RESEARCH ARTICLE

Analysing Radiographic Cardiothoracic Indices Across Age Groups in Pugs: A Comparative Study

Hiren M. Barot[1*], Pinesh V. Parikh[1], Bhairavi N. Sodagar[2], Ashish C. Patel[3], Ankush J. Mayani[1], Forum A. Asodiya[1]

Abstract

The present research work was carried out to standardize normal reference values of various radiographic indices in 13 healthy Pugs and compare for different age effects. The dogs were divided into two age groups (Group P1, > 1 to < 4 years, n=6, and Group P2, > 4 to < 8 years, n=7) to evaluate whether cardiothoracic radiographic indices differ between the two age groups of dogs. Cardiothoracic radiography was taken without any sedation or anaesthesia and all radiographic measurements were done using software MicroDicom DICOM Viewer. Various cardiothoracic radiography indices studied in the Pug dogs did not vary significantly between the age groups. However, mean values of various cardiothoracic radiography indices, *viz.,* Vertebral Heart Score (VHS), Radiographic Left Atrial Dimension (RLAD), Vertebral Left Atrial Size (VLAS), LAwidth, LAtotal, Thoracic Inlet Heart Size (THIS), Manubrium Heart Score (MHS) and Cardiothoracic Ratio (CTR) can be used for diagnosis of left atrial enlargement and cardiomegaly in DCM affected dogs as an adjunct to echocardiography. Based on present findings, we concluded that mean values of various cardiothoracic radiography indices can be used as breed-specific reference values for screening of dogs suspected for cardiac disease.

Key words: Cardiothoracic indices, DCM, Pugs, Radiographic indices, Reference values.

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Introduction

Cardiothoracic radiography is a routinely performed radiographic examination in small animal practice to evaluate the shape, size, and position of the heart (Berry *et al.,* 2007). Multiple methods have been developed to assess and quantify heart size in small animals which are being commonly used in clinical practice (Johnson *et. al.,* 2008). The Vertebral Heart Score (VHS) may be most useful in assessing the change in size of the heart in an individual patient over time as there is good correlation between heart size and body length.

Recently, novel radiographic measurement methods, *viz.,* Vertebral Left Atrial Size (VLAS) (Malcolm *et al.,* 2018), Radiographic Left Atrial Dimension (RLAD) (Sanchez Salguero *et al.,* 2019), Modified Vertebral Left Atrial Size (M-VLAS) (Lam *et al.,* 2021), Left Atrial width (LAwidth) and Left Atrial total (LAtotal) (Stepien *et al.,* 2020), and Heart to Spine measurements (Sanchez Salguero *et al.,* 2019) have been developed for radiographic detection of left atrial enlargement in dogs. Manubrium Heart Score (MHS) (Mostafa *et al.,* 2020), Thoracic Inlet to Heart Size (TIHS) (Marbella Fernandez *et al.,* 2023) and Cardiac Sphericity Index (Gugliemini *et al.,* 2012) are another objective methods for screening of heart disease. VHS in healthy Pug (Kavitha *et al.,* 2020) has been reported by numerous workers. However, no reports on novel cardiothoracic radiography indices and their changes with age are available in healthy Pugs, which is most widely familiar breed in India. Hence, this study was aimed to analyse radiographic cardiothoracic indices across age groups in Pug breed of dog.

[1]Department of Veterinary Surgery and Radiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Anand - 388001, Gujarat, India

[2]Tata Trust Small Animal Hospital, Mahalaxmi, Mumbai, Maharastra, India

[3]Department of Animal Genetics and Breeding, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Anand - 388001, Gujarat, India

Corresponding Author: Hiren M. Barot, Department of Veterinary Surgery and Radiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Anand - 388001, Gujarat, India. e-mail: barothiren1996@gmail.com

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Materials and Methods

The present research work was conducted on 13 client owned clinically healthy Pugs, irrespective of sex, presented at the Department of Veterinary Surgery and Radiology, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Anand, Gujarat (India). The dogs were divided into two age groups (Group P1, > 1 to < 4 years, n=6 and Group P2, > 4 to < 8 years, n=7) to evaluate whether cardiothoracic radiographic indices differ between different age groups of dogs.

The dogs enrolled for present study were considered as healthy and fit for standardization of various cardiac indices after initial screening. The mean age, body weight and body surface area measurements for the P1 and P2 groups were found to be 2.37 ± 0.46 and 5.71 ± 0.56 years, 9.17 ± 1.05 and 10.00 ± 0.84 kg, and 0.37 to 0.58 and 0.33 to 0.54 m^2, respectively.

Screening of dogs included patient signalment, history, clinical signs, physical examination, cardiothoracic auscultation, haemato-biochemical examination, electro-cardiography, cardiothoracic radiography, and abdominal ultrasonography. All dogs were positioned in right lateral, left lateral as well as ventrodorsal recumbency without any sedation or anaesthesia to obtain digital radiographs of thoracic region using Direct Digital Radiography (DDR) unit (CXDI-401C, Compact Digital Radiography, DR System, Canon) and standard exposure techniques. After taking quality images all measurements were done using software MicroDicom DICOM Viewer.

VHS was determined by using the two different methods. One described by Buchanan and Bucheler (1995), whereas other one was as elucidated by Ljubica *et al.* (2007) (Fig. 1) on both right and left lateral cardiothoracic radiograph. Radiographic indices, *viz.,* Vertebral Left Atrial Size (VLAS, Fig. 2) (Malcolm *et al.,* 2018), Radiographic Left Atrial Dimension (RLAD, Fig. 3) (Sanchez Salguero *et al.,* 2019), Modified Vertebral Left Atrial Size (M-VLAS) (Lam *et al.,* 2021), Left Atrial width (LAwidth) (Fig. 4) and Left Atrial total (LAtotal) (Stepien *et al.,* 2020), Heart to Spine measurements (Sanchez Salguero *et al.,* 2019), CVC^d/AO^d, CVC^d/T4, CVC^d/R4, AO^d/T4 and AO^d/R4 Ratio (Lehmukhl *et al.,* 1997) and Thoracic Inlet Heart Size (THIS, Fig. 5) (Marbella Fernandez *et al.* (2023) measured from right lateral cardiothoracic radiograph were taken according to measurements method described by respective authors. Cardio-thoracic Ratio (CTR) was evaluated by using Schillaci *et al.* (2009) and Azevedo *et al.* (2016) methods on VD radiographs.

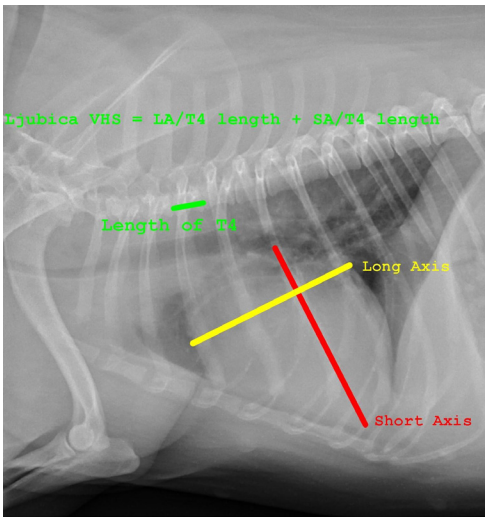

Fig. 1: Measurements of VHS using Ljubica method from right lateral radiograph

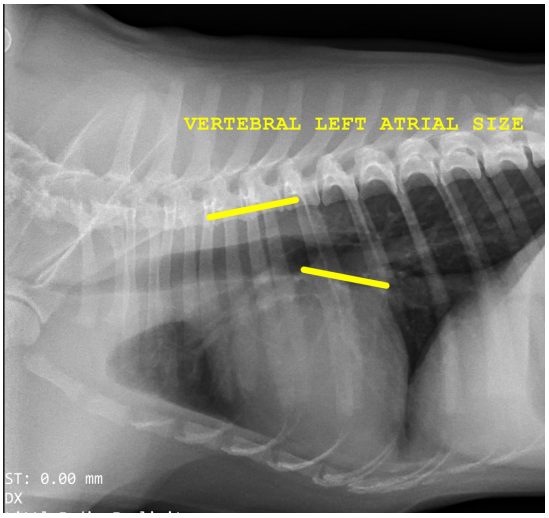

Fig. 2: Measurements of VLAS from right lateral radiograph

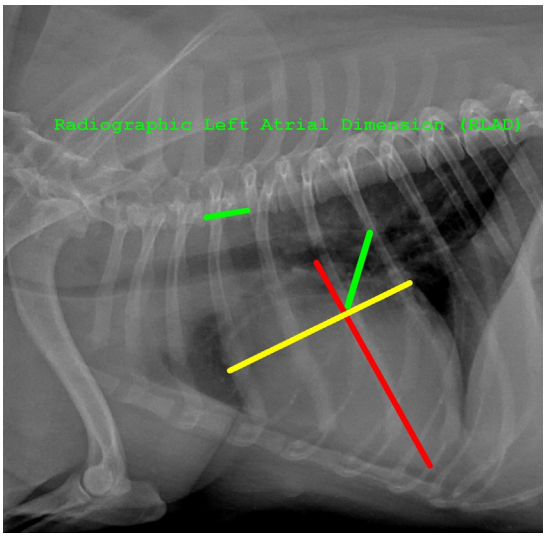

Fig. 3: Measurements of RLAD from right lateral radiograph

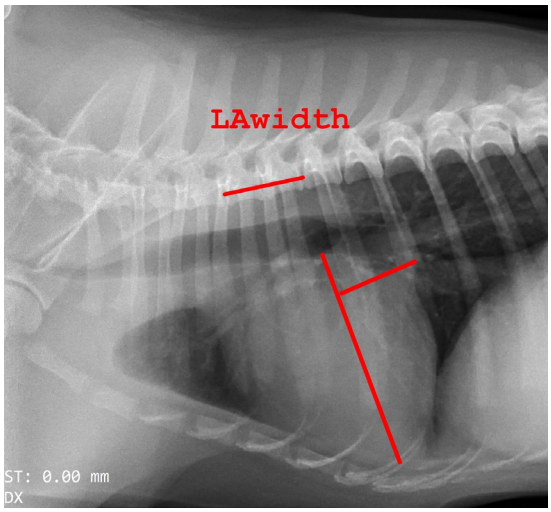

Fig. 4: Measurements of LAwidth from right lateral radiograph

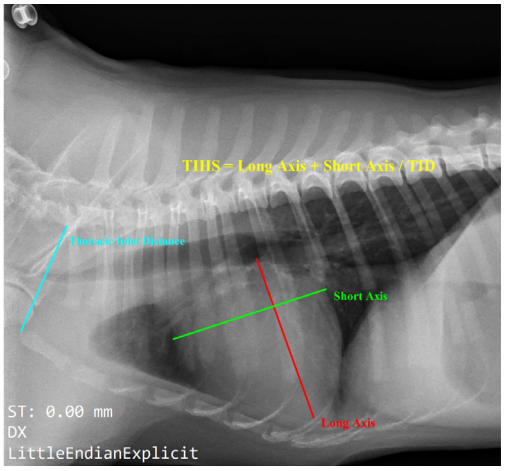

Fig. 5: Measurements of TIHS from right lateral radiograph

Thoracic depth to width ratio was determined for the classification of barrel and deep chested dog breeds. The depth of the thorax was assessed in right lateral radiographic projections and width of the thorax was measured on a ventrodorsal radiograph projection according to the method described by Jepsen-Grant *et al.* (2013). Dog breeds with a thoracic depth to width ratio < 0.75 were considered to have a broad or barrel chest, while those with a thoracic depth to width ratio of > 1.25 were considered to have a deep chest (Jepsen-Grant *et al.,* 2013).

Right lateral short axis, long axis, overall MHS and VD short axis, long and overall MHS were calculated from right lateral and VD radiograph, respectively (Fig. 6), using method suggested by Mostafa *et al.* (2020). CSI was evaluated from right lateral and ventrodorsal thoracic radiographic views to obtain the lateral CSI (Fig. 7) and ventrodorsal CSI, respectively (Gugliemini *et al.,* 2012). The sum of the lateral CSI and ventrodorsal CSI values represents the global CSI.

Statistical analysis was performed using IBM SPSS (Statistical Package for Social Science) software version 20. All data were presented as mean ± SE. Unpaired Student's 't' test was used to compare the differences between various indices in two age groups of Pugs. A value of $p<0.05$ was considered significant and value of $p<0.01$ was considered as highly significant (Snedecor and Cochran, 2014).

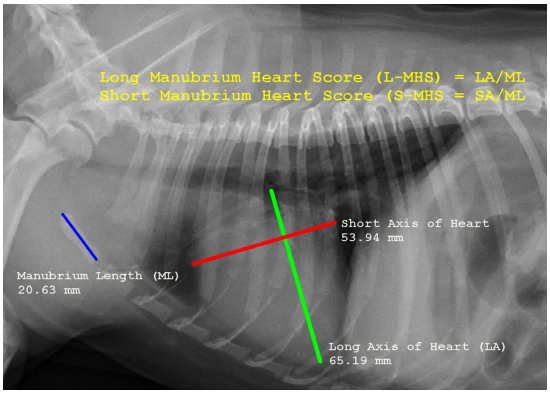

Fig. 6: Measurements of MHS from right lateral radiograph

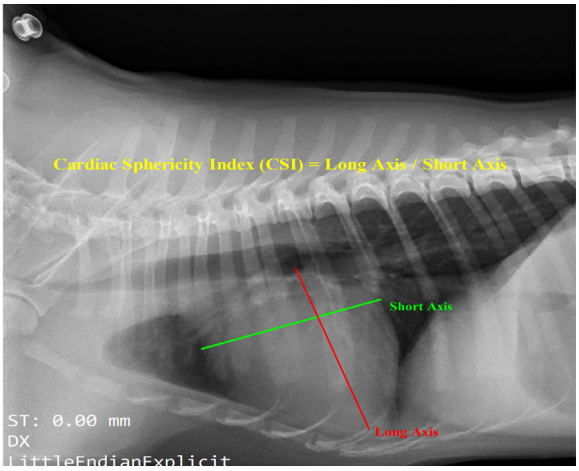

Fig. 7: Measurements of CSI from right lateral radiograph

Results and Discussion

Right lateral, left lateral, and VD VHS calculated using Buchanan and Bucheler (1995) method were observed to differ non-significantly between the two age groups of Pugs. However, the mean values of the right lateral and left lateral VHS calculated using Buchanan and Bucheler method were apparently higher with lower mean value of VD VHS than in P1 group (Table 1). Similarly, a non-significant difference in VHS with respect to age was observed by Gulanber *et al.* (2005) in Turkish Shepherd, and by Spasojevic *et al.* (2017) in young and old German Shepherd dogs. In Pugs, older age dog had higher VHS compared to young dog. This could be owing to age related degenerative changes of the vertebral column resulting in vertebral shortening and narrowing of inter-vertebral disk space. Another potential explanation is increased VHS with age due to epicardial fat deposition surrounding heart. In humans, epicardial fat deposition has been shown to increase with advancing age (Silaghi *et al.,* 2008; Birks *et al.* 2017).

The mean values of the right and left lateral VHS calculated by Ljubica *et al.* (2007) method showed statistically non-significant differences between the two age groups of Pugs (Table 1). The average values of right lateral VHS in different age groups of Pug of present study were greater than earlier report of Sharma (2020) in small breeds dogs as 10.62 ± 1.77 (range = 9.09 to 12.6) vertebrae. Ljubica method for calculation of vertebral heart score was more valuable and appropriate than Buchanan VHS method in brachycephalic dog or dog with vertebral or spine abnormality (Fig. 8) because in this method long and short axis were divided by length of 4th thoracic vertebrae to obtain VHS value.

The average values of various left atrial indices when compared between two groups of Pug breed did not differ significantly (Table 1). Mean values of RLAD and VALS in both age groups of Pug fell within normal range suggested by Weigel *et al.* (2022) in mean 4.8 years age group Pugs. Mean values of M-VLAS in both age groups of Pug were slightly

lower than those reported by Lam *et al.* (2021). Mean value of LAwidth and LAtotal in different age groups of Pug fell within normal range suggested by Stepien *et al.* (2020), who generated 1.7 v value for LAwidth and 3.8 v value for LAtotal in various breeds of dog.

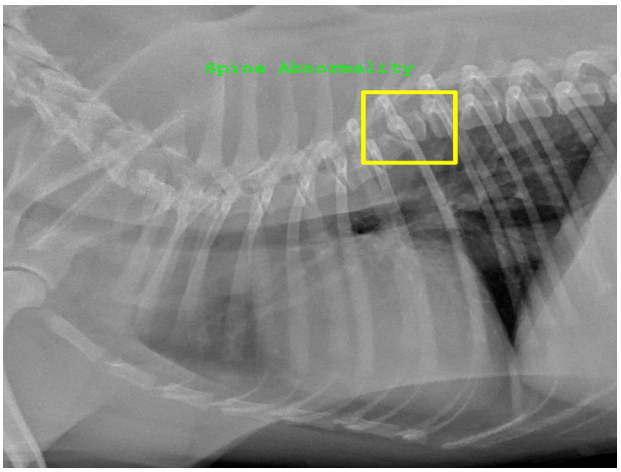

Fig. 8: Right lateral radiograph of Pug showing vertebral/spine abnormality

Table 1: Mean ± SE values of different radiographic cardiothoracic indices in two age groups of Pugs

Indices	Age groups		p-Value
	Group P1 (> 1 to < 4 years)	Group P2 (> 4 to < 8 years)	
Right lateral VHS (Buchanan and Bucheler method)	10.86 ± 0.08 v	11.15 ± 0.11 v	0.061
Left lateral VHS (Buchanan and Bucheler method)	10.53 ± 0.09 v	10.64 ± 0.14 v	0.548
VD VHS (Buchanan and Bucheler method)	11.33 ± 0.16 v	11.14 ± 0.16 v	0.492
Right lateral VHS (Ljubica method)	12.13 ± 0.21 v	12.35 ± 0.28 v	0.541
Left lateral VHS (Ljubica method)	12.21 ± 0.26 v	11.78 ± 0.42 v	0.419
RLAD	1.48 ± 0.11 v	1.46 ± 0.12 v	0.909
VLAS	1.94 ± 0.12 v	2.01 ± 0.03 v	0.553
M-VLAS	2.18 ± 0.18 v	2.27 ± 0.17 v	0.686
LAwidth	1.57 ± 0.12 v	1.53 ± 0.06 v	0.763
LAtotal	3.85 ± 0.15 v	3.32 ± 0.19 v	0.055
Br to spine	1.55 ± 0.05 v	1.88 ± 0.24 v	0.235
RLAD to spine	1.59 ± 0.07 v	1.58 ± 0.10 v	0.919

Table 1: Continued...

Indices	Age groups		p-Value
	Group P1 (> 1 to < 4 years)	Group P2 (> 4 to < 8 years)	
Azevedo CTR	0.56 ± 0.02	0.65 ± 0.13	0.527
Schillaci CTR	0.54 ± 0.02	0.64 ± 0.13	0.488
CVCd/AOd	1.08 ± 0.07	1.01 ± 0.01	0.216
CVCd/T4	1.01 ± 0.05	0.95 ± 0.03	0.324
CVCd/R4	3.18 ± 0.25	2.82 ± 0.15	0.234
AOd/T4	0.96 ± 0.01	0.94 ± 0.03	0.618
AOd/R4	3.06 ± 0.04	2.80 ± 0.12	0.119
Right lateral CSI	1.12 ± 0.03	1.17 ± 0.02	0.178
VD CSI	1.27 ± 0.03	1.29 ± 0.09	0.861
Global CSI	1.19 ± 0.02	1.18 ± 0.01	0.591
TIHS	2.91 ± 0.10	2.91 ± 0.05	0.990
TD-TW Ratio	0.77 ± 0.02	0.72 ± 0.03	0.297
Right lateral short axis MHS	2.80 ± 0.15	2.66 ± 0.15	0.496
Right lateral long axis MHS	3.18 ± 0.10	3.08 ± 0.15	0.586
Right lateral overall MHS	5.15 ± 0.92	5.75 ± 0.28	0.545
VD short axis MHS	2.82 ± 0.14	2.66 ± 0.16	0.483
VD long axis MHS	3.63 ± 0.15	3.23 ± 0.17	0.122
VD overall MHS	6.36 ± 0.28	5.90 ± 0.32	0.324

In Pugs, non-significant differences in mean values of Br to spine and RLAD to spine were observed between age group P1 (1.55 ± 0.05 and 1.59 ± 0.07 v) and P2 (1.88 ± 0.24 and 1.58 ± 0.10 v) (Table 1). No age wise analogous data of Heart to spine measurements were available in canine cardiac radiology. Further, higher mean values of CTR using both Azevedo and Schillaci method were found in age group P2 (0.65 ± 0.13 and 0.64 ± 0.13) as compared to P1 (0.56 ± 0.02 and 0.54 ± 0.02, respectively). However, values of CTR differed non-significantly between two age groups of Pugs (Table 1).

On grouping Pugs according to age groups, non-significantly lower values of CVCd/AOd, CVCd/T4, CVCd/R4, AOd/T4 and AOd/R4 were seen in age group of 4 to 8 years (P2) as compared to 1 to 4 years (P1) (Table 1). The common observations noted by authors in most of the dogs were size of caudal or inferior or posterior vena cava, Aorta and 4th thoracic vertebrae were almost same and that's why ratio of

CVCd/AOd, CVCd/T4 and AOd/T4 were almost 1.0 or nearly 1.0. However, According Suter and Lord (1984), Root and Bahr (2002) and Owens and Biery (1999) the diameter of the caudal vena cava is subjected to both individual and physiologic variations. These variations are influenced by factors such as the phase of respiration, pleural pressure, phase of the cardiac cycle, and volume.

Mean values of right lateral CSI, VD CSI and global CSI were statistically non-significant between two groups of Pug (Table 1). The lack of significance in cardiac sphericity index occurs due to rounded appearance of heart in Pug. According to Berry *et al.* (2007) cardiac silhouettes typically exhibit a rounded appearance in the ventrodorsal radiographic view of the thorax in healthy dogs with deep and narrow chests. No age wise analogous data of cardiac sphericity index were available in canine cardiac radiology. However, the mean values for all were within normal range given by Gugliemini *et al.* (2012). Similarly, no significant changes were observed between groups P1 and P2 of Pug in TIHS (Table 1).

Mean values of TD-TW ratio were 0.77 and 0.72 in group P1 and P2, respectively. Based on present finding, Pug (ratio, <0.75) had a barrel or broad chest conformation. Moreover, the Manubrium heart score did not show any significant variation between two age groups of Pugs. No age specific literature was available about these novel techniques. However, all MHS values in Pugs were in line with results of Mostafa *et al.* (2020) in small breed dogs.

Conclusion

The study revealed that the cardiothoracic radiography indices in the Pug dogs did not vary significantly among the age groups, However, mean values of various cardiothoracic radiography indices, *viz.,* Vertebral Heart Score (VHS), Radiographic Left Atrial Dimension (RLAD), Vertebral Left Atrial Size (VLAS), LAwidth, LAtotal, Thoracic Inlet Heart Size (THIS), Manubrium Heart Score (MHS) and Cardiothoracic Ratio (CTR) can be used for diagnosis of left atrial enlargement and cardiomegaly in DCM affected dogs as an adjunct to echocardiography.

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References

Azevedo, G.M., Pessoa, G.T., Moura, L.D.S., Sousa, F.D.C.A., Rodrigues, R.P.D.S., Sanches, M.P., Fontenele, R.D., Barbosa, M.A.P.D.S., Neves, W.C., Sousa, J.M.D., & Alves, F.R. (2016). Comparative study of the vertebral heart scale (VHS) and the cardiothoracic ratio (CTR) in healthy Poodle breed dogs. *Acta Scientiae Veterinariae, 44*(1), 1-7.

Berry, C.R., Graham, P.R., & Thrall, D.E. (2007). Interpretation paradigms for the small animal thorax. In D. E. Thrall, 5th eds., *Textbook of Veterinary Diagnostic Imaging*, St. Louis: Saunders-Elsevier, pp. 462-485.

Birks, R., Fine, D.M., Leach, S.B., Clay, S.E., Eason, B.D., Britt, L.G., & Lamb, K.E. (2017). Breed-specific vertebral heart scale for the Dachshund. *Journal of the American Animal Hospital Association, 53*(2), 73-79.

Buchanan, J.W., & Bucheler, J. (1995). Vertebral scale system to measure canine heart size in radiographs. *Journal of the American Veterinary Medical Association, 206*(2), 194-199.

Guglielmini, C., Diana, A., Santarelli, G., Torbidone, A., Di Tommaso, M., Baron Toaldo, M., & Cipone, M. (2012). Accuracy of radiographic vertebral heart score and sphericity index in the detection of pericardial effusion in dogs. *Journal of the American Veterinary Medical Association, 241*(8), 1048-1055.

Gulanber, E.G., Gonenci, G., Kaya, U., Aksoy, O., & Birsik, H.S. (2005). Vertebral scale system to measure heart size in thoracic radiographs of Turkish Shepherd (Kangal) dogs. *Turkish Journal of Veterinary & Animal Sciences, 29,* 723-726.

Jepsen-Grant, K., Pollard, R., & Johnson, L. (2013). Vertebral heart scores in eight dog breeds. *Veterinary Radiology & Ultrasound, 54*(1), 3-8.

Johnson, V., Hansson, K., Mai, W., Dukes-McEwan, J., Lester, N., Schwarz, T., Chapman, P., & Morandi, F. (2008). The heart and major vassels. In: Schwarz T, Johnson V. *Manual of Canine and Feline thoracic Imaging*, 1st eds., BSAVA, pp. 86-176.

Kavitha, S., Jeyaraja, K., Thirunavukkarasu, P., Thirunavukkarasu, P.S., & Chandrasekaran, D. (2020). Echocardiographic parameters and indices in Pug dogs. *Intas Polivet, 21*(1), 176-178.

Lam, C., Gavaghan, B.J., & Meyers, F.E. (2021). Radiographic quantification of left atrial size in dogs with myxomatous mitral valve disease. *Journal of Veterinary Internal Medicine, 35,* 747-754.

Lehmukhl, L.B., Bonagura, J.D., Biller, D.S., & Hartman, W.M. (1997). Radiographic evaluation of caudal vena cava size in dogs. *Veterinary Radiology & Ultrasound, 38*(2), 94-100.

Ljubica, S.K., Krstic, N., & Trailovic, R.D. (2007). Comparison of three methods of measuring vertebral heart size in German Shepherd dogs. *Acta Veterinaria, 57*(2-3), 133-141.

Malcolm, E.L., Visser, L.C., Phillips, K.L., & Johnson, L.R. (2018). Diagnostic value of vertebral left atrial size as determined from thoracic radiographs for assessment of left atrial size in dogs with myxomatous mitral valve disease. *Journal of the American Veterinary Medical Association, 253*(8), 1038-1045.

Marbella Fernández, D., García, V., Santana, A.J., & Montoya-Alonso, J.A. (2023). The thoracic inlet heart size: A new approach to radiographic cardiac measurement. *Animals, 13*(389), 1-14.

Mostafa, A.A., Peper, K.E., & Berry, C.R. (2020). Use of cardiac sphericity index and manubrium heart scores to assess radiographic cardiac silhouettes in large- and small-breed dogs with and without cardiac disease. *Journal of the American Veterinary Medical Association, 256*(8), 888-898.

Owens, J.M., & Biery, D.N. (1999). *Radiographic Interpretation for the Small Animal Clinician*. 2nd eds., Missouri: Ralston Purina Company, pp. 89-132.

Root, C.R., & Bahr, R.J. (2002). The heart and great vessels: In: *Textbook of Diagnostic Veterinary Radiology*. 4th eds., W.B. Saunders Company, Philadelphia, pp. 402-419.

Sanchez Salguero, X., Prandi, D., Llabrés-Díaz, F., Manzanilla, E. G., Badiella, L., & Bussadori, C. (2019). Heart to spine measurements to detect left atrial enlargement in dogs with mitral insufficiency. *Irish Veterinary Journal, 72*(1), 1-4.

Schillaci, M.A., Parish, S., & Jones-Engel, L. (2009). Radiographic measurement of the cardiothoracic ratio in pet macaques from Sulawesi, Indonesia. *Radiography, 15*(4), e29–e33.

Sharma, P. (2020). Studies on thoracic radiography, electrocardiography and echocardiography in small breed dogs. *M.V.Sc Thesis.,* U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan (DUVASU), Mathura-281001 UP, India.

Silaghi, A., Piercecchi-Marti, M.D., Grino, M., Leonetti, G., Alessi, M.C., Clement, K., Dadoun, F., & Dutour, A. (2008). Epicardial adipose tissue extent: Relationship with age, body fat distribution, and coronaropathy. *Obesity, 16*(11), 2424-2430.

Snedecor, G.W. & Cochran, W.G. (2014). *Statistical methods*, paperback. 8th eds., East West Press Pvt. Ltd., New Delhi.

Spasojevic, K., Trailovic, D.R. & Krstic, N. (2017). Age-dependent electrocardiographic and echocardiographic changes in German Shepherd dogs. *Iranian Journal of Veterinary Research, 18*(1), 43-48.

Stepien, R.L., Rak, M.B., & Blume, L.M. (2020). Use of radiographic measurements to diagnose stage B2 preclinical myxomatous mitral valve disease in dogs. *Journal of the American Veterinary Medical Association, 256*(10), 1129-1136.

Suter, P.F., & Lord, P.F. (1984). A critical evaluation of the radiographic findings in canine cardiovascular diseases. *Journal of the American Veterinary Medical Association, 158*(3), 358-371.

Weigel, P.S., Nolte, I., Mach, R., Freise, F., & Bach, J. (2022). Reference ranges for standard-echocardiography in Pugs and impact of clinical severity of brachycephalic obstructive airway syndrome (BOAS) on echocardiographic parameters. *BMC Veterinary Research, 18*(282), 1-13.