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Original Research Article

RADIOLOGIC EVALUATION OF THORACIC ANGULAR RECESSES IN THE NIGERIAN INDIGENOUS DOG

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ABSTRACT
The aim of this prospective cross-sectional research was to determine angular relationships or recesses of thoracic organs useable for evaluation of canine thoracic radiographs. We used, for this investigation, thirty healthy Nigerian Indigenous Dogs (NIDs) with average body weight of 8.19±2.45 kg and equal sex distribution. Sixty plain right lateral (RtL) and left lateral (LeL) thoracic projections of the dogs were taken and processed. With measuring instruments, the angular recesses formed (1) between the dorsal surface of the trachea and the ventral board of the thoracic vertebrae at the tracheovertebral confluence, called tracheal inclination angle (TIA); (2) between the dorsum of sternum and craniocaudal border of the heart at the sternocardiac contact point, the cardiac inclination angle (CIA); (3) at the aortico-vertebral junction, the aortic inclination angle (AIA); and (4) at the convergence of the ventral surface of the post caval vein and the caudoventral edge of the cardiac silhouette, the cardiocaval angle (CCA) were determinedin both RtL and LeL radiographs. Mean values of TIA is $13.73{\pm}0.43^{\mathbf{0}}$ and $13.10{\pm}0.41^{0}$ for RtL and LeL radiographs, respectively. Mean results of normal cardiac inclination angle is $21.63{\pm}0.62^{0}$ in RtL radiographs and $21.37{\pm}0.53^{0}$ in LeL projections. The mean angular values of AIA were $13.83{\pm}0.62^{\mathbf{0}}$and $14.53{\pm}0.61^{0}$ for the RtL and LeL views, respectively; while the CCA means determined in the RtL and LeL radiographs were $66.30{\pm}1.67^{0}$ and$71.60{\pm}1.42^{0}$, respectively. This study is clinically relevant because it establishes measurement angular indices for radiologic assessment of the thoracic silhouette in the NID.

Keywords: Angular recesses, Nigerian dog, Radiology, thoracic evaluation

INTRODUCTION
Radiographic assessment of thoracic features is used in animals, as in man, as a primary diagnostic tool in the detection of thoracic anomaly, evaluation of clinical response to therapy, or monitoring of the disease progression (Berry *et al.*, 2007). Thoracic abnormalities affecting the canine species may be congenital disorders (e.g. pectus deformity) or acquired conditions (e.g. heart failure) (Fossum, 2002; Williams & Crabbe, 2003). Pectus deformation is an anomaly of the thoracic cage in which several ribs and the sternum grows abnormally, producing a convex shape (*pectus carinatum*) or concave appearance (*pectus excavatum*) in the ventral aspect of thoracic wall (Fossum, 2002; Williams & Crabbe, 2003). Pectus deformities have been reported in animals, most frequently in cats and dogs (Fossum *et al.*, 1989; McAnulty & Harvey, 1989; Williams & Crabbe, 2003; Ellison & Halling, 2004). The inward displacement of some of the sternebrae secondarily alters the shape of the caudoventral aspect of the thoracic cavity thereby diminishing the size of cardiosternal recess. Radiographic indicators of *pectus excavatum*, often pronounced in ventrodorsal views, are a marked dorsal deviation of the caudal aspect of the sternum, resulting in abnormally

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reduced sternospinal distance (dorsal to ventral narrowing of thorax) at the affected part, acute angulation of the associated costal cartilages, and dorsal displacement of the heart in lateral views (Kealy, 1989).

Anatomic conditions of the spine that result in abnormal values of canine thoracic recesses and contour include scoliosis, lordosis, and kyphosis. Radiographically, scoliosis is the lateral bowing, in dorsoventral/ventrodorsal (DV/VD) projections, of the vertebrae with either right or left convexity (Linklater & Smith, 1997). While kyphosis is abnormal dorsal bulging (convex appearance), lordosis is abnormal ventral curvature (concave shape) of the spine as seen in a lateral radiograph (Linklater & Smith, 1997). Radiographic changes of spondylitis or vertebral inflammation are majorly increased opacity of affected vertebral bodies and periosteal response resulting in increased thickness of the vertebrae due to exostosis. In the presence of osteomyelitis, radiographic findings of spondylitis include patchy lysis of vertebral bodies and irregular formation of bone spurs (Hugnet *et al.*, 2009; Csebi *et al.*, 2010).

It is general knowledge that cardiac and other thoracic organ size evaluations, often made subjectively, are the most common radiologic investigation in the small animal practice. However, a number of thoracic anomalies are associated with structural displacement without visible and measurable changes in organ sizes. Rather than morphometric measurements, evaluations of angular relationships of organs to neighbouring structures are usually useful in certain diagnoses of diseases associated with organ mal-positioning. In the Nigerian indigenous dog breed, there are not reported indices that could evaluate positional relationship of various thoracic organs. The aim of the present study was to introduce new guides for the evaluation of angular sinuses in the Nigerian Indigenous Dog (NID) associated with the heart, trachea, caudal vena cava, thoracic vertebrae, and the aorta.

MATERIALS AND METHODS

LOCATION OF THE STUDY

The research was performed in the Department of Veterinary Surgery & Radiology, Michael Okpara University of Agriculture, Umudike, Abia State. Umudike lies between latitudes 5º 29'N and longitudes7º 33'E in the tropical rainforest zone of South-eastern Nigeria at the elevation of 122 metres above sea level with average annual rainfall of 1245 mm and a temperature range of 22.4° to 30.6°C.

PROCUREMENT OF RESEARCH ANIMALS AND THEIR ADAPTATION

Prospective radiologic cross-sectional design was adopted for the study. Thirty sex-matched NIDs (average body weight = 8.19±2.45 kg, obtained with a weighing balance) were procured from breeders and used for this research, in line with the recommended sample size of ≥30 considered appropriate for most clinical investigation (Festing & Altman, 2002; Patel *et al.*, 2003).

The dogs were housed separately and adapted for about 30 days. Home-made food and portable water was provided daily for the animals and they were subjected to general examination within the acclimatization period.

The vital parameters of each animal were all within the normal ranges documented for dogs, and so they were adjudged adequate for the work (Straub *et al.*, 2002). Each dog was identified with a numbered neck pendant.

RADIOGRAPHY

Thoracic projections of each study dog were obtained following administration of chemical restraint to each animal using: xylazine hydrochloride (XYL–M2®, VMD, Belgium) at the dose of 2.0mg/kg intramuscularly and ketamine hydrochloride (Ketanir®, Aculife Healthcare, India) injected at 10mg/kg i.m.

Each animal was placed in lateral recumbent position on the x-ray table. The x-ray tube was overhead directed from a distance of 120 cm (91 in), using air-gap technique. Exposure factors including the kilovolt peak - kVp (range: 40 – 65kV) and milliampere-second mAs (range: 5 – 10mAs) were carefully and adequately selected depending on individual differences in thoracic thickness of the dogs using a mobile x-ray unit (Dean, Dynamax 40, GEC Medical Equipment Group Ltd, England).

Each dog was monitored closely over time as it breathed in and out to ensure that all exposures were taken at the peak of inspiration. The whole thoracic region, in each case, from the first rib to the first lumbar vertebra, was placed in the x-ray field which was centred at the mid line of the fourth intercostal space. Two peak inspirational radiographs of each dog, giving a total of 60 right lateral (RtL) and left lateral (LeL) canine thoracic projections, were acquired. The exposed films were processed in the dark room and placed in numbered envelopes for appraisal.

INCLUSION AND EXCLUSION CRITERIA

Radiographs of healthy animals were used for the research. Poorly exposed or artefactual radiographs and the use of inadequate dark room techniques for thoracic radiography were criteria for excluding affected, deficient, radiographs from the research.

Animals with thoracic deformities, such as *pectus* disorders, scoliosis (lordosis and kyphosis), and those with cardiothoracic disease, and pregnancy irrespective of gestational duration were all excluded from the study.

RADIOLOGIC MEASUREMENTS

Radiographic measurements on the experimental radiographs were performed using a viewing box, metre rule and a standard transparent protractor. Radiographic measurements made in the lateral projections (Figures Ia and b) were as follows: Tracheal Inclination Angle (TIA), the angle formed at the thoracic inlet between the dorsal surface of the trachea and the ventral board of the thoracic vertebrae at the tracheovertebral confluence; Cardiac Inclination Angle (CIA), formed between the dorsum of sternum and craniocaudal border of the heart at the sternocardiac contact point; Aortic Inclination Angle (AIA), formed at the aortico-vertebral junction; and Cardio-Caval Angle (CCA), formed at the convergence of the ventral surface of the post caval vein and the caudoventral edge of the cardiac silhouette.

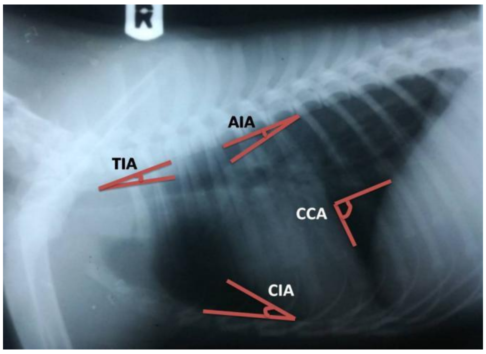

Figure I (a): Lateral thoracic radiographs of healthy Nigerian Indigenous Dog explaining dimensional measurements used for the evaluation of thoracic index angles.

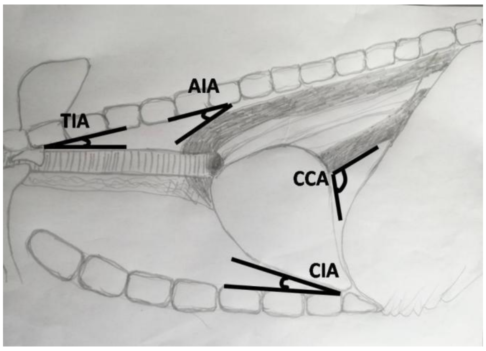

Figure I (b): Annotated diagram of lateral thoracic radiograph of the Nigerian indigenous dog

Legend: TIA = tracheal inclination angle; AIA = aortic inclination angle; CIA = cardiac inclination angle; CCA = cardiocaval angle

RESULTS

In the pooled samples (Figure II), the mean value of TIA in RtL views (13.73 ± 0.43^0) is greater than its mean value (13.10 ± 0.41^0) in LeL radiographs and their difference is not significant statistically ($P\geq0.05$). The mean values of TIA in the male and female NIDs are represented in Figure III. The TIA mean values are greater in RtL/LeL views of the female dogs (14.33 ± 0.79^0/13.47 ± 0.73^0) than values obtained in the same views for male animals (13.13 ± 0.31^0/12.73 ± 0.3^0), respectively. However, there is no significant sex difference ($P\geq0.05$) between any two of the mean values. The male TIA means are less than, but not significantly different from, the female values in both RtL and LeL projections ($P \geq 0.05$). Table I represents the TIA values in the RtL and LeL thoracic radiographs of puppies versus adult NIDs recorded in the present research. Puppy TIA means are less than the mean indices for adult dog in RtL as well as in LeL thoracic views. The mean TIA values obtained between puppies and adults are not significantly different ($P\geq0.05$).

The CIA mean value in RtL (21.63 ± 0.62^0) views, in the combined samples, is not statistically different from the CIA mean in LeL projections (21.37 ± 0.53^0), respectively (Figure IV). Figure V illustrates male and female CIA means in the views studied. In the RtL/LeL radiographs, the male CIA mean values (22.33 ± 0.66^0/22.00 ± 0.74^0) vary insignificantly, between opposite (RtL versus LeL) views and within similar (RtL or LeL) radiographs, with the female mean values (21.13 ± 1.07^0/20.53 ± 0.70^0) ($P \geq 0.05$), respectively. In both RtL and LeL thoracic views, puppy CIA means are repeatedly greater than the values derived for adult dogs in those views, but not significantly different from each other ($P \geq 0.05$) (Table II).

As seen in Figure VI, the pooled AIA mean value is less in RtL views ($13.83\pm0.62^{\mathbf{0}}$) than the mean value obtained in LeL projections ($14.53\pm0.61^{\mathbf{0}}$); however, both means are significantly different from each other ($P \geq 0.05$).There is slight sexual dichotomy in mean AIAs (Figure VII). Female AIA means ($15.00\pm1.04^{\mathbf{0}}$/$15.27\pm1.03^{\mathbf{0}}$) are larger than the male AIA mean values ($12.67\pm0.55^{\mathbf{0}}$/$13.80\pm0.63^{\mathbf{0}}$) ($P \geq 0.05$) in the RtL/LeL radiographs, respectively. Age difference of no statistical significance also exists ($P \geq 0.05$). Adult dog AIA means in RtL and LeL thoracic projections ($14.70\pm0.83^{\mathbf{0}}$ and $15.15\pm0.84^{\mathbf{0}}$) are both slightly but not significantly bigger ($P \geq 0.05$) than the AIA mean values recorded for puppies ($12.10\pm0.55^{\mathbf{0}}$ and $13.3\pm0.56^{\mathbf{0}}$) in the same views, respectively (Figure VIII).

In Figure IX, CCA mean is significantly larger in LeL radiographs ($71.60\pm1.42^{\mathbf{0}}$) compared with the CCA mean value obtained in RtL views ($66.30\pm1.67^{\mathbf{0}}$), respectively ($P \leq 0.05$). Again, as observed in Figure X, female CCA

means (67.40 ± 2.21^0/71.00 ± 1.98^0)and the male CCA mean values (65.07 ± 2.57^0/72.20 ± 2.10^0) are significantly different in RtL projections ($P \leq 0.05$) but do not vary statistically in LeL radiographs, respectively ($P \geq 0.05$). Significant age differences are equally observed in Figure XI where the CCA means is significantly less in puppies (64.40 ± 2.52^0) than CCA mean values established for adult dogs (67.25 ± 2.05^0) in RtL views ($P \leq 0.05$), whereas in LeL views CCA mean for puppies (71.50 ± 2.28^0) is not statistically different from the adult dog mean (71.65 ± 1.84^0) ($P \geq 0.05$).
The mean angular values of three thoracic recesses (TIA, CIA, and AIA) are slightly varied but not significantly different between sexes, ages, and radiographic views ($p \geq 0.05$). However, the CCA mean indices are significantly different between RtL and LeL views, males and females, and age categories ($P \leq 0.05$).

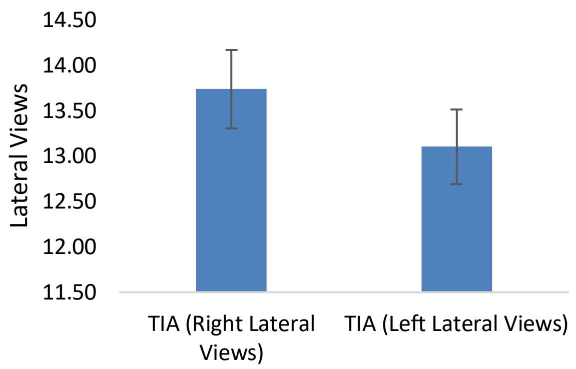

Figure II: Tracheal inclination angles measured in right lateral and left lateral thoracic radiographs of the Nigerian Indigenous Dog

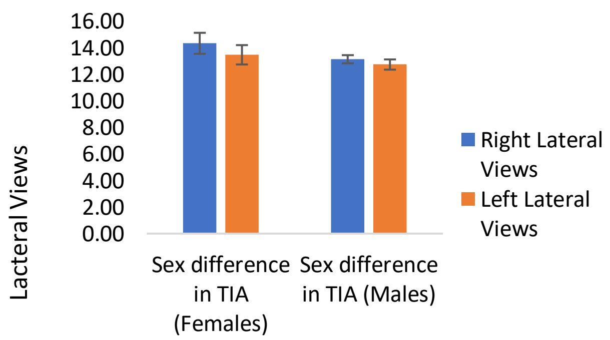

Figure III: Tracheal inclination angles measured in right lateral and left lateral thoracic radiographs of male and female Nigerian Indigenous Dog

TABLE I: Tracheal inclination angle in right lateral and left lateral thoracic radiographs of Nigerian Indigenous Dogs of different ages

Lateral Views	Age difference in TIA (Adults)	Age difference in TIA (Puppies)
Right lateral views	13.80 ± 0.58^0	13.60 ± 0.49^0
Left lateral views	13.65 ± 0.49^0	12.00 ± 0.50^0

Mean values not significantly different from each other ($P \geq 0.05$)

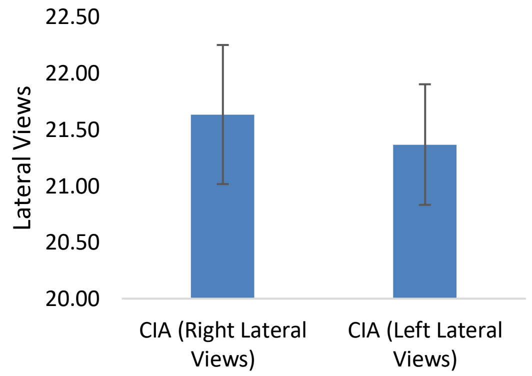

Figure IV: Cardiac inclination angle in right lateral and left lateral thoracic radiographs of Nigerian Indigenous Dogs

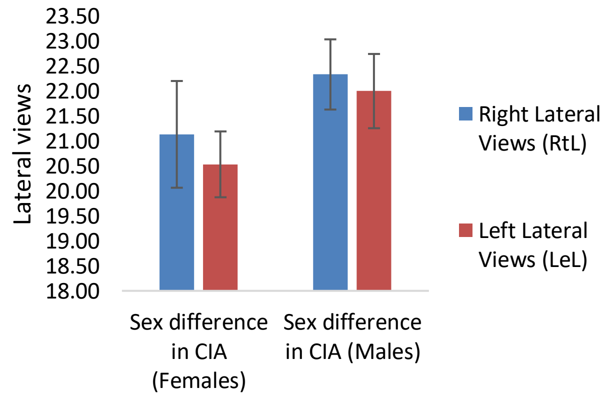

Figure V: Cardiac inclination angle in right lateral and left lateral thoracic radiographs of male and female Nigerian Indigenous Dogs

TABLE II: Cardiac inclination angles in right lateral and left lateral thoracic radiographs of Nigerian Indigenous Dogs (adult dogs and puppies)

Lateral views	Age difference in CIA (Adult dogs)	Age difference in CIA (Puppies)
Right lateral views	21.40±0.73^0	22.1±0.26^0
Left lateral views	20.55±0.65^0	23.00±0.26^0

Mean values not significantly different from each other (P≥0.05)

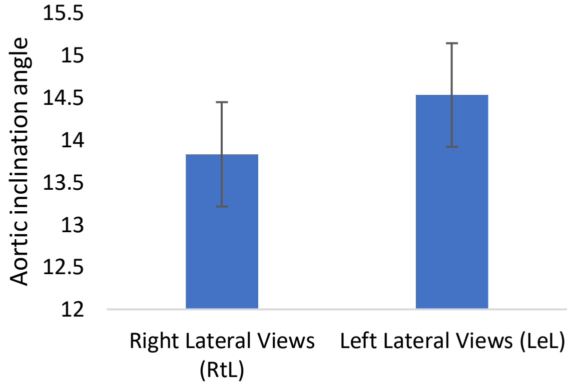

Figure VI: Aortic inclination angle in right lateral and left lateral thoracic radiographs of Nigerian Indigenous Dogs

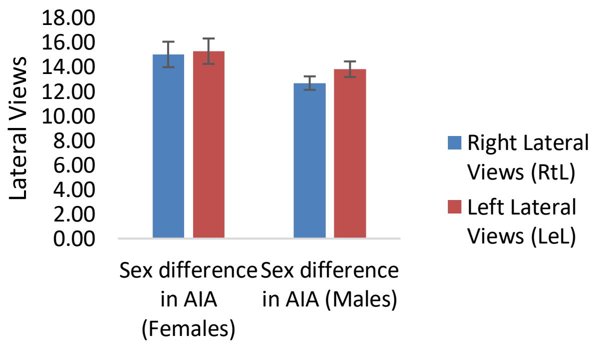

Figure VII: Aortic inclination angle in right lateral and left lateral thoracic radiographs of male and female Nigerian Indigenous Dogs

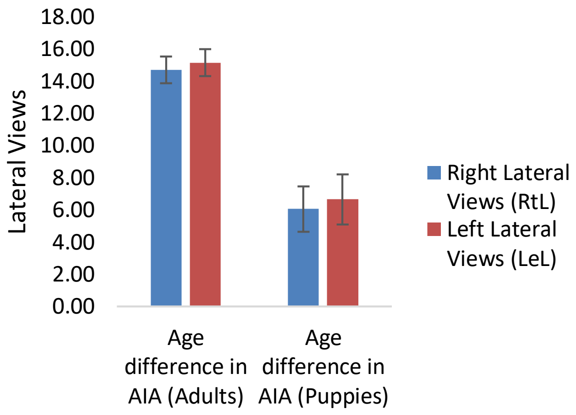

Figure VIII: Aortic inclination angle in right lateral and left lateral thoracic radiographs of puppies and adult Nigerian Indigenous Dogs

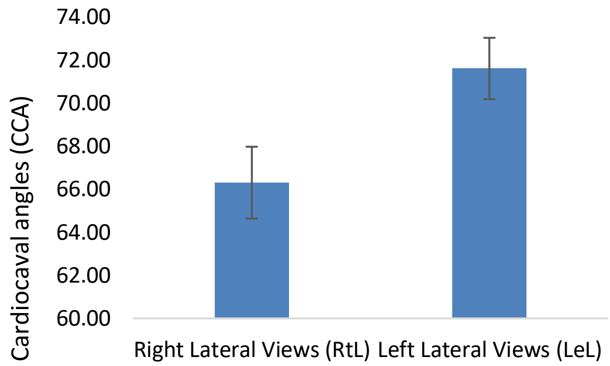

Figure IX: Cardiocaval angle in right lateral and left lateral thoracic radiographs of the Nigerian Indigenous Dogs

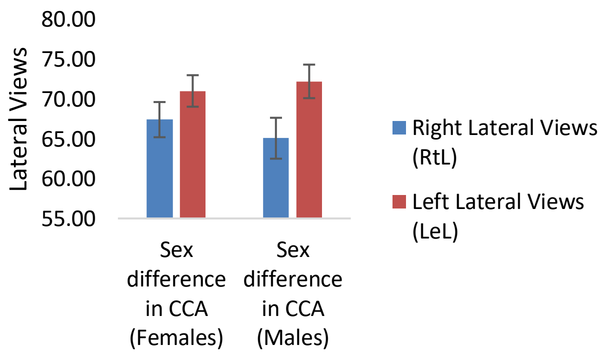

Figure X: Cardiocaval angle in right lateral and left lateral thoracic radiographs of male and female Nigerian Indigenous Dogs

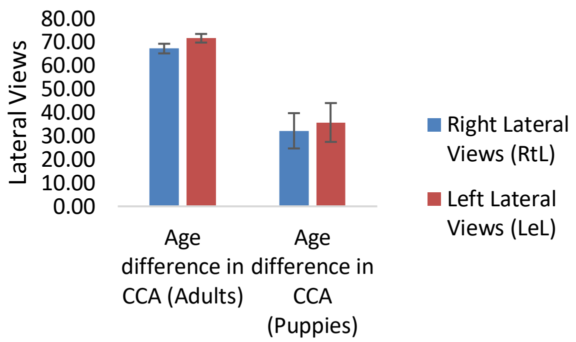

Figure XI: Cardio-caval angle in right lateral and left lateral thoracic radiographs of puppies and adult Nigerian Indigenous Dogs

DISCUSSION

Tracheal rings mineralize with age and become visualized. A ratio between tracheal diameter and thoracic inlet height is proportionally larger in dogs with greater body weight and smaller in brachycephalic breeds (Harvey & Fink, 1982). The tracheal diameter as a ratio to the thoracic inlet in the lateral radiograph should not be less than 0.20 in normal, non-brachycephalic dogs; in brachycephalic dogs, the ratio should be 0.16 or higher; and the ratio in bulldogs may be as low as 0.13 (Harvey & Fink, 1982).

The trachea, in the present research, was observed to be inclined to the vertebral column at an angle in the lateral projection. The tracheal inclination angular (TIA) results were not significantly varied ($p \geq 0.05$), between RtL and LeL views both in the pooled mean values, in the male versus female means, and in the adults versus puppies mean results. These findings did not concur with the agouti values of 9.93 ± 3.23^0 for males and 8.40 ± 0.30^0 for females obtained by Diniz *et al.* (2013), probably due to differences in radiographic techniques or body conformations between the animal models used in these two investigations. In lateral projection, dorsal displacement of the caudal thoracic trachea and carina reduced the TIA (also known as tracheovertebral angle), and is seen with (left-sided) cardiomegaly (as in left heart failure and endocardiosis). The tracheal bifurcation is situated on top of the left atrium and the trachea sitting on the left atrial roof, at the point of the carina, becomes elevated. The trachea loses its normal caudoventral course over the heart, and with marked left heart enlargement, becomes nearly parallel with the thoracic vertebrae above. Ventral displacement is associated with tracheobronchial lymphadenopathy and increased tracheal inclination angle. Tracheal narrowing, oesophagomegaly and other similar neighbouring space-occupying lesions e.g. (mural or extramural) cervical and precardiac mediastinal neoplasms equally result in abnormal values of tracheal inclination angle. Abnormal inclination angle of the trachea is diagnosed by comparison with the normal TIA values.

The heart was equally slanted or inclined normally at an angle to the sternum resulting in a cardiosternal recess. There was no significant difference ($p \geq 0.05$) between RtL and LeL CIA means between male and female and between adult and puppy values. Scientific information on canine sternocardiac angle is very scanty or rather not visible. However, our results were similar to the value (21.2 ± 6.4^0) established by Diniz*et al.* (2013) in agouti (*Dasyprocta primnolopha* Wagler, 1831). These authors reported a significant difference ($p \leq 0.05$) between mean values of female (22.80±8.50) and male (16.73±7.12). Cardiac inclination angle is clearly useful in the diagnosis of cardiac size anomalies (microcardia or cardiomegaly) and also a good tool for the determination of the severity and type of *pectus* deformities.

Ukaha *et al.* (2022) and Kennedy *et al.* (2025) reported that aortic diameter is crucial in the dimensional assessment of aortic arch and cardiac health in the dog. Widening of cranial mediastinum whenever seen in dorsoventral/ventrodorsal (DV/VD) projections can indicate dilation of aortic arch, while a focal bulge in the descending aorta in the DV/VD views can be observed in patients with aortic stenosis and patent ductus arteriosus (Bahr, 2013). In lateral radiographs, an enlarged aortic arch can create increased mass at the cranial aspect of the cardiac silhouette (Bahr, 2013). Space-occupying lesions and other affections associated with alterations in the course and width of the aorta will cause a reduction or an increase, beyond the normal values, of the aortic inclination angle (AIA). Reference AIAs, as measured in the present report for the NID, can be used to identify pathological alterations in terms of diameter and angulation of the aortic arch in the NID. However, according to Moon *et al.* (1993), some older cats will develop a tortuous appearing aorta in lateral projections with the orientation of the aortic arch being more vertical. Moon *et al*. (1993) noticed that the aortic arch then curves upwards and caudally, assuming a serpentine contour as it progresses caudally towards the diaphragm. In dorsoventral or ventrodorsal views, the feline aortic contour may be projected away from the mediastinum and be misinterpreted as a pulmonary nodule when projected end-on. Moon *et al.* (1993) then concluded that a tortuous aorta is clinically insignificant in aged cats. There was no significant difference in the pooled AIA means between the right and left lateral views ($P \geq 0.05$), and between sex and age means.

The use of cardiocaval angle CCA (or the angle made by the caudal border of the heart and the ventral surface of

TABLE III: Summaries of pooled, sex and age indices of thoracic angles: TIA, CIA, AIA, and CCA. Key: n = number of animals studied; SEM = standard error of mean, with index ranges; TIA = tracheal inclination angle; CIA = cardiac inclination angle; AIA = aortic inclination angle; CCA = cardiocaval angle; θ = degrees.

	TIA$^{\theta}$ Mean±SEM in RtL/LeL (range in RtL/LeL)	**CIA$^{\theta}$** Mean±SEM in RtL/LeL (range in RtL/LeL)	**AIA$^{\theta}$** Mean±SEM in RtL/LeL (range in RtL/LeL)	**CCA$^{\theta}$** Mean±SEM in RtL/LeL (range in RtL/LeL)
Male	**13.13±0.31/12.73±0.38**	**22.33±0.66/22.00±0.74**	**12.67±0.55/13.80±0.63**	**65.07±2.57/72.20±2.10***
(n = 15)	(12.0-16.0/10.0-15.0)	(19.0-26.0/17.0-26.0)	(10.0-17.0/9.0-18.0)	(46.0-85.0/52.0-84.0)
Female	**14.33±0.79/13.47±0.73**	**21.4±1.07/20.53±0.70**	**15.00±1.04/15.27±1.03**	**67.40±2.21/71.00±1.98***
(n = 15)	(10.0-22.0/10.0-21.0)	(13.0-27.0/15.0-25.0)	(10.0-25.0/12.0-25.0)	(53.0-80.0/56.0-87.0)
Adult	**13.80±0.58/13.65±0.49**	**21.40±0.73/20.55±0.65**	**14.70±0.83/15.15±0.84**	**67.25±2.05/71.65±1.84***
(n = 20)	(10.0-22.0/11.0-21.0)	(13.0-26.0/15.0-26.0)	(10.0-25.0/9.0-25.0)	(50.0 –85.0/52.0-87.0)
Puppy	**13.65±0.49/12.00±0.50**	**22.10±0.26/23.00±0.26**	**12.10±0.55/13.30±0.56**	**64.40±2.52/71.50±2.28***
(n = 10)	(11.0-17.0/10.0-17.0)	(15.0-27.0/19.0-26.0)	(10.0-14.0/11.0-18.0)	(46.0-75.0/56.0-84.0)
Pooled	**13.73±0.43/13.10±0.41**	**21.63±0.62/21.37±0.53**	**13.83±0.62/14.53±0.61**	**66.30±1.67/71.60±1.42***
(n = 30)	(10.0-22.0/10.0-21.0)	(13.0-27.0/15.0-26.0)	(10.0-25.0/9.0-25.0)	(46.0-85.0/52.0-87.0)

Results in table are presented as Mean±SEM. Sex and age means are not significantly different from each other P ≥ 0.05, except in CCA* P ≤ 0.05.

the postcava), as a standard for evaluation of thoracic dimensions, is either not yet documented or invisible in small animal literature. The mean CCA values established in this investigation (Table IIIa-c) between views, sexes and age brackets were all statistically different (P ≤ 0.05). These stark differences may probably be due to the influence of the right-sided location (from mid-line) of postcaval vein which courses through the caval foramen in the diaphragmatic hiatus (Evans, 1993; Dennis *et al.*, 2010; Thrall, 2013a). In other words, the anatomic position of the caudal vena cava in the right half of the thoracic cavity may be responsible for the widely varied caval angulation observed between the right and left lateral projections. However, CCA will probably work well for the evaluation of canine heart size and diagnosis of severe dehydration, acute blood loss or chronic metabolic hypovolaemia sometimes due to Addison's disease manifested by reduced heart size, diminished postcaval diameter (Klein and Peterson, 2010) and abnormal cardiocaval angulation.

In all the research animals, all the inclination angles were acute both in the lateral, dorsal and ventral projections just as Ruskin *et al.* (1987) and Diniz *et al.* (2013) reported in other mammalian species. According to Armato *et al.* (1998), Light (2010) and Bahr (2013), abnormal inclination angles may be due to space-occupying lesions e.g. pulmonary nodules and masses, heartworm disease, and causes of cardiac size anomalies (cardiomegaly and microcardia).

The mean angular values of three of the thoracic recesses (TIA, CIA, and AIA) were slightly varied but not significantly different between sexes, ages, and views (P ≥ 0.05). The only exception was the CCA means which were significantly different between RtL and LeL views of the pooled, sex and age categories (P ≤ 0.05).

CONCLUSION

The present investigation has documented reference thoracic angular indices of the NID, namely: TIA, CIA, AIA, and CCA, which do not vary with sex and age of dogs except for the CCA. Application of these thoracic angular measurements will reduce subjective assessment error. And these results are reproducible and easily applied measurement tools for radiologic appraisals needed every day in small animal clinical practice. Therefore, the authors consider these results useful first line guides, or adjunct to other imaging modalities, in canine thoracic diagnosis. However, the results of this study should be validated with larger sample sizes and clinical cases.

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