of 11 radiographs, one case in Group II could not have CVC and AO measures obtained because the segment's radiographic sharpness was insufficient. The ratios were subsequently computed in 10 cases. Mean±S.E. values of aorta (AO) diameter, caudal vena cava (CVC) diameter, length of fourth thoracic vertebrae (T_4) and width of fourth thoracic rib (R_4) were 1.71±0.10 (range 1.2 - 2) cm, 1.65±0.10 (range 1.1 - 2) cm 2.03±0.05 (range 1.8 - 2) cm and 0.85±0.05 (range 0.6 - 1.1) cm, respectively in animals of the group-I (Fig.2; Table2). Non-significant ($p\geq0.05$) positive correlation of aorta (AO) diameter, caudal vena cava (CVC) diameter with age and non-significant ($p\geq0.05$) negative correlation with body weight was found. Non-significant ($p\geq0.05$) negative correlation of both T_4 and R_4 with body weight and age was found.

Mean±S.E. values of aorta (AO) diameter, caudal vena cava (CVC) diameter length of fourth thoracic vertebrae (T_4), width of fourth thoracic rib (R_4) were 2±0 (range 0-2) cm,

1.85±0.05 (range 1.8 - 1.9) cm, 2.13±0.07 (range 2 - 2.2) cm and 0.98±0.17 (range 0.73-1.3) cm, respectively in animals of the group-II (Fig.2; Table 2).

Mean±S.E. values of CVC/AO, CVC/ T_4, CVC/ R_4, AO/ T_4 and AO/ R_4 were 0.96±0.02 (range 0.92 - 1.05), 0.81±0.04 (range 0.58 - 0.95), 2.00±0.19 (range 1.28 - 2.83) 0.84±0.04 (range 0.63 - 0.95) and 2.07±0.18 (range 1.4 - 3), respectively in animals of the group-I (Fig.2; Table 2).

Non-significant ($p \geq 0.05$) negative correlation of CVC/AO with body weight and age was found. Non-significant ($p \geq 0.05$) positive correlation of CVC/ T_4, CVC/ R_4, AO/ T_4 and AO/ R_4 with body weight and age was found.

Mean±S.E. values of CVC/AO, CVC/ T_4, CVC/ R_4, AO/ T_4 and AO/ R_4 were 0.93±0.03 (range 0.9 - 0.95), 0.88±0.02 (range 0.86 - 0.9), 1.96±0.50 (range 1.46 - 2.47) 0.95±0.05 (range 0.91 - 1) and 2.14±0.60 (range 1.54 - 2.74), respectively in animals of the group-II (Fig. 2; Table 2).

Table 1: Mean±S.E. values of various clinico-physiological parameters in dogs of group-I and II.

Case no.	Body weight (Kg)	Age (months)	Temperature F	Respiratory system		Cardiovascular system			
				Respiratory rate (breaths/min)	Lung auscultation	Heart rate	Rhythm	Pulse rate (bpm)	Pulse quality
Group-I									
1.	33.2	72	100.5	34	NAD	88	Regular	96	Regular, Strong
2.	24.9	54	101.4	39	NAD	84	Regular	93	Regular, Strong
3.	23.8	48	101.2	26	NAD	90	Regular	86	Regular, Strong
4.	22	36	100.8	29	NAD	79	Regular	88	Regular, Strong
5.	29.3	60	101.0	26	NAD	74	Regular	85	Regular, Strong
6.	29	58	100.6	33	NAD	86	Regular	91	Regular, Strong
7.	26.7	56	100.4	31	NAD	86	Regular	93	Regular, Strong
8.	25.5	56	101.4	35	NAD	84	Regular	93	Regular, Strong
Mean±S.E.	26.80±1.26	55.00±3.62	100.91±0.14	31.63±1.60		93.63±4.16		90.63±1.37	
Correlation with age	0.938	1	-0.496	0.135		-0.150		0.409	
Correlation with body weight	1	0.938	-0.277	0.310		-0.432		0.534	
Group- II									
1.	35	72	102	45	AD	56	Irregular	-	Irregular, Feeble
2.	39	60	103.2	52	AD	65	Irregular	-	Irregular, Feeble
3.	34	72	102.6	49	AD	71	Irregular	-	Irregular, Feeble
Mean±S.E.	36±1.53	68±4.00	102.6±0.35	48.67±2.03		64±4.36	-	-	-

*Correlation is significant at the 0.01 level, ** Correlation is significant at 0.05 level

Table 2: Mean±S.E. values of various cardiac parameters and their ratio with vertebrae and rib in right lateral thoracic radiographs in dogs of group-I and II.

Case no.	AO (cm)	CVC (cm)	T_4 (cm)	R_4 (cm)	CVC/AO	CVC/ T_4	CVC/ R_4	AO/ T_4	AO/ R_4
Group-I									
1.	1.8	1.7	1.8	0.6	0.94	0.94	2.83	1	3
2.	1.9	2	2.1	0.77	1.05	0.95	2.6	0.90	2.47
3.	1.4	1.4	2	0.84	1	0.7	1.67	0.7	1.67
4.	2	1.9	2.2	0.95	0.95	0.86	2	0.91	2.11
5.	1.8	1.8	2.2	0.83	1	0.82	2.17	0.82	2.17
6.	2	1.7	2.1	1.1	0.85	0.81	1.55	0.95	1.82
7.	1.6	1.6	1.9	0.82	1	0.84	1.95	0.84	1.95
8.	1.2	1.1	1.9	0.86	0.92	0.58	1.28	0.63	1.4
Mean±S.E.	1.71±0.10	1.65±0.10	2.03±0.05	0.85±0.05	0.96±0.02	0.81±0.04	2.00±0.19	0.84±0.04	2.07±0.18
Correlation with age	0.178	0.057	-0.422	-0.394	-0.279	0.315	0.424	0.462	0.549
Correlation with body weight	-0.062	-0.106	-0.580	-0.524	-0.131	0.195	0.389	0.260	0.463
Group-II									
1.	2	1.9	2.2	1.3	0.95	0.86	1.46	0.91	1.54
2.	--	--	2.2	0.91	--	--	--	--	--
3.	2	1.8	2	0.73	0.9	0.9	2.47	1	2.74
Mean±S.E	2±0	1.85±0.05	2.13±0.07	0.98±0.17	0.93±0.03	0.88±0.02	1.96±0.50	0.95±0.05	2.14±0.60

* Correlation is significant at the 0.01 level, ** Correlation is significant at 0.05 level

The CVC's width is affected by both individual and physiological factors (Suter and Lord, 1984; Root and Bahr, 1998; Owens and Biery, 1999) [10, 6, 5]. CVC/Ao, CVC/T_4, and CVC/R_4 ratios revealed that dogs with right heart disease had greater caudal vena cava sizes than normal dogs. A larger CVC, as well as a narrow aorta, may have contributed to the higher CVC/Ao ratio. It's possible that a small aorta develops as a result of the diminished output caused by the underlying heart illness. CVC size as a ratio to the Ao, VL, or R_4 on radiographic examination may offer a diagnostic indication that right-sided cardiac abnormalities are present.

A right-sided pressure abnormality should be evaluated if a CVC/Ao > 1.25, CVC/VL > 1.00, or CVC/R_4 > 3.00 is observed, since each of these values is roughly twice as likely to be seen in a dog with a right-sided heart abnormality It's highly likely that a patient with a CVC/Ao > 1.50, CVC/VL >

1.30, or CVC/R_4 > 3.50 has a right-sided cardiac defect. However, the absence of a higher CVC ratio does not rule out the possibility of right-sided congestive heart failure (Lehmkhul *et al*., 1997) [3].

The ratio of CVC/R_4 was found to be lowest in Pomeranians (1.56±0.26) but highest in German shepherds i.e., 2.03±0.16. However, no statistical difference was found in this ratio among different breeds of dogs (Sharma D., 2018) [7]. Lehmkuhl at al. (1997) [3] also found the Ao/T_4 ratio smaller in dogs with right heart disease. These ratios are helpful in evaluating the cardiac diseases. Losonsky *et al* (1983) [4] reported mean CVC/R4 ratio as 2.07±0.69 in normal cardiac size of dogs. Whereas, it was 2.25±0.64 in cases of moderately enlarged hearts and 2.60±.68 in severely enlarged hearts. Similarly, Thrall and Calvert (1983) [11] reported CVC/R4 ratio as 2.95±0.76 in 28 dogs with history of heartworm disease and right heart failure. In a different study performed on 19 dogs Arya M *et al* (2021) [1] reported Mean CVC/AO ratio to be 0.79±0.22, CVC/VL as 0.68±0.21; CVC/R4 as 1.63±0.44; AO/VL as 0.84±0.12 and AO/R4 as 2.05±0.32.

The range of CVC/AO and CVC/VL in the current study surpassed the values recommended to categorically deem the dogs normal, even if the greater range of these ratios remained lower than those suggestive of right-sided cardiac abnormalities as per both of the studies described above. The mean readings, however, generally stayed within the usual range. Additionally, in one case, the CVC/R4 ratio was noticed to be quite close to the mean reported by Losonsky *et al* (1983) [4] in cases of severely enlarged hearts in dogs, despite the fact that the heart size in that particular dog was considered normal based on VHS and other parameters and it exhibited no clinical signs of cardiomegaly. The value of CVC/Ao, CVC/T_4 and CVC/R_4 were within the normal limit and were in agreement with the findings proposed by Losonsky *et al* (1983) [4], Thrall and Calvert (1983) [11], Lehmkuhl *et al*. (1997) [3], Sharma D. (2018) [7],

In terms of the AO/R4 ratio, Lehmkuhl *et al*. (1997) [3] noted an insignificant difference in this ratio in between right-side heart disease (2.36 0.52) and healthy (2.22±0.42) dogs. In the present study, the AO/VL ratio of healthy dogs remained in between the mean values for healthy and the ones with right side heart disease as reported by Lehmkuhl *et al* (1997) [3]

Due to changes in measuring technique, some disparity between our results and those of the earlier researches is to be expected ((Losonsky *et al*., 1983; Thrall and Calvert, 1983) [4, 11]. The diameter of R_4 immediately ventral to the spine was assessed in each investigation. In earlier investigations, the CVC was measured at the level of the ninth intercostal space or ninth rib, whereas we measured it at its widest point (varying from the fifth to the ninth intercostal space). In this study, the ninth intercostal space was caudal to the line of measurement, and the aorta was not as evident there. The lower average ratios in past research might be due to these variables.

Conclusion

CVC size as a ratio to the Ao, VL, or R4 on radiographic examination may offer a diagnostic indication that right-sided cardiac abnormalities are present. Non-significant ($p \geq 0.05$) positive correlation of aorta (AO) diameter, caudal vena cava (CVC) diameter with age and non-significant ($p \geq 0.05$) negative correlation with body weight was found. Positive correlation with age and body weight were observed in CVC/ T_4, CVC/ R_4, AO/ T_4 and AO/ R_4 while Negative correlation with age and body weight were observed in CVC/AO. Thus, as per the findings the reference values of caudal vena cava and aortic parameters obtained in this study can be utilised to diagnose cardiac affections in German shepherd dogs.

Conflict of Interest

"The Authors declares that there is no conflict of interest".

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