Journal of Sustainable Veterinary & Allied Sciences
p-ISSN: 2695-2661 e-ISSN: 2811-1346

JoSVAS 2021, Vol 1, Issue 1: 7-14

Original Research Article

Cardiac size appraisals in thoracic radiographs of Nigerian Indigenous dogs: reference guides in clinical practice

[1]*Ukaha R.O., [2]Kene R.O.C. & [3]Agwu, K.K.

[1]*Department of Veterinary Surgery & Radiology, College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike,* [2]*Department of Veterinary Surgery, Faculty of Veterinary Medicine, University of Nigeria, Nsukka,* [3]*Department of Radiography and Radiological Sciences, College of Medicine, University of Nigeria, Enugu Campus, Enugu State, Nigeria.*

*Corresponding author: ukarock1@gmail.com; *+2348061530565*

ABSTRACT

The application of radiologic measurement methods has provided very sensitive and more accurate evaluation, compared with subjective assessment, especially in subtle cases of thoracic organ size anomaly. The objective of the study was to determine radiologic ratios for diagnostic and biometric cardiothoracic evaluations in the Nigerian Indigenous Dog. Thirty healthy dogs (average body weight: 8.2 kg; range: 4.0 – 15.6 kg) consisting of equal number of males and females were recruited for the investigation. Sixty dorsoventral versus ventrodorsal thoracic projections of each of the research dogs were acquired. Parameters in each radiograph were objectively evaluated, as follows: thoracic diameter, cardiac diameter in views, cardiac length and cardiac width. Indices generated in the views were the cardiothoracic ratios (CTR) and the cardiac indices (CI). Mean ± standard error of mean CTR and CI values were 0.50±0.01/0.56±0.01 and 0.56±0.01/0.61±0.01, between the opposite views, respectively. These results are objective, reproducible and easily applicable to veterinary clinical practice for radiologic cardiac appraisal.

Keywords: Diagnosis, Nigerian dogs, radiology, thoracic measurements.

INTRODUCTION

The purpose of radiographic investigation is generally to propose, confirm or refute a provisional clinical diagnosis. Therefore, a detailed and complete physical examination is necessary to establish a reason, in the first place, for the radiographic evaluation and to determine the views of the patient to be studied. Clinical findings of forelimbs abduction, dry and or chronic cough, reluctance to lie down, ascites, syncope, venous distension, oedema, arrhythmias, bradycardia, and tachycardia are a few indications of thoracic radiologic study (Fraser, 1991).

When performing a thoracic radiographic study, it is important to ensure that the entire thorax is brought within the x-ray field including part of the neck, part of the abdomen, the thoracic vertebral bodies, and the sternum.

Heart size is not assessed by absolute measurement, but rather in relation to the total thoracic width or other dimensions such as vertebral length and breadth, and is expressed as a ratio (Lloyd, 2021). The heart size should be evaluated in every thoracic roentgenograph that is diagnostically adequate.

All breeds of dogs are at a risk of developing various types of congenital and acquired thoracic diseases, namely: pectus deformities, patent ductus arteriosus (PDA), pulmonic and aortic stenoses, defect of the ventricular septum, tetralogy of Fallot, heartworm disease, heart failure, cardiomyopathy, pericardial effusion, endocarditis, scoliosis, space-occupying lesions, etc (Darke, 1980; Fossum *et al*., 1989; Jones *et al*., 1997; Ellison & Halling, 2004; Moon, 2006; Rahal *et al*., 2008). The degree and type of such risk varies with dog breed. For instance, small breeds seem to have a high risk of developing chronic degenerative valvular disease, PDA, and pulmonic stenosis, while large dog breeds often develop dilated aortic stenosis, cardiomyopathy, pericardial effusion, and endocarditis more frequently (Hogan, 2002). Heart failure is commonly seen in middle-aged and older dogs and cats. Ascites, pleural effusion, and peripheral oedema are clinical signs of failure of the right ventricle, while left

http://doi.org/10.54328/covm.josvas.2021.004

ventricular failure is associated with pulmonary oedema (Knight, 1989; Moon, 2006). PDA is common in dogs and thoracic radiographs of affected animals often reveal cardiac enlargement. Radiographic signs of long standing PDA are marked left ventricular and left atrial enlargement, prominent pulmonary vascular pattern, and finally, left-sided heart failure (Darke, 1989). Cardiomegaly is also a common radiographic sign associated with canine patients affected with ventricular septal defect, pulmonic and aortic stenotic conditions (Darke, 1989).

Radiographic signs of heartworm disease, a parasitic infestation of the dog (transmitted by mosquitoes) due to *Dirofilaria species*, are right ventricular enlargement, dilation of the main pulmonary and lobar arteries, etc (Kealy & McAllister, 2000). Cardiomyopathy and valvular insufficiency are other acquired cardiac anomalies associated with abnormal increase in heart size and shape causing greater than normal cardiosternal contact, abnormal elevation of cardiac apex (Bonagura, 1989; Knight, 1989). Enlarged or globoid canine cardiac silhouette may be due to distension of pericardial sac with pathological fluid, known as pericardial effusion or hydropericardium. In all these disease conditions, diagnosis of the heart size anomalies can be evaluated or supported in thoracic radiographs using thoracic indices as handy guides. Studies have shown a satisfactory correlation (greater than 0.7) between the heart size measured on radiographs and that found at postmortem (Murphy *et al*., 1985). Scientific publications on canine cardiac measurements are mostly results obtained in various exotic dog breeds, and may lead to error in diagnosis if applied in Nigerian Indigenous Dogs due to conformational differences in body habitus. Therefore, the aim of the study was to determine radiologic ratios for cardiac evaluation in the Nigerian Indigenous Dog.

MATERIALS AND METHODS

STUDY LOCATION

The research was performed in the Department of Veterinary Surgery & Radiology, Michael Okpara University of Agriculture, Umudike, Abia State. Umudike lies between latitudes 5° 29'N and longitudes 7° 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.

ANIMAL PROCUREMENT AND ADAPTATION

The design adopted was prospective radiologic cross-sectional study. Thirty dogs, aged ≥ 7 months, (average body weight-8.19 kg; ranging from 4.0 – 15.6 kg) were bought from local breeders and used for this project. The dogs were housed separately and adapted for about 30 days. Home-made food and clean 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 numbered neck pendant.

ETHICAL APPROVAL

The authors abided by the international standards of housing, environment, and management of the research animals. And ethical approval for using the dogs for this study was obtained from College of Veterinary Medicine Research Ethical Committee (MOUAU/CVM/REC/202115).

INSTRUMENTATION

A mobile x-ray machine (Dean, Dynamax 40, GEC Medical Equipment Group Ltd, England) was used to obtain all the research radiographs. The focus-film-distance was set at 90cm for all the radiographs. Also used were a viewing box, a brand of x-ray film (Begood® Medical X-ray Blue Sensitive Film, China), cassettes and screens (High-speed Rareearth blue 400, NACAL Medical, England), and processing chemicals: developer and fixer powders (Begood®, China). A standard metre rule and a measuring tape were used for linear measurements, while body weights of the research dogs were obtained with a weighing scale.

INCLUSION AND EXCLUSION CRITERIA

Only radiographs of clinically normal animals were used for the research. Radiographs without any evidence of cardiopulmonary diseases, hypovolaemia, or pregnancy state were included. Under-exposure or over-exposure of radiographs, presence of artefacts, and the use of inadequate dark room techniques for thoracic radiography were criteria for excluding affected, deficient, radiographs from the research. Excessive thoracic rotation and obliquity especially in the dorsoventral and ventrodorsal projections of the animals was another exclusion criterion (Holmes *et al*., 1985). Radiographs with abnormal thoracic cage were also excluded.

RADIOGRAPHY

Thoracic projections of each study dog were obtained following administration of comfortable 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. The same set of exposure factors was used for all animals except the kilovolt peak (kVp) which was adjusted due to differences in thoracic thickness of the dogs. Two dorsoventral (DV) and ventrodorsal (VD) thoracic views were acquired of each animal (totaling 60 radiographs) and appraised.

In Figure 1, the measurements obtained were longest right (A) and longest left (B) horizontal distances of the cardiac silhouette from a line (within the heart image) drawn on the spinal shadow to the lateral borders; thoracic diameter (TD), measured at the diaphragmatic apices between the two pleural surfaces. To determine the cardiothoracic ratio (CTR), the sum of A and B (i.e. the cardiac diameter) was divided by TD, the thoracic diameter. Arithmetically, CTR = (A+B) ÷ TD (Miller *et al*., 2000; Baron, 2004). In Figure 2, radiographic parameters recorded were the cardiac length (CL) or the apicobasilar distance of the heart and the greatest cardiac width perpendicular to CL (HW). The cardiac index (CI) was generated by the relationship: CI = ½(CL+HW) ÷ TD.

STATISTICAL ANALYSES

Data obtained were expressed in descriptive statistics and presented in tables. Differences between index mean values (Tables I-III and IV-VI) were subjected to Student's t-test using SPSS version 22 for windows. Pearson's product moment correlation coefficient of CTR and CI with LA, SA, CD, TD, CL, and HW were calculated. The ranges, means, and standard errors of means were calculated for each sex, age bracket separately, and for all animals pooled. Variance was also calculated for the pooled results. A probability value of less than, or equal to, five percent ($P \leq 0.05$) was considered statistically significant.

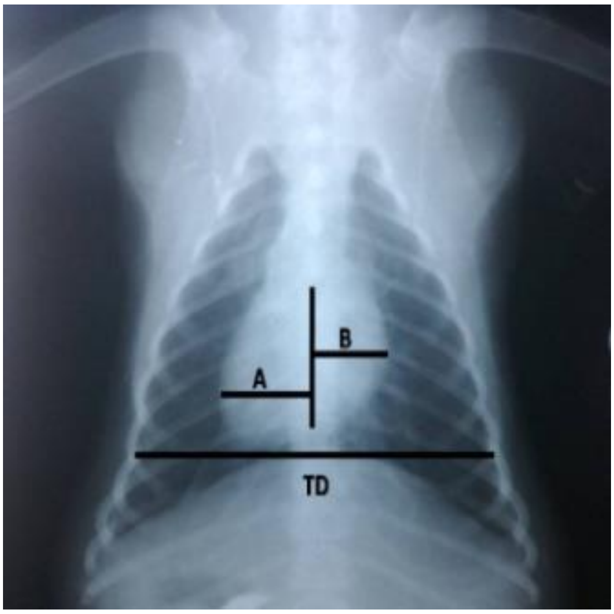

Figure 1: Thoracic dorsoventral roentgenographs of the NID illustrating parameters measured: TD = thoracic diameter, (A + B) = cardiac diameter. All parameters were measured in centimetres

RESULTS

The mean CD and TD values for the dorsoventral views were 5.93 ± 0.12 and 11.87 ± 0.279 (cm) while those of ventrodorsal views were 6.11 ± 0.13 and 11.44 ± 0.28 (cm) respectively (Table I). There was no significant difference ($P > 0.05$) in these values and the cardiothoracic ratio.

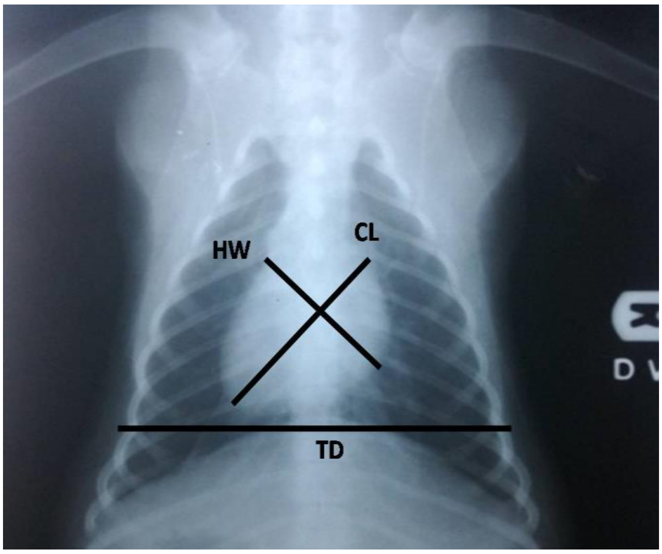

Figure II: Thoracic dorsoventral radiograph of the NID illustrating parameters measured: CL = cardiac length, HW = heart width, TD = thoracic diameter. All parameters were measured in centimetres.

The results of the comparison of sex differences in cardiothoracic ratios, CTRs in their respective DV versus VD views are presented in Table II. The dordal view of the CD and TD were 6.02 ± 0.15 and 11.89 ± 0.31 (cm) for females and 5.83 ± 0.19 and 11.84 ± 0.44 (cm) for the males respectively. There were no significant ($P \geq 0.05$) differences in these values and their CDR. The same trend was observed for age differences of similar parameters in puppies and adults (Table III) and no significant ($P \geq 0.05$) differences were observed in their respective DV versus VD views across different puppies and adult animals. The results of Comparison of two-thirds rule (i.e., ⅔TD>CD) obtained in DV and VD radiographs are presented in Table IV and no significant different was observed despite that the mean value of the two-thirds rule (i.e., ⅔TD>CD) was less in the ventrodorsal (VD) radiographs compared with its value in dorsoventral (DV) views.

The results of cardiac indices are presented in Table V. The mean cardiac length and width in DV and VD views were

Table 1: Comparison of cardiothoracic ratios, CTR in DV versus VD radiographs; measurements in cm.

Cardiothoracic ratio	Dorsoventral views (DV)	Ventrodorsal views (VD)
CD	5.93±0.12	6.11±0.13
TD	11.87±0.27	11.44±0.28
CTR=CD/TD	0.50±0.01	0.53±0.01

7.57 ± 0.15 and 8.00 ± 0.17 cm respectively. Mean thoracic diameters of DV (11.86 ± 0.25 cm) and VD (11.44 ± 0.28 cm) were also statistically similar. There were no significant differences in CI of DV and VD parameters. Similarly, the mean parameters CL, CW, T and CI across males and females in their respective DV and VD views were not also significantly (P ≥ 0.05) difference from one another and presented in Table VI.

The DV and VD views of adult animals had mean CL of 7.97 ± 0.14 and 8.51 ± 0.13 cm while similar values for puppies were 6.78 ± 0.78 and 7.00 ± 0.81cm respectively (Table VII). The CW and CW of both DV and VD views across different ages in this experiment were statistically (P ≥ 0.05) similar. Summary of Sex and age distributions of cardiac ratios (CTR and CI) in the NID in DV versus VD radiographs are presented in Table VIII.

Table II: Comparison of sex differences in cardiothoracic ratios, CTRs in their respective DV versus VD views; measurements in cm

CTRs	DV (Females)	VD (Females)	DV (Males)	VD (Males)
CD	6.02±0.15	6.22±0.18	5.83±0.19	6.00±0.20
TD	11.89±0.31	11.53±0.37	11.84±0.44	11.38±0.44
CTR	0.51±0.01	0.54±0.01	0.50±0.01	0.53±0.02

Table IV: Comparison of two-thirds rule (i.e., ⅔TD>CD) results obtained in DV and VD radiographs.

Thoracic Parameter	DV Views	VD Views
CD (cm)	5.93±0.12	6.11±0.13
TD (cm)	11.86±0.27	11.44±0.28
⅔TD	7.90±0.18	7.64±0.19

Table III: Comparison of age Differences in cardiothoracic ratios, CTRs in their respective DV versus VD views; measurements in cm

Cardio-thoracic ratio	Dorsoventral views (Adults)	Ventrodorsal views (Adults)	Dorsoventral views (Puppies)	Ventrodorsal views (Puppies)
CD	6.21±0.12	6.41±0.14	5.36±0.62	5.51±0.64
TD	12.52±0.27	12.16±0.27	10.57±1.22	10.04±1.17
CTR	0.50±0.01	0.53±0.02	0.51±0.01	0.55±0.01

Table V: Cardiac index, CI. CL=cardiac length, CW=cardiac width, TD=thoracic diameter, CI = ½(CL+CW)/TD, measurements in cm.

Cardiac indices	Dorsoventral views	Ventrodorsal views
CL	7.57±0.15	8.00±0.17
CW	5.64±0.11	5.85±0.11
TD	11.86±0.25	11.44±0.28
CI	0.56±0.01	0.61±0.01

Table VI. Comparison of sex differences in cardiac indices between their respective dorsoventral and ventrodorsal projections (15 Nigerian Indigenous Dogs of each sex); measurements in cm; CI = ½(CL+CW)/TD.

Cardiac indices	DV (Females)	VD (Females)	DV (Males)	VD (Males)
CL	7.55±0.17	8.07±0.22	7.59±0.25	7.93±0.27
CW	5.66±0.12	5.84±0.12	5.63±0.19	5.86±0.19
TD	11.88±0.31	11.55±0.36	11.83±0.44	11.34±0.43
CI	0.56±0.01	0.61±0.01	0.56±0.01	0.61±0.01

Table VII: Age Differences in cardiac indices, CIs. CL=cardiac length, CW=cardiac width, TD=thoracic diameter, CI = ½(CL+CW)/TD, measurements in cm.

Cardiac indices	DV (Adults)	VD (Adults)	DV (Puppies)	VD (Puppies)
CL	7.97±0.14	8.51±0.13	6.78±0.78	7.00±0.81
CW	5.90±0.11	6.12±0.10	5.14±0.59	5.32±0.62
TD	12.51±0.27	12.15±0.27	10.57±1.22	10.04±1.17
CI	0.56±0.01	0.61±0.01	0.57±0.01	0.62±0.01

The pooled mean variances, as presented in Table VIII, obtained of their respective cardiac indices were all very low. Results in the Table were presented as Mean ± SEM. Sex and age cardiac size (cardiothoracic ratio, CTR and cardiac index, CI). These means were not significantly different from each other, respectively ($P \geq 0.05$).

Pearson's correlation coefficient was used to determine the relationship between mean values and thoracic parameters (CL = cardiac length; CD = cardiac diameter; TD = thoracic diameter) at ≤0.05 probability level (Table IX). Significant ($P<0.05$) correlation was observed only with TD in both CTR and CI.

Table VIII: Summary of Sex and age distributions of cardiac ratios (CTR and CI) in the NID in DV versus VD radiographs. n = number of radiographs studied; SEM = standard error of mean; Var = pooled variance.

Individual Group	CTR (DV/VD) Mean±SEM (Ranges in DV/VD)	CI (DV/VD) Mean±SEM (Ranges in DV/VD)
Male (n = 15)	**0.50±0.01/0.53±0.02** (0.43–0.58/0.43-0.65)	**0.56±0.01/0.61±0.01** (0.50–0.61/0.55-0.69)
Female (n = 15)	**0.51±0.01/0.54±0.01** (0.45–0.57/0.46-0.58)	**0.56±0.01/0.61±0.01** (0.48–0.63/0.53-0.66)
Adult (n = 20)	**0.50±0.01/0.53±0.01** (0.43–0.58/0.43-0.65)	**0.56±0.01/0.61±0.01** (0.48–0.61/0.53-0.69)
Puppy (n = 10)	**0.51±0.01/0.55±0.01** (0.45–0.57/0.49-0.63)	**0.57±0.1/0.62±0.01** (0.52–0.63/0.56-0.68)
Pooled (n = 30)	**0.50±0.01/0.54±0.01** (0.45–0.58/0.43-0.65)	**0.56±0.01/0.61±0.01** (0.48–0.63/0.53-0.69)
Var	**0.0015/0.0023**	**0.0013/0.0019**

Table IX: Pearson's correlation coefficient was used to determine the relationship between index mean values and thoracic organ parameters at ≤0.05 probability level. CTR = cardiothoracic ratio; CI = cardiac index; CL = cardiac length; CD = cardiac diameter; TD = thoracic diameter; * = significant correlation.

Index		CD	CL	TD
CTR	**P. Correlation**	0.100	-0.302	-.513**
	Sig. (2-tailed)	0.600	0 .105	0.004
	N	30	30	30
CI	**P. Correlation**	-0.188	-.053	-0.552**
	Sig. (2-tailed)	0.319	0.782	0.002
	N	30	30	30

Guidelines for determination of index- parameter association are shown in in Table X. Strengths of association were rated small (0.1 – 0.3), medium (0.3 – 0.5), and high (0.5 – 1.0). Cardiac diameter, CTR and cardiac index, CI correlated significantly (($r = -.513$, $n=30$, $P < 0.05$) but negatively with only thoracic diameter, TD.

Table X: Guidelines for determination of strength of association:

Strength of Association	Coefficient, *r* Positive	Negative
Small	**0.1 to .3**	**-0.1 to -0.3**
Medium	**0.3 to .5**	**-0.3 to -0.5**
Large	**0.5 to 1.0**	**-0.5 to -1.0**

DISCUSSION

In the radiographs studied, there was no significant difference ($P \geq 0.05$) in the mean cardiothoracic ratios (CTRs) between sexes, age brackets, and projections.

However, CTR means were always, though insignificantly, smaller in the DV views compared with VD values, probably due to magnification of cardiac silhouette in latter views (Tables I-III and VIII). This finding may probably be one of the reasons, in clinical practice, that DV radiographs are preferred over VD projections for cardiac assessment (Dennis *et al.*, 2010). The pooled means (0.50±0.01) in the DV views and (0.54±0.01) in the VD views (Table I) were comparable to values reported for some exotic dog breeds (0.60 – 0.65) by Schnelling (1995), psittacines (0.51 – 0.61) by Straub *et al.*, (2002), for the flying fox species (0.45 – 0.68) by Gardner *et al.* (2007), and for humans (0.46 – 0.60) by Herring and Ostrum (2003), Baron (2004), Oladipo *et al.* (2012) and Mensah *et al.* (2015). In the NID and based on the normal CTR ranges (0.45-0.58/0.43-0.65 for DVVD, respectively) determined in the present study (Table VIII), any CTR value >0.65 may indicate cardiomegaly. In the DV versus VD roentgenographs respectively (Table IV), the cardiac-thoracic relationship was in the NID exactly within the two-thirds rule for dogs and *Felis sylvestris catus* (a feline sub-species), which states that the diameter of a normal heart should be less than two-thirds the thoracic diameter (Ettinger & Suter, 1970; Van den Broek &

Darke, 1987; Gardner *et al.*, 2007). The two-thirds rule provides a working estimate of cardiac size assessment. Justin and his co-workers (2007) opined that cardiothoracic ratio is a very simple and useful tool which can serve as an index of cardiac size in screening for cardiovascular diseases. According to these authors, when the normal CTR value for any breed is known, it serves as a baseline for proper cardiac assessment of members of that particular breed.

Cardiac index (also known as CTR index) was developed by Miller *et al.* (2000). These researchers derived the index by relating the average of cardiac length and cardiac width measurements to the thoracic diameter. In the present research (Tables V-VII and VIII), the pooled mean cardiac indices obtained in the DV and VD views were not significantly different from each other (P≥0.05). There was equally no statistical difference in cardiac index means between the sexes and the age brackets of the research dogs (P≥0.05). The pooled results, however, diverged from mean value of 0.48 (P≤0.05) established in man in a retrospective tomographic study by Miller *et al.*, (2000), probably due to differences in animal species and imaging modalities used by these authors. We also noticed that cardiac index means were repeatedly slightly greater in the VD radiographs compared with the mean values in DV roentgenographs, for the reason already given. Cardiac index may be more sensitive in the assessment of cardiac size because it factors in heart length as against CTR that is determined using only the cardiac and thoracic diameters. In other words, disorders associated primarily with abnormal heart length may not be accurately detected by the application of CTR.

Though greater in the pooled results, sex, and age values, the mean VD CTRs were not significantly different from the DV values (P > 0.05). The mean CI values were also not significantly different between sexes, ages, and views (P > 0.05) (Table VIII). CTR (r = -.513, n=30, P < 0.05) and CI (r = -0.513, n=30, p < 0.05) correlated significantly highly, strongly, but negatively with TD.

LIMITATIONS

This research aimed at developing guidelines for the interpretation of thoracic radiographs in the NID, but a few limitations were recognized. Though the sample size was adequate, the ages of the dogs were not evenly divided, with 10 puppies (33%) and 20 adult dogs (67%). It would be interesting to compare results from this population with another collection with an equal age (adult versus puppies) distributions. However, Sleeper & Buchanan (2001) published four different heart size results they obtained, in the same set of dogs, at the ages of 3, 6, 12 and 36 months and obtained mean values that were comparable with each other. Olatunji-Akioye & Alabi (2015) also did not find any significant canine age difference in the thoracic indices they established in another study, suggesting further that age of dogs may have little or no influence on cardiothoracic sizes.

Many authors have reported that the phase of cardiac cycle has little or no impact on heart size (Norman *et al*., 1971; Toal *et al*., 1985; Baron, 2004; Gardner *et al*., 2007). Other experts, namely: Birkemeier *et al*. (2011), Albertal *et al*. (2013), and Hassan *et al*. (2019) believe there is evidence that phase of respiration has an influence on thoracic conformation. For this reason, in the present study, each of the research animals was exposed at the peak of inspiration, thereby ruling out the phasic differential effect on thoracic size.

CONCLUSION

It is pertinent to reiterate that radiologists and experienced clinicians can achieve an acceptable degree of interpretative accuracy by their subjective observation of radiographs. However, in morphometric evaluation, the exact measurement of thoracic image size is not necessary. Radiographic ratios are means for the assessment of cardiothoracic parameters. Nevertheless, a normal thoracic silhouette does not rule out all the time the presence of a thoracic organ anomaly. Therefore, in most cases, radiographic findings should be compared with at least a result of another imaging modality such as computed tomography, echocardiography or electrocardiography, in the light of case history and the outcomes of general examination and laboratory investigations.

Findings of this work could probably be reference guides to the diagnosis of thoracic disease in the NID. They could also be an immense contribution to future radio-biometric researches. The applicability of radiomorphometric indices is objective and straightforward in clinical practice for assessing thoracic organ sizes. These investigations, made in the NID, are equally needed in other dog breeds.

CONFLICT OF INTEREST

The authors declare that conflicting interest does not exist.

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Article history:
Received: May 7, 2021,
Revised: July 3,2021
Accepted: July5, 2021