Indian J Anim Health (2025), 64(1): 140- 147
DOI: https://doi.org/10.36062/ijah.2025.06724

Research Article

Measurement of various retrocardiac thoracic indices in Labrador dogs using computed radiography (CR)

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Abstract

Present study was conducted on client owned 24 healthy and cardiac affected Labrador dogs of either sex; the animals were divided into two groups each containing 12 animals. In group-I, healthy dogs that were free from cardiothoracic disease and in group-II, cardiac affected dogs (diagnosed by clinical signs, biochemical test and electrocardiography). Quantitative assessment of various radiographic cardiothoracic indices was done in both the groups by using 500mA X-Ray machine (EP-CORSA 40 kw/Epsilon Health care solutions Pvt. Ltd). A complete radiographic examination of the thorax was done in right lateral (RL) or left lateral (LL) and dorso-ventral (DV) or ventro-dorsal (VD) views by including thoracic inlet, manubrium, all the thoracic vertebrae, complete cardiac silhouette, sternum and diaphragm. The radiographs were evaluated quantitatively and abnormal radiographs having severe lung effusions and cardiac effacement were excluded from the study tracheal (TrD) and Thoracic inlet (ThID) diameter, cardiac inclination angle, cardiosternal contact, cardio-phrenic contact, caudal vena cava (CVC) diameter, costo phrenic angle, tracheal inclination angle, distance between the thoracic wall and the cardiac silhouette, thoracic depth (TD), width (TW) and thoracic length (TL) based on findings it can be concluded that all the indices did not show any significant change in both the groups as well as comparable radiographic views in all the indices.

Keywords: Cardiac, Radiography, Thoracic

Highlights

- Quantitative assessment of radiographic cardiothoracic indices
- Cardiac affected Labrador dogs

INTRODUCTION

A frequently utilized and easily available diagnostic tool in small animal is radiography. It is an affordable, accessible, and secure way for doing preliminary research. Radiographic measurement of different thoracic parameters quantitatively in healthy dogs may act as a reference range for the evaluation of the pathological conditions of the thoracic cavity without much variation of age and body weight (Mishra *et al*., 2020; Ninama *et al*., 2024). Thoracic radiography is a common non-invasive diagnostic tool for both cardiac and non-cardiac thoracic structures (Houdellier *et al*., 2018). It is convenient and important diagnostic tool to evaluate the cardiovascular system. It allows a fast and little invasive assessment to obtain valuable information on the lung fields, cardiac silhouette, vascularization (Root and Bahr, 2002; Azevedo *et al*., 2016). It is one the most widely used tools for diagnosis for the clinical assessment of dogs that might suffer cardiothoracic disease (Marin *et al*., 2007). To obtain a complete diagnosis, a comprehensive clinical evaluation that includes laboratory, physical, and historical clinical tests must always come before the radiographic examination. Important details regarding the thoracic musculoskeletal conformation and conditions, pleural changes, lung and vascular patterns, and cardiac size, shape, and contour can be obtained via thoracic radiography (Fox, 2003).

To view the heart mediastinum, complete lungs parenchyma, lateral dorsal-ventral position and ventro-dorsal exposures are required (Hornof and Koblik, 2011). The recumbency of the animals either in ventral or dorsal are related to the appearance of the thoracic structures. Pulmonary vessels and cardiac silhouette are evaluated in dorso-ventral recumbency, while lungs are evaluated in ventro-lateral recumbency in cases of pleural effusions (Suter and Lord, 1984).

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Assessment of the cardiac silhouette is done in reference to size and shape or for subjective and objective evaluation (Puccinelli *et al*., 2020). Subjective methods are used in the majority of radiography evaluations of cardiovascular structures. But there are now quantitative techniques for assessing heart dimensions (Root and Bahr, 2002). Quantitative measurements provide more reliable results when analyzing thoracic radiographs than subjective methods, particularly in cases of preclinical and mild disorders linked to organ size anomalies (e.g., cardiac) (Ukaha *et al*., 2021).

Thoracic width, depth, and inlet measurement can help assess the form of the thorax in each breed of dog and its influence on the measurement of various cardiothoracic parameters (Jepsen-Grant *et al*., 2013). Thoracic conformation can be measured by thoracic depth: width measurement, Buchanan and Bucheler (1995). Right lateral recumbency is for depth measurement and dorso-ventral radiographs are recommended for width measurement (Avner and Kirberger, 2005). Numerous studies use measurements of the thoracic intake diameters, the tracheal diameter, and their ratio to determine the state of coughing, the tracheal collapse, and the relationship between respiratory pathology and tracheal diameter change (Lee *et al*., 2017). A number of cardiovascular conditions caused the right side of the hear enlargement, which in turn caused the caudal vena cava (CVC) to enlarge (Bhargavi *et al*., 2018). Right ventricular hypertrophy is suggested by sternal contact exceeding 3.0 intercostal spaces, which is typical for exotic dogs, which have cardiac contact with the sternum ranging from 2.5 to 3.0 intercostal spaces (Ukaha *et al*., 2021). Cardio-sternal and cardio-phrenic contact may be utilized to detect thoracic hyperinflation or evaluate microcardia (Kealy *et al*., 2011). Cardiac inclination angle has diagnostic importance in clinical medicine because progressive increase in the size of right ventricle can change the heart shape and decrease the cardiac inclination angle to the sternum (Kealy *et al*., 2011). Tracheal angle assessment is an indirect method for evaluation of the heart size by quantitative method; radiographic signs in cardiomegaly can be evident by reduced tracheal angle (Mattoon *et al*., 2001).

The accuracy of radiographic diagnosis of thoracic pathology is based on changes in the normal radiographic anatomy of the cardiac silhouette and other thoracic structures like lung field, changes in mediastenum position, trachea position and cardiac attachments with the surroundings in thoracic cavity, which are also reflected in the dimensional changes of different quantitative parameters (Lord and Suter, 1999). So present study was undertaken for measurement of various radiographic thoracic indices in Labrador dogs.

MATERIALS AND METHODS

Present study was conducted on 24 clients owned adult healthy and cardiac affected Labrador dogs of either sex presented to Veterinary clinical complex (VCC) PGIVER, Jaipur. The healthy and cardiac affected dogs were selected based on clinical signs, physiological viz. Temperature (°F), Respiratory rate (breaths/min) and heart rate (beats/min), hematological, biochemical and electrocardiographic (ECG) examination as shown in Fig. 1 to 3. All the animals were categorized into two groups; 12 animals in each group. In GroupI- healthy dogs free from cardiothoracic diseases and in Group II- Cardiac affected dogs, diagnosed by their clinical signs, electrocardiography, biochemical and hematological parameters. A complete radiographic examination of the thorax was done in right lateral (RL) or left lateral (LL) and dorso-ventral (DV) or ventro-dorsal (VD) views by including thoracic inlet, manubrium, all the thoracic vertebrae, complete cardiac silhouette, sternum and diaphragm. All the radiographs were taken without sedation and only those radiographs in which cardiac silhouette and lungs parenchyma were clearly demarcated, were selected for the study in both the groups. Radiographic images were acquired after exposure using a Computed radiography (CR) system (FCR-CAPSULA XLII) for the evaluation. Thoracic inlet diameter (ThID) and Tracheal Diameter (TrD); the diameter of thoracic inlet (ThI) was measured from the first thoracic vertebra to the dorso-cranial aspect of the manubrium and the tracheal diameter (TrD) was measured where the thoracic inlet line intersects the trachea (Mostafa and Berry, 2022) as shown in Fig. 4. Cardiac Inclination angle; the angle of cardiac inclination was formed by the cranial border of the heart and the dorsal margin of the sternum as described by (Mishra *et al*., 2020) as shown in Fig. 5. Cardiosternal contact was measured by the number of sternebrae contact with the cardiac silhouette. Cardiosternal contact points were recorded to the nearest 0.05 intercostal space (Ninama *et al*., 2022) as indicated in Fig. 4. The measurement of the cardio-phrenic contact, determined by the distance from the apex of the heart to the dorsal-most point of intersection of the cardiac silhouette with diaphragm (Babicsak *et al*., 2017) as shown in Fig. 5. Caudal vena cava (CVC) was measured as described by Jojima *et al*. (2019). The CVC was measured where the vessel overlapped with the caudal border of the heart having greatest diameter as shown in Fig. 6. The costo-phrenic angles were measured from the right and left sides through the ventrodorsal or dorsoventral projection of the thoracic cavity (Ninama *et al*., 2022) as shown in Fig. 7. Tracheal inclination angle; tracheal angle was determined by drawing lines along the dorsal border of the trachea and the ventral margin of the cranial thoracic vertebrae and measuring the resultant angle as described by Mattoon *et al*. (2001) and Ninama *et al*. (2022) indicated in Fig. 5. DV or VD projection were used to measure the distance between cardiac silhouette and thoracic wall on right and left side Alves *et al*. (2012) as shown in Fig. 8. Right lateral radiographic views were used to measure the thoracic depth (TD) by measuring the connecting line from ventral border of vertebral column to cranial border of xiphoid process as shown in Fig. 9. Dorso-ventral radiographs were used to measure the width (TW) of thorax by measuring the distance of medial borders of eights rib at their curvatures (Ninama *et al*., 2022; Ahn *et al*., 2023). The thoracic cavity (TL) length was measured in ventrodorsal or dorsoventral projection radiographs, by the distance between the thoracic inlet and the most cranial portion

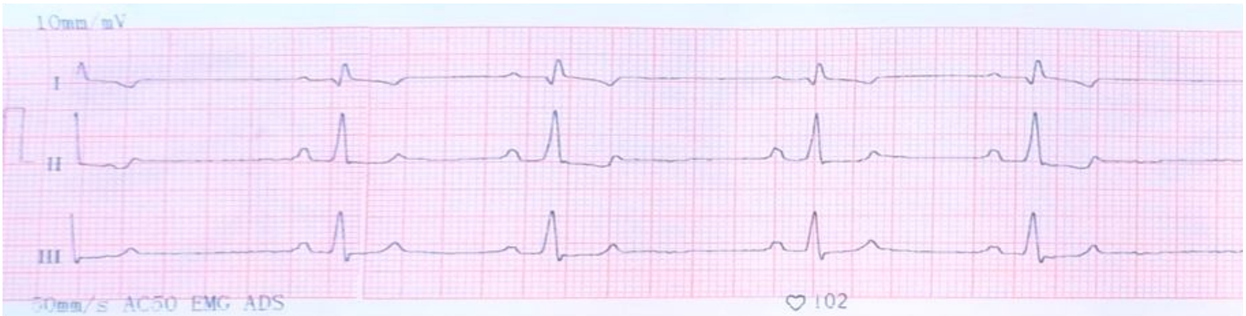

Fig. 1. ECG from a Labrador showing a normal sinus rhythm at a rate of 102/min (50 mm/s and 10 mm/mV)

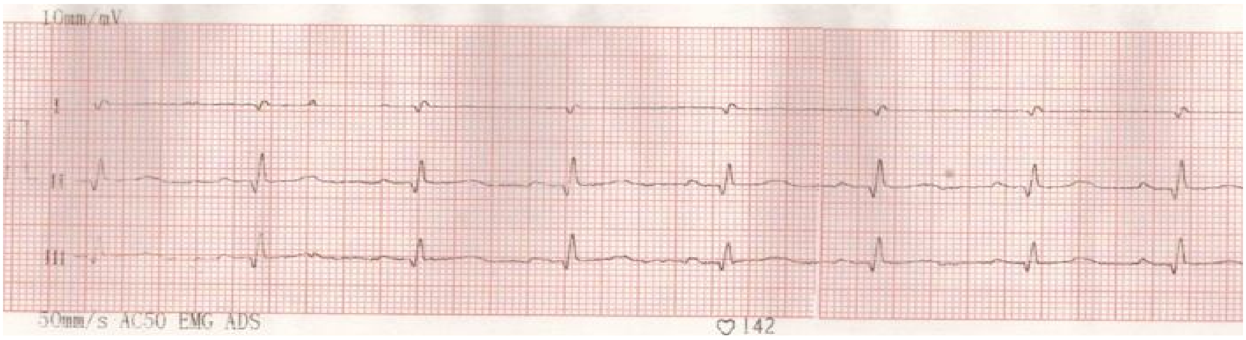

Fig. 2. ECG from a Labrador showing a Low voltage QRS-complex (amplitude <0.5 mV) at a rate of 102/min (50 mm/s and 10 mm/mV) a case of pericardial effusion

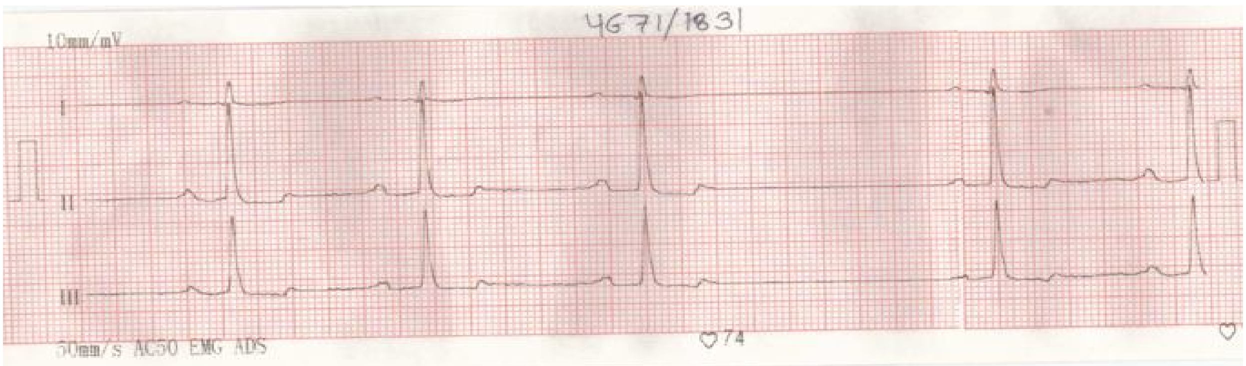

Fig. 3. ECG from a Labrador showing sinus block (a pause is twice of the R–R interval) at a rate of 74/min (50 mm/s and 10 mm/mV)

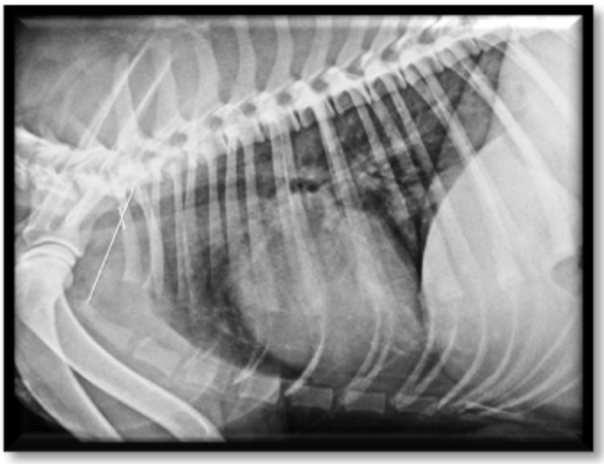

Fig. 4. Tracheal diameter (TrD) the diameter of thoracic inlet diameter (ThID) and Cardio sternal contact

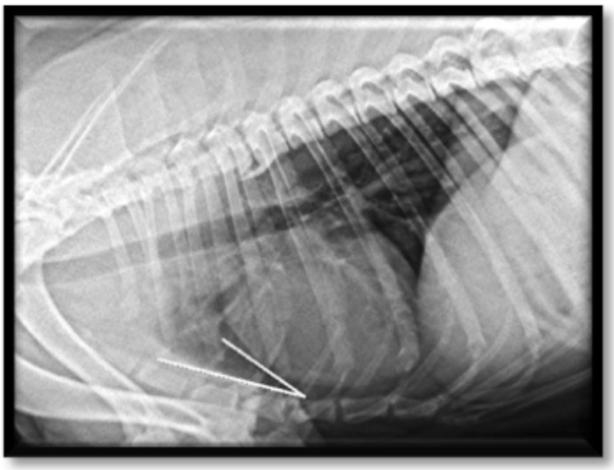

Fig. 5. Tracheal inclination angle, Cardiac inclination angle and cardio phrenic contact

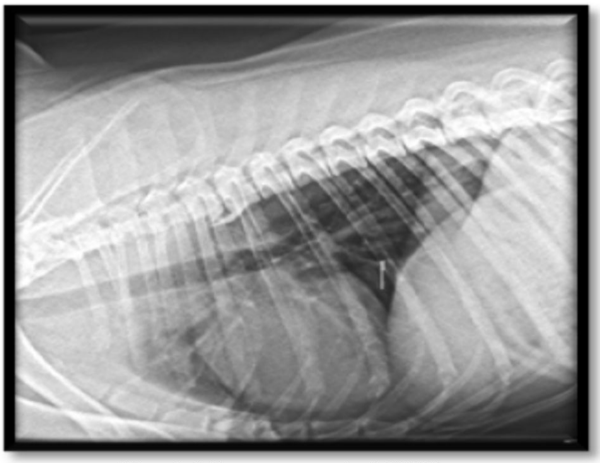

Fig. 6. Measurement of CVC

Fig. 7. Measurement of costo-phrenic angles from the right and left sides

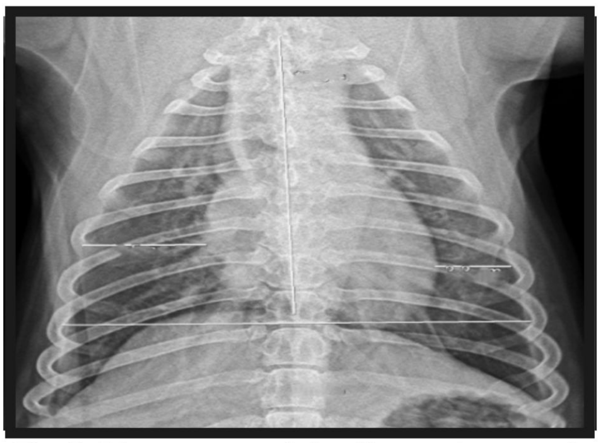

Fig. 8. Measurement of the distance between the thoracic wall and cardiac silhouette. Thoracic length and Thoracic width at the level of 8th thoracic ribs

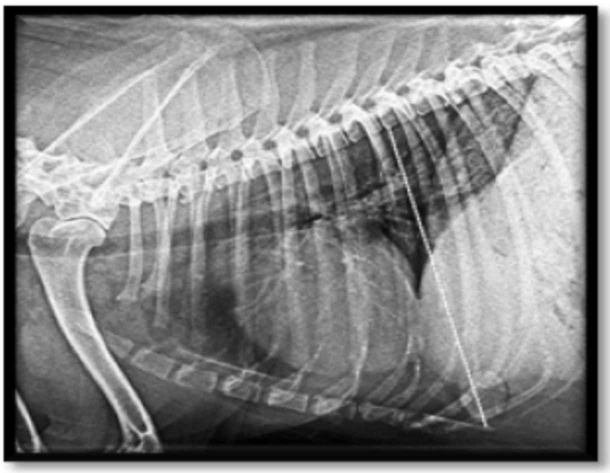

Fig. 9. Measurement of Thoracic depth (TD)

of the cupula of the diaphragm as described by Ninama *et al*. (2022) and Ahn *et al*. (2023) as shown in Fig. 8.

RESULTS

In the present study all the parameters of study did not show any significant difference. Values of cardiac inclination angle, tracheal inclination angle, costophrenic angle and distance between thoracic wall and cardiac silhouette in group -II were reduced as compare to group-I. Values of tracheal diameter, thoracic inlet diameter, cardiosternal contact, cardiophrenic contact, CVC diameter were non significantly increased in group-II as compare to group-I.

The mean (±SE) values of tracheal diameter (TrD) in group-I for right and left lateral view was 1.67±0.108and 1.68±0.098 and in group-II it was 1.66±0.103and 1.73±0.096.

The mean (±SE) values of thoracic inlet diameter (ThID) in group-I was 7.48±0.202 and 7.53±0.23 and in group-II, it was 7.60±0.316 and 7.78±0.26 for right and left lateral recumbency respectively. The difference between both the groups in right side and left side recumbency is non-significant (P> 0.05).

The mean (±SE) values of sternal contact in group-I was 2.68±0.119s and 2.38±0.115s and in group-II it was 2.86±0.141s and 2.74±0.178s for right and left lateral recumbency respectively. The difference of right and left lateral sternal contact between the groups was not significant (P>0.05). The mean (±SE) values of cardio phrenic contact in group I were 4.77±0.208s and 4.9±0.315s and in group-II it was 5.99±0.582s and 5.38±0.358s for right and left lateral recumbency respectively. The difference of right and left lateral cardio phrenic contact between the groups was not significant (P>0.05).

The mean (±SE) values of CVC diameter in group-I was1.64±0.11 and 1.92±0.104 and in group-II it was 1.92±0.081 and 2.02±0.064 for right and left lateral recumbency respectively. The difference between the right and left lateral recumbency was not significant in both the groups (P>0.05).

The mean (±SE) values of costo-phrenic angle in group-I was 32.33±1.544 degree and 33.33±1.554 degree. In group II, it was 28.33±2.571 degree and 30.67±2.179 degree for right and left side in dorsoventral view respectively. For ventro-dorsal view values was 31.58±0.763 degree and 34.25±1.28 degree in group-I and in group-II, it was 31.17±2.225 degree and 33.33±2.629 degree for right and left side.

The mean (±SE) values of tracheal inclination angle was measured in group-I; 12.58±0.908 and 13.08±0.773. In group-II, it was 10.50±0.883 and 12.00±0.798 for right and left lateral recumbency respectively. The difference between right and left lateral recumbency was not significant in both the groups (P>0.05). The mean (±SE) values of cardiac inclination angle in group-I was 22.42±0.668 degree and 24.00±0.508 degree and in group-II, it was 21.83±1.862 degree and 24.50±1.535 degree for right and left lateral recumbency respectively. The

Table 1. Mean (±SE) values of different parameters in group-I and II

S.No.	Parameters		Group-I	Group-II
1.	ThID (Right)^{NS}		7.48±0.202	7.60±0.316
2.	ThID (Left)^{NS}		7.53±0.23	7.78±0.26
3.	Tr. D. (Right)^{NS}		1.67±0.108	1.66±0.103
4.	Tr. D. (Left)^{NS}		1.68±0.098	1.73±0.096
5.	Cardiac inclination angle (Right)^{NS}		22.42±0.668	21.83±1.862
6.	Cardiac inclination angle (Left)^{NS}		24.10±0.508	24.00±1.535
7.	Cardio Sternal Contact ^{NS} (Right)		2.68±0.119	2.86±0.141
8.	Cardio Sternal Contact ^{NS}(Left)		2.38±0.115	2.74±0.178
9.	Cardio Phrenic Contact ^{NS} (Right)		4.77±0.208	5.99±0.582
10.	Cardio Phrenic Contact ^{NS} (Left)		4.9±0.315	5.38±0.358
11.	Costo-Phrenic Angle ^{NS}(D/V)	Right	32.33±1.544	28.33±2.571
		Left	33.33±1.554	30.67±2.179
12.	Costo-Phrenic Angle ^{NS}(V/D)	Right	31.58±0.763	31.17±2.225
		Left	34.25±1.28	33.33±2.629
13.	CVC Diameter (Right)^{NS}		1.64±0.11	1.92±0.081
14.	CVC Diameter (Left)^{NS}		1.92±0.104	2.02±0.064
15.	Tracheal inclination angle ^{NS} (Right)		12.58±0.908	10.50±0.883

Cont. Table 1.

Table 1., Cont. ...

S.No.	Parameters		Group-I	Group-II
16.	Tracheal inclination angle ^{NS} (Left)		13.08±0.773	12.00±0.798
17.	Distance between TW & CS (D/V)^{NS}	Right ^{NS}	3.33±0.184	3.21±0.263
		Left ^{NS}	3.73±0.239	3.02±0.26
18.	Distance between TW & CS (V/D)^{NS}	Right ^{NS}	3.60±0.16	3.23±0.345
		Left ^{NS}	3.88±0.253	3.30±0.159
19.	Thoracic depth (Right)^{NS}		19.11±0.443	19.36±0.529
20.	Thoracic depth (Left)^{NS}		19.04±0.406	19.17±0.463
21.	Thoracic Width (DV)^{NS}		20.7±0.279	21.1±0.456
22.	Thoracic Width (VD) ^{NS}		20.75±0.349	21.12±0.401
23.	Thoracic Length (DV) ^{NS}		19.28±0.223	19.51±0.653
24.	Thoracic Length (VD) ^{NS}		19.43±0.32	19.48±0.646

The superscript (NS) showed no significant (at the level of P>0.05) difference between Mean±SE value of group-I and group-II

Table 2. Normal parameters of ECG (Fig. 1)

Parameters	P-wave (D)	P-wave (Amp)	QRS-D	QRS-Amp	T-D	T-amp	PR interval	QT interval	St segment
Value	0.04 sec	0.2 mV	0.04 sec	1.0 mV	0.04 sec	0.1 mV	0.10 sec	0.14 sec	0.10 sec

difference between both the groups in right and left side recumbency was not significant (P>0.05) as depicted in Table1.

The mean (±SE) of thoracic wall to cardiac silhouette distance in group-I was 3.33±0.184 and 3.73±0.239. In group-II it was 3.5±0.263 and 3.02±0.26 for right and left side respectively for dorsoventral view. For ventro dorsal view in group-I, it was 3.60±0.16 and 3.88±0.253. In group-II it was 3.23±0.345 and 3.30±0.159 for right and left side respectively. The difference between right and left side of ventro-dorsal view and dorsoventral were not significant in both the groups (P>0.05).

The mean (±SE) values of Thoracic depth in group-I was 19.11±0.443 and 19.04±0.406. In group-II it was 19.36±0.529 and 19.17±0.463 for right and left lateral recumbency respectively. The mean (±SE) values of Thoracic width (TW) in dorsoventral view (DV) view were 20.7±0.279 and 21.1±0.456 for group-I and group-II. For ventrodorsal view (VD) view were 20.75±0.349 and 21.12±0.401 for group-I and group-II respectively. The mean (±SE) values of Thoracic length (TL) dorsoventral view (DV) view were 19.28±0.223 and 19.51±0.653 for group-I and group-II respectively. Ventrodorsal view (VD) was 19.43±0.32 and 19.48±0.646 for group-I and group-II respectively. The difference of values between the groups was non-significant P>0.05 as shown in Table 1. Normal electrocardiographic parameters values are presented in Table 2 for group-I animals.

DISCUSSION

Various cardiothoracic indices studied in the present research work are used to subjectively evaluation of cardiac size; particular cardiac chamber enlargement, lymph node enlargement, any tumourous growth and other pathological conditions in the thoracic cavity (Singh *et al*., 2012; Gugjoo *et al*., 2013; Apetrei *et al*., 2014; Lebastard *et al*., 2020; Ukaha *et al*., 2021). Tracheal and thoracic inlet diameter was non-significantly different in both recumbency in Group-I and Group-II. Change in the tracheal diameter and its ratio with thoracic inlet diameter has been used to know the pathology of the respiration either coughing status or collapse of trachea (Mostafa and Berry, 2022). Measurements of cardio-sternal contact, cardio-phrenic contact, costo-phrenic angle, tracheal and cardiac inclination angle, in both lateral recumbency showed non-significant differences between the both the groups. In comparison to the left lateral view, which reveals a more rounded cardiac silhouette with an apex that may be somewhat displaced dorsally from the sternum, the Right lateral view's cardiac silhouette is more constant in shape and location, and it may also have a longer sternal contact area (Johnson *et al*., 2008). The values of group-I were found to be higher, 3.20±0.08 (RL) and 3.15±0.08 (LL) (Ukaha *et al*., 2021). The reference values of the Cardio-sternal contact in healthy German sphered dogs values were 2.42±0.22 (range 2-3.5) and with cardio thoracic disease values were 2.70±0.60 (range 2.1-3.3) (Mishra *et al*., 2020). Hypertrophy or dilation of right ventricle often causes an increased sternal contact in the lateral view thus sternal contact in excess of 3 intercostal spaces suggests right ventricular enlargement (Bahr, 2013) and it also can be used to assess a small heart or help in determining hyperinflation of the thorax (Mattoon *et al*., 2001).

Cardio-phrenic contact can be used to assess a dog or cat's heart size subjectively (Mishra *et al*., 2020). An increased cardio-phrenic contact can be related to increased abdominal pressure or diseased conditions of the lungs which cause the hypoventilation; like pulmonary fibrosis and obstruction of the upper airway (Mattoon *et al*., 2001; Alves *et al*. 2012). Alves *et al*. (2012) documented the mean±S.E. values of the costo-phrenic right side angles (degree) 33.8±1.75 and left side angles (degree) 31.1±1.10 in the monkey.

Ratio of (TrD/ThID) has been used in different studies to objective assessment of lumen size; this ratio is variable in different breeds of dogs in the long range of (0.11±0.03 to 0.21±0.03) and respiratory phase does not change this ratio significantly but extension of head and neck can reduce the tracheal lumen (Hayward *et al*., 2008). Brachycephalic breeds, both with and without respiratory signs, have a smaller average tracheal-diameter-to-thoracic-inlet ratio than non-brachycephalic dogs and bulldogs have even more smaller ratio as compare to other brachycephalic breeds (Harvey and Fink, 1982). Measurement of tracheal diameter, thoracic inlet diameters and their ration has been used in many studies to know the tracheal collapse, coughing status and relation of respiratory pathology in relation to tracheal diameter change (Ingman *et al*., 2014; Lee *et al*., 2017)

Tracheal angle were observed in both recumbency; values of these parameters were non-significantly differ in group-I as well as group-II. Decreased tracheal angle suggests a dorsal location of the trachea, a radiographic sign typically in cardiomegaly; tracheal angle measurement is an indirect parameter useful in quantitative radiographic measuring evaluation of the cardiac size too (Mattoon *et al*., 2001). As a Cardiac inclination angle has diagnostic importance in clinical medicine because progressively increases in heart shape especially in the right ventricle, decrease the cardiac inclination angle to the sternum (Kealy *et al*., 2011).

In this study there was non-significant difference were observed for the measurement of caudal vena cava (CVC) in both recumbency of groups-I and II. In German shepherd dogs, the mean ±S.E. values of CVC diameter was 1.59±0.5 (range 1.1 - 2) cm (Ninama *et al*., 2022). In indigenous dog breeds of Tamil Nadu CVC diameter was 1.51±0.59 cm and 1.56±0.67 cm in two breeds (Bhargavi *et al*., 2018). Cardiac disorders of the right side can be identified by using descending aorta and caudal vena cava diameter which are used as indicators for right atrium lesions, heart worm and congestive heart failure (Marine *et al*., 2007). Previously the CVC diameter and its values have been quantified in normal dogs as 1.47±0.40 cm (Lehmkuhl *et al*., 1997). The distance between TW and CS were obtained in group-I and II in D/V and V/D positions there is non-significant variations present in both groups. In previous studies heart to thoracic wall distance in right side indicates the cardiac silhouette towards the left side of thoracic cavity (Alves *et al*., 2012; Diniz *et al*., 2013). In the present study thoracic depth (TD), width (TW) and length (TL) showed, non-significantly different in both the groups and the values of healthy animals can be used to compare the diseased conditions of the thoracic cavity in Labrador dogs.

Thoracic Indices of present study were found to be non - significantly differ in normal and affected animals. Cardio-sternal and cardio-phrenic contact, CVC diameter were found to be increased while tracheal inclination angle values decreased non significantly. These indices in combination of electrocardiography and biochemical parameters could be a better and add on benefit for screening of cardiac diseases in Labrador dogs. Detailed study is needed for individual parameters to know the significant changes in pathological conditions of the cardiac and non cardiac origin of the thoracic cavity.

Conflict of interest: Author does not have any conflict of interest. Any person related to this research does not have any personal relationship with other people of organizations that may influence present research work.

Author's contribution: NP, SS: Conception and design of work, and interpretation of results, conduction of ECG, radiographic and biochemical examination; MCP, RS, NM: Acquisition of data, selection of cases, statistical analysis of data, physiological and haematological examination.

Data availability statement: Present study was conducted on the healthy as well as cardiac affected owner client dogs which were presented to veterinary clinical complex (VCC) of Post Graduate Institute of Veterinary Education and Research (PGIVER) for general check up and diseased condition.

Ethical statement: No Experimental animal was used in the study. It was conducted on client owned dogs; presented to veterinary clinical complex (VCC).

ACKNOWLEDGEMENT

Authors acknowledge the faculty and staff members of veterinary clinical complex (VCC) for providing diagnostic facilities and smooth conduction of work.

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Received - 13.05.2024, Accepted - 05.03.2025, Published - 15.04.2025(Online), 01.06.2025 (Print)
Section Editor: Prof. S. K. Nandi, Associate Editor