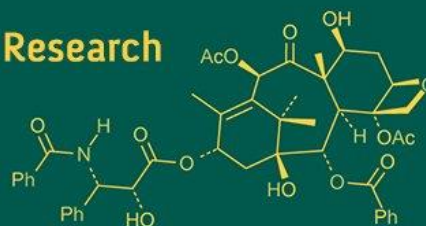
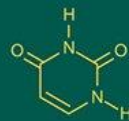
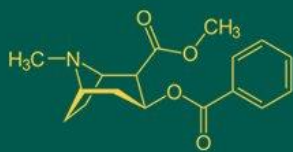


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(11): 275-280
www.biochemjournal.com
Received: 22-08-2025
Accepted: 26-09-2025

Hardiben N Patel
M.V.Sc., Department of Veterinary
Anatomy, College of Veterinary
Science & Animal Husbandry,
Kamdhenu University,
Sardarkrushinagar, Gujarat, India

KB Patel
Retd. Professor and Head,
Department of Veterinary
Anatomy, College of Veterinary
Science & Animal Husbandry,
Kamdhenu University,
Sardarkrushinagar, Gujarat, India

SS Patil
Associate Professor and Head,
Department of Animal Nutrition,
College of Veterinary Science &
Animal Husbandry, Kamdhenu
University, Sardarkrushinagar,
Gujarat, India

PT Sutaria
Assistant Professor, Department of
Veterinary Surgery and Radiology,
College of Veterinary Science &
Animal Husbandry, Kamdhenu
University, Sardarkrushinagar,
Gujarat, India

AM Patel
Assistant Professor, Department of
Veterinary Surgery and Radiology,
College of Veterinary Science &
Animal Husbandry, Kamdhenu
University, Sardarkrushinagar,
Gujarat, India

JD Chaudhary
Assistant Professor, Department of
Animal Genetics and Breeding,
College of Veterinary Science &
Animal Husbandry, Kamdhenu
University, Sardarkrushinagar,
Gujarat, India

MC Desai
Retd. Professor and Head,
Department of Veterinary
Anatomy, College of Veterinary
Science & Animal Husbandry,
Kamdhenu University,
Sardarkrushinagar, Gujarat, India

Corresponding Author:
Hardiben N Patel
M.V.Sc., Department of Veterinary
Anatomy, College of Veterinary
Science & Animal Husbandry,
Kamdhenu University,
Sardarkrushinagar, Gujarat, India

Radiographic biometry of the thorax in female Mehsana goat (*Capra hircus*)

Hardiben N Patel, KB Patel, SS Patil, PT Sutaria, AM Patel, JD Chaudhary and MC Desai

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i11d.6248>

Abstract

The present study was conducted on total 24 apparently healthy female Mehsana goats free from cardiovascular disease. The animals were divided into four age groups (Group-I to Group-IV) ranging from 6 to 24 months, at 6 months $\pm$ 2 weeks interval. Thoracic radiography was performed on right lateral (RL) recumbency.

The cardiac long axis (CLA) and cardiac short axis (CSA) values across the different age groups ranged from 10.16 $\pm$ 0.09 to 12.29 $\pm$ 0.16 cm and 5.94 $\pm$ 0.16 to 7.13 $\pm$ 0.07 cm, respectively. The vertebral heart size (VHS) values ranged from 8.45 $\pm$ 0.08 to 8.93 $\pm$ 0.12 vertebrae. The cardiac inclination angle, cardiosternal contact, thoracic height and thoracic inlet diameter (TID) values ranged from 19.93 $\pm$ 0.99 to 26.80 $\pm$ 0.95 degree; 4.44 $\pm$ 0.29 to 5.10 $\pm$ 0.25 cm; 14.73 $\pm$ 0.19 to 18.13 $\pm$ 0.18 cm and 7.35 $\pm$ 0.18 to 9.33 $\pm$ 0.30 cm, respectively from 6 to 24 months age. The tracheal diameter (TrD) and tracheal angle (TrA) values ranged from 1.18 $\pm$ 0.03 to 1.31 $\pm$ 0.03 cm and 20.08 $\pm$ 0.89 to 23.53 $\pm$ 0.64 degree. The values of T₄ length and T₃-T₅ length ranged from 1.74 $\pm$ 0.06 to 2.11 $\pm$ 0.02 cm and 5.64 $\pm$ 0.08 to 6.35 $\pm$ 0.05 cm. The caudal vena cava diameter (CVC) and aorta diameter (AO) values ranged from 1.11 $\pm$ 0.05 to 1.52 $\pm$ 0.03 cm and 1.29 $\pm$ 0.06 to 1.59 $\pm$ 0.07 cm, respectively. The values of cardiac long axis (CLA), cardiac short axis (CSA), vertebral heart size (VHS), cardiac inclination angle, thoracic height, thoracic inlet diameter (TID), caudal vena cava (CVC), aorta (AO) diameter, T₄ length and T₃-T₅ length exhibited significant variation across different age groups. While, the values of tracheal diameter (TrD), tracheal angle (TrA) and spino-phrenic angle did not show significant difference across age groups. The study established baseline reference data of cardiothoracic parameters for Mehsana goats across different age groups, useful for clinical diagnosis and research.

Keywords: Radiographic biometry, Mehsana goat, thorax, lateral projection

1. Introduction

The goat (*Capra hircus*) is one of the important domestic livestock species in India. Goat have been studied for their anatomical structures, as they are considered a key model for understanding the biology, physiology of small ruminants and biomedical research (Mohan *et al.*, 2005) [16]. Radiographic anatomy provides detailed information regarding the normal position, size and appearance of organs and structures (Abd-Elbasset *et al.*, 2021) [1]. The thoracic radiography is a quick and commonly used diagnostic modality in small ruminants because of its accessibility and cost-effectiveness. Thoracic radiography facilitates information regarding normal lung fields, cardiac shape, size, position and vascularization which can aid in diagnosis of suspected cases of cardiac disease, respiratory disease and other thoracic disorders.

Radiographic biometry of the thorax involves measuring dimensions of the thoracic organs such as heart, trachea, aorta and caudal vena cava on thoracic radiographs in different radiographic positions. Radiographic evaluation across different age groups reveals marked changes in the size and shape of cardiac silhouette, relative positioning of thoracic organs and skeletal structures. In young individuals, the heart appears proportionally larger in relation to the thoracic cavity size in comparison to adult animals (Kealy *et al.*, 2011) [11]. The age related variation in heart size have been reported in various species in respect to the normal radiographic anatomy, including dogs (Sleeper and Buchanan, 2001; Bhargavi *et al.*, 2018^a; Bhargavi *et al.*, 2019; Swetha *et al.*, 2020) [20, 5, 21], cattle (Jilintai *et al.*, 2006; Verma *et al.*, 2022) [10], buffalo (Verma *et al.*, 2022) [23], monkeys (Harada *et al.*, 2010) [9], alpacas

(Nelson *et al.*, 2011)^[17] and lamb (Ulian *et al.*, 2018)^[22] to create species and age specific base reference values. The present study was planned to generate normal radiographic biometric values of thorax and to evaluate correlation between age and body weight with each radiographic biometric values of the thorax in the Mehsana goat.

2. Materials and Methods

A general clinical examination was performed on all goats to assess presence of any cardiopulmonary disease. Mehsana goat without any signs of lethargy, abnormal appetite, fainting, and respiratory distress were included in the present study. The cardiac and pulmonary auscultation was performed. Total 24 apparently healthy female Mehsana goats were selected according to age.

For the purpose of age associated comparison of radiographic biometric data, the Mehsana goats were divided into four groups (Group-I to Group-IV) from 6 to 24 months at 6 months $\pm$ 2 weeks interval. In the present investigation, the mean $\pm$ SE value of body weight was 16.67 $\pm$ 1.28 kg in Group-I, 26.50 $\pm$ 1.18 kg in Group-II, 37.83 $\pm$ 2.04 kg in Group-III and 43.83 $\pm$ 0.83 kg in Group-IV for Mehsana goat.

The X-ray machine (Multimobil 10, Siemens) with computed radiography system was used for imaging. All radiographs were obtained without the use of anaesthesia or sedation. Lateral thoracic radiographs were performed in right lateral (RL) recumbency, with the thoracic limbs extended cranially to expose the thoracic region. Radiographic images of complete thoracic region from thoracic inlet to diaphragm was obtained. The thorax of an animal was kept directly on the X-ray plate to keep the Object Film Distance (OFD) minimum. The Focal Film Distance (FFD) was kept 90 cm constant for all animals. The exposure factor ranged from 5 to 10 mAs and 55 to 60 kVp, adjusted according to the animal's body weight, age and thoracic thickness. The radiographs were taken during full inspiration to the greatest extent feasible. Exposed x-ray plate was read using a computed radiography system.

2.1 Radiographic biometric parameters of thorax in right lateral (RL) View

Each computed radiograph was interpreted and the following parameters were measured from right lateral (RL) radiographs using the digital scale provided in the software.

- 1. Cardiac Long Axis (CLA):** The cardiac long axis was measured from the ventral border of the carina at the base to the most distant ventral contour of the heart (Mattoon *et al.*, 2001)^[15].
- 2. Cardiac Short Axis (CSA):** The cardiac short axis (cranial-to-caudal) was measured at the widest part of the cardiac silhouette, perpendicular to the long axis (Mattoon *et al.*, 2001)^[15].
- 3. Vertebral Heart Size (VHS):** The vertebral heart size (VHS) was determined by Buchanan and Bucheler (1995)^[7] method. The cardiac long axis and cardiac short axis were measured as described above, and these measurements were transferred to the vertebrae, starting at the cranial edge of T₄, and the number of vertebrae that fall within the calliper points was counted to the nearest 0.1 vertebra. VHS was calculated using following formula VHS = CLA+CSA. One vertebral unit was defined as the distance from one cranial end-

plate to the beginning of the following vertebral cranial end-plate.

- 4. Cardiac Inclination Angle:** The cardiac inclination angle was measured at the angle between the cranial border of heart and dorsal margin of the sternum (Diniz *et al.*, 2013)^[18].
- 5. Cardiosternal Contact:** The cardiosternal contact was measured from the cardiac apex to the point where the cranioventral margin the cardiac silhouette diverges from the sternum (Nelson *et al.*, 2011)^[17].
- 6. Thoracic Height:** The thoracic height was measured by a line drawn from the cardiac apex to ventral margin of the 4th thoracic vertebrae (Abdelhakiem *et al.*, 2020)^[20].
- 7. Thoracic Inlet Diameter (TID):** The thoracic inlet diameter was measured from the ventral aspect of the vertebral column at the midpoint of the most cranial rib to the cranial border of the manubrium (Makungu and Paulo, 2014)^[14].
- 8. Tracheal Diameter (TrD):** The tracheal diameter was measured between the internal surface of the tracheal wall perpendicular to the tracheal long axis at the point where the thoracic inlet diameter crosses the midpoint of the tracheal lumen (Makungu and Paulo, 2014)^[14].
- 9. Tracheal Angle (TrA):** The tracheal angle was measured between the ventral margins of T₃-T₅ vertebrae and the dorsal margin of the trachea at the thoracic inlet (Nelson *et al.*, 2011)^[17].
- 10. Caudal Vena Cava Diameter (CVC):** The caudal vena cava diameter was measured from its ventral to dorsal limits in the region of greatest diameter, not overlapping the heart or diaphragm (Lehmukhl *et al.*, 1997)^[13].
- 11. Aorta Diameter (AO):** The diameter of the descending aorta was measured from its ventral to dorsal limit at the same intercostal space where the CVC measurement was taken (Lehmukhl *et al.*, 1997)^[13].
- 12. Spinophrenic Angle:** The spino-phrenic angle was measured between the ventral border of the caudal thoracic vertebrae and the diaphragmatic crus dorsally (Abdelhakiem *et al.*, 2020)^[20].
- 13. Length of the 4th Thoracic Vertebrae (T₄ Length):** The length of the fourth thoracic vertebra (T₄) was measured from the mid-point of the cranial endplate to the caudal endplate (Kumar *et al.*, 2019^a)^[12].
- 14. Length of 3rd to 5th Thoracic Vertebral (T₃-T₅ Length):** The length of thoracic vertebrae 3rd-5th was measured from the mid-point of the cranial end plate of the 3rd thoracic vertebra to the mid-point of the caudal endplate of the 5th thoracic vertebra (Kumar *et al.*, 2019^a)^[12].

2.2 Statistical Analysis

The data generated in the present investigation were described by mean and standard error (Mean $\pm$ SE) for each set of radiographic parameters. One-way analysis of variance (ANOVA) was performed using R programme software (R version 4.5.0) to compare the parameters across four age groups.

Further, Pearson's correlation was used to assess the relationship between various radiographic parameters and ratios with the age and body weight of the animals. The level of statistical significance was set at $p < 0.05$.

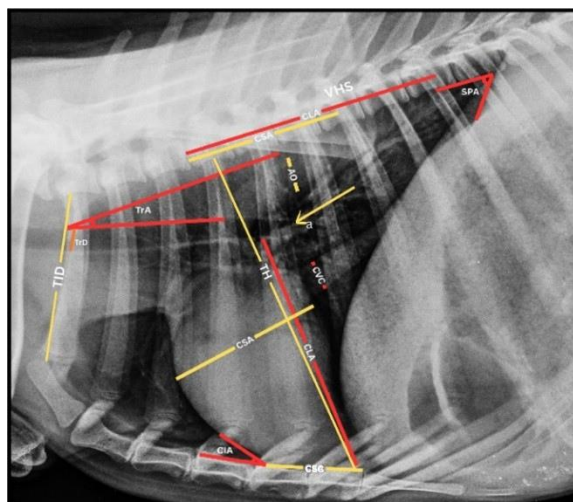


Fig 1: Right lateral thoracic radiograph of goat showing the measurement landmark of cardiac long axis (CLA), cardiac short axis (CSA), vertebral heart size (VHS), cardiac inclination angle (CIA), cardiosternal contact (CSC), thoracic inlet diameter (TID), tracheal diameter (TrD), thoracic height (TH), tracheal angle (TrA), spino-phrenic angle (SPA), caudal vena cava diameter (CVC), aorta diameter (AO) location of carina (a).

3. Results and Discussion

The mean $\pm$ SE values of various radiographic parameters

and their correlation with age and body weight in Mehsana goats are presented in Table.

Table 1: The mean $\pm$ SE values of various radiographic parameters and their correlation with age and body weight in Mehsana goats are presented

Radiographic parameter	Experimental Age groups				p-value	Correlation with age	Correlation with body weight
	Group I (6 months $\pm$ 2 weeks)	Group II (12 months $\pm$ 2 weeks)	Group III (18 months $\pm$ 2 weeks)	Group IV (24 months $\pm$ 2 weeks)			
Cardiac long axis (CLA) (cm)	10.16 $\pm$ 0.09 ^a	10.71 $\pm$ 0.28 ^a	11.68 $\pm$ 0.16 ^b	12.29 $\pm$ 0.16 ^c	0.001	0.887**	0.847**
Cardiac short axis (CSA) (cm)	5.94 $\pm$ 0.16 ^a	6.11 $\pm$ 0.16 ^a	6.73 $\pm$ 0.19 ^b	7.13 $\pm$ 0.07 ^b	0.001	0.799**	0.796**
Vertebral heart size (VHS) (vertebrae)	8.45 $\pm$ 0.08 ^a	8.93 $\pm$ 0.12 ^b	8.87 $\pm$ 0.15 ^b	8.78 $\pm$ 0.09 ^b	0.031	0.333	0.283
Cardiac inclination angle (degree)	26.80 $\pm$ 0.95 ^b	25.80 $\pm$ 0.87 ^b	23.77 $\pm$ 1.43 ^b	19.93 $\pm$ 0.99 ^a	0.001	-0.708**	-0.654**
Cardio sternal contact (cm)	05.10 $\pm$ 0.25	04.81 $\pm$ 0.19	04.39 $\pm$ 0.26	04.44 $\pm$ 0.29	0.181	-0.427*	-0.407*
Thoracic height (cm)	14.73 $\pm$ 0.19 ^a	15.14 $\pm$ 0.35 ^a	16.46 $\pm$ 0.19 ^b	18.13 $\pm$ 0.18 ^c	0.001	0.899**	0.860**
Thoracic inlet diameter (TID) (cm)	07.35 $\pm$ 0.18 ^a	07.37 $\pm$ 0.17 ^a	07.85 $\pm$ 0.16 ^a	09.33 $\pm$ 0.30 ^b	0.001	0.770**	0.784**
Tracheal diameter (TrD) (cm)	01.18 $\pm$ 0.03	01.18 $\pm$ 0.07	01.24 $\pm$ 0.06	01.31 $\pm$ 0.03	0.258	0.394	0.492*
Tracheal angle (TrA) (degree)	20.08 $\pm$ 0.89	22.35 $\pm$ 0.10	22.28 $\pm$ 1.54	23.53 $\pm$ 0.64	0.106	0.469*	0.455*
Caudal vena cava diameter (CVC) (cm)	1.11 $\pm$ 0.05 ^a	1.18 $\pm$ 0.04 ^a	1.50 $\pm$ 0.08 ^b	1.52 $\pm$ 0.03 ^b	0.001	0.786**	0.787**
Aorta diameter (AO) (cm)	1.29 $\pm$ 0.06 ^a	1.63 $\pm$ 0.08 ^b	1.53 $\pm$ 0.11 ^{ab}	1.59 $\pm$ 0.07 ^b	0.036	0.391	0.236
Spinophrenic angle (degree)	43.13 $\pm$ 1.26	41.22 $\pm$ 2.18	40.03 $\pm$ 2.31	39.25 $\pm$ 1.89	0.536	-0.311	-0.299
T ₄ length (cm)	01.74 $\pm$ 0.06 ^a	01.78 $\pm$ 0.06 ^a	01.96 $\pm$ 0.05 ^b	02.11 $\pm$ 0.02 ^b	0.001	0.769**	0.705**
T ₃ to T ₅ length (cm)	05.64 $\pm$ 0.08 ^a	05.68 $\pm$ 0.11 ^a	06.06 $\pm$ 0.09 ^b	06.35 $\pm$ 0.05 ^c	0.001	0.814**	0.822**

^{a, b, c} Means of row with different superscript showing significant differences at 5 % level or as otherwise mentioned specifically in table. ** indicates the level of significance at 1% * indicates the level of significance at 5%

3.1 Cardiac long axis (CLA) and Cardiac short axis (CSA)

The radiographic cardiac long axis (CLA), cardiac short axis (CSA) and vertebral heart size (VHS), are potential parameters for evaluation of cardiac size. The mean cardiac long axis (CLA) was 10.16 $\pm$ 0.09, 10.71 $\pm$ 0.28, 11.68 $\pm$ 0.16 and 12.29 $\pm$ 0.16 cm in Group-I to IV, respectively. The values of cardiac short axis (CSA) were 5.94 $\pm$ 0.16, 6.11 $\pm$ 0.16, 6.73 $\pm$ 0.19 and 7.13 $\pm$ 0.07 cm in Group-I to IV, respectively. Statistical analysis showed significant difference ($p \leq 0.01$) in cardiac long axis and cardiac short axis measurements in different experimental groups. The correlation analysis revealed statistically significant ($p \leq 0.01$), positive and higher correlation between cardiac

long axis (CLA) and cardiac short axis (CSA) with both age and body weight of Mehsana goats.

The present findings of cardiac long axis (CLA) and cardiac short axis (CSA) measurement was lower than the mean values reported by Abdelhakiem *et al.* (2020) [20], who reported values of 13.17 $\pm$ 1.44 cm and 7.70 $\pm$ 1.26 cm in right lateral (RL) view and 12.86 $\pm$ 1.17 cm and 8.15 $\pm$ 1.24 cm in left lateral (LL) view, respectively in goats age of 2.9 years. Similarly, Kumar *et al.* (2019^a) [12] documented cardiac long axis and cardiac short axis of 10.55 $\pm$ 0.48 cm and 6.47 $\pm$ 0.35 cm in goat of Group-I (3-6 months) and 11.98 $\pm$ 0.32 cm and 6.78 $\pm$ 0.26 cm in Group-II (6-12 months), which were higher than the present findings of corresponding group.

3.2 Vertebral heart size (VHS)

The vertebral heart size (VHS) is widely accepted method that provides the ratio of the heart size in comparison to the thoracic vertebrae and it is helpful to evaluate the cardiac silhouette size and quantitative progressive changes over time as well as in cardiac disease (Buchanan and Bucheler, 1995; Sleeper and Buchanan, 2001; Birks *et al.*, 2017) [7, 20, 6]. The vertebral heart size (VHS) values were 8.45 ± 0.08 , 8.93 ± 0.12 , 8.87 ± 0.15 and 8.78 ± 0.09 vertebrae in Group-I to IV, respectively. A statistically significant difference in vertebral heart size was observed across different groups ($p \leq 0.05$). The mean vertebral heart size value of Group-I was significantly lower than Group-II, III and IV, while there were no significant differences found among Group-II, III, and IV. While, statistically non-significant ($p \geq 0.05$) and low positive correlation was observed between vertebral heart size (VHS) with age and body weight. The present study results were closely aligned with Abdelhakiem *et al.* (2020) [20] who recorded mean vertebral heart size (VHS) values of 8.88 ± 0.58 vertebrae in right lateral (RL) view and 8.95 ± 0.49 vertebrae in left lateral (LL) view in goat (mean age 2.9 years). Babicsak *et al.* (2017) [3] and Singh *et al.* (2020) [19] reported VHS in almost same range to that of present study, in Bergamasca sheep and Muzaffarnagari sheep, respectively.

3.3 Cardiac inclination angle and Cardio sternal contact

The mean values of the cardiac inclination angle were 26.80 ± 0.95 , 25.80 ± 0.87 , 23.77 ± 1.43 and 19.93 ± 0.99 degree for Group-I to IV respectively in Mehsana goat. The mean cardiac inclination angle values differed significantly ($p \leq 0.01$) across different experimental groups and demonstrated progressive declining with advancing age. The cardiac inclination angle (CIA) exhibited statistically significant ($p \leq 0.01$), high negative correlation with age and moderate negative correlation with body weight. Kumar *et al.* (2019a) [12] reported mean cardiac inclination angle of 23.00 ± 2.31 degree in Group-I (3-6 months) and 22.33 ± 2.08 degree in Group-II (6-12 months) in goats, the present study demonstrated relatively higher values in corresponding groups.

The cardio sternal contact values for Group-I to IV were 5.10 ± 0.25 , 4.81 ± 0.19 , 4.39 ± 0.26 and 4.44 ± 0.29 cm, respectively. The difference in the cardio sternal contact among groups was not statistically significant ($p \geq 0.05$). The cardio sternal contact showed a significant ($p < 0.05$) low negative correlation with age and body weight of Mehsana goat. Cardiosternal contact values in the present study were comparatively lower than those reported by Makungu and Paulo (2014) [14], who observed a mean value of 5.74 ± 0.97 cm in east African goats.

3.4 Thoracic height and Thoracic inlet diameter (TID)

The values of the thoracic height were 14.73 ± 0.19 , 15.14 ± 0.35 , 16.46 ± 0.19 and 18.13 ± 0.18 cm in Group-I to IV, respectively. The thoracic inlet diameter (TID) values were 7.35 ± 0.18 , 7.37 ± 0.17 , 7.85 ± 0.16 and 9.33 ± 0.30 cm in Group-I to IV, respectively. There was a statistically high significant difference ($p \leq 0.01$) in thoracic height and thoracic inlet diameter across different experimental groups. There was statistically significant ($p \leq 0.01$) and high positive correlation between thoracic height and thoracic inlet diameter with both age and body weight of experimental Mehsana goat.

Thoracic height measurements in the present study were in accordance with Abdelhakiem *et al.* (2020) [20], who reported thoracic height and thoracic inlet diameter (TID) of 18.67 ± 2.23 cm and 8.58 ± 1.07 cm in right lateral (RL) and 18.41 ± 2.4 cm and 8.675 ± 1.10 cm in left lateral (LL) radiographic view for goats of 2.9 years age. Kumar *et al.* (2019a) [12] also reported almost similar thoracic height in goats of Group-I (3-6 months) as 14.22 ± 0.72 cm and in Group-II (6-12 months) as 16.77 ± 0.54 cm.

3.5 Tracheal diameter (TrD) and Tracheal angle (TrA)

The tracheal diameter, thoracic inlet diameter and its ratios are essential for diagnosis of conditions such as tracheal collapse, congenital tracheal stenosis and reduction in luminal diameter by inflammation or accumulation of exudate. Tracheal angle measurement is an indirect parameter useful in radiographic evaluation, since a reduced tracheal angle indicates a dorsal deviation of the trachea, a radiographic sign usually evident in cardiomegaly, tracheobronchial lymph node enlargement and mediastinal mass (Mattoon *et al.*, 2001) [15].

For age groups I to IV, the mean tracheal diameter measurements were 1.18 ± 0.03 , 1.18 ± 0.07 , 1.24 ± 0.06 and 1.31 ± 0.03 cm, respectively. The tracheal angle values in Group-I was 20.08 ± 0.89 degree, 22.35 ± 0.10 degree in Group-II, 22.28 ± 1.54 degree in Group-III, and 23.53 ± 0.64 degree in Group-IV. The comparison of tracheal diameter and tracheal angle across age groups did not show any statistically significant difference ($p > 0.05$). The tracheal diameter and tracheal angle showed significant positive correlation with both body weight and age.

The present study results were in accordance with Abdelhakiem *et al.* (2020) [20], who reported mean tracheal diameter of 1.36 ± 0.26 cm in right lateral (RL) and 1.35 ± 0.27 cm in left lateral (LL) radiographic view in goats age of 2.9 years. In the present study groups the tracheal diameter values were slightly higher than earlier reported by Kumar *et al.* (2019a) [12] in goats of Group-I (3-6 months) as 0.89 ± 0.03 cm and in Group-II (6-12 months) as 0.97 ± 0.08 cm. Reddy *et al.* (2024) [18] documented mean tracheal diameter and tracheal angle of 1.52 ± 0.03 cm and 21.66 ± 0.39 degree, respectively in Nellore brown sheep. Kumar *et al.* (2019a) [12] reported lower tracheal angle measurements of 14.83 ± 1.51 degree in Group-I (3-6 months) and 17.83 ± 1.58 degree in Group-II (6-12 months) of goat.

3.6 Caudal vena cava diameter (CVC) and Aorta diameter (AO)

Radiographic measurement of the caudal vena cava and aorta diameter offer critical insight into the vascular system. Alteration in the relative diameter of the caudal vena cava and aorta are significant indicators of the right sided cardiac enlargement (Lehmkuhl *et al.*, 1997) [13]. In the present study, mean value of caudal vena cava diameter were 1.11 ± 0.05 , 1.18 ± 0.04 , 1.50 ± 0.08 and 1.52 ± 0.03 cm in Group-I to IV, respectively. A statistically significant ($p \leq 0.01$) difference in caudal vena cava diameter was observed across different experimental groups. Correlation analysis revealed statistically significant ($p \leq 0.01$) and high positive correlation was found between caudal vena cava diameter with age and body weight in Mehsana goats. Makungu and Paulo (2014) [14] reported similar caudal vena cava diameter values of 1.42 ± 0.13 cm in east African goats.

On right lateral radiographic view, the aortic arch and proximal portion of the descending aorta was visible as a soft tissue opaque tubular structure dorsal to tracheal and ventral to the thoracic vertebrae. The mean values of aorta diameter were 1.29 ± 0.06 , 1.63 ± 0.08 , 1.53 ± 0.11 , and 1.59 ± 0.07 cm in Group-I to IV, respectively. A statistically significant ($p < 0.05$) difference in aorta diameter was observed across different the age groups. A low positive but non-significant ($p \geq 0.05$) correlation was found between aorta diameter with body weight and age. The present findings were comparatively lower than the value reported by Abdelhakiem *et al.* (2020) [20], who documented aorta diameter of 2.1 ± 0.43 cm in right lateral (RL) and 2.1 ± 0.37 cm in left lateral (LL) radiographic view.

3.7 Spino-phrenic angle

The mean values of the spino-phrenic angle were 43.13 ± 1.26 , 41.22 ± 2.18 , 40.03 ± 2.31 , and 39.25 ± 1.89 degree for groups I to IV, respectively. There was no statistically significant ($p \geq 0.05$) difference in the spino-phrenic angle among the experimental groups. There was non-significant ($p \geq 0.05$) and low negative correlation between the spino-phrenic angle with age and body weight. The findings of the present study were in agreement with Abdelhakiem *et al.* (2020) [20], who observed similar mean value of spino-phrenic angle in goats was 39.25 ± 7.496 in right lateral (RL) and 37.59 ± 6.5 degree in left lateral (LL) view.

3.8 Length of the fourth thoracic vertebra (T₄) and Length of 3rd to 5th Thoracic Vertebral (T₃-T₅ Length)

The mean length of the fourth thoracic vertebra (T₄) was 1.74 ± 0.06 , 1.78 ± 0.06 , 1.96 ± 0.05 and 2.11 ± 0.02 cm in groups I to IV, respectively, while the combined length of the third to fifth thoracic vertebrae (T₃-T₅) measured was 5.64 ± 0.08 , 5.68 ± 0.11 , 6.06 ± 0.09 , and 6.35 ± 0.05 cm across

age groups. A statistically high significant ($p \leq 0.01$) difference was observed across different experimental groups. There was statistically significant ($p \leq 0.01$) and high positive correlation between T₄ length and T₃ to T₅ length with both age and body weight of experimental Mehsana goats.

The mean values of T₄ length in the present study were slightly lower than Kumar *et al.* (2019^a) [12], who reported T₄ length and T₃ to T₅ length of 1.92 ± 0.09 cm and 6.0 ± 0.25 cm for Group-I (3-6 months) and 2.13 ± 0.11 cm and 6.78 ± 0.26 cm for Group-II (6-12 months) in goats.

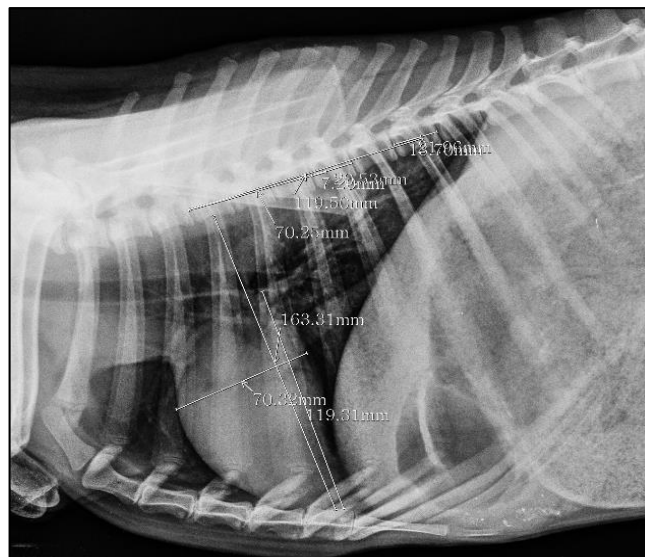


Fig 2: Right lateral thoracic radiograph showing cardiac long axis (CLA), cardiac short axis (CSA), vertebral heart size (VHS) and thoracic height in goat.

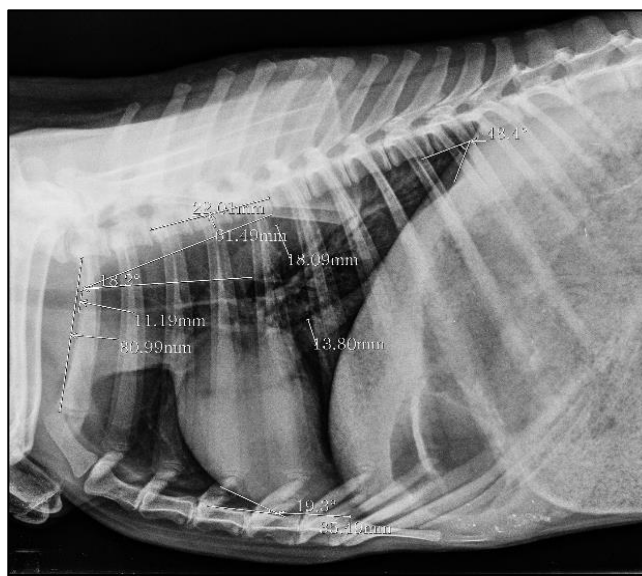


Fig 3: Right lateral thoracic radiograph showing T₄ length, T₃-T₅ length, thoracic inlet diameter (TID), tracheal diameter (TrD), tracheal angle, caudal vena cava diameter (CVC), aorta diameter (AO), cardiac inclination angle, cardio sternal contact and spino-phrenic angle in goat.

4. Conclusion

Cardiac dimensions increase with age, with the decreasing cardiac inclination angle. Thoracic skeletal parameters, including thoracic height, thoracic inlet diameter, and vertebral lengths, increase significantly with age. Tracheal

diameter, tracheal angle and their ratios remain relatively stable, increase proportionally with skeletal growth. Vascular structures, including the aorta and caudal vena cava, show moderate growth proportional to thoracic development. The present study on normal radiographic

biometry of thorax in Mehsana goat provide baseline reference data of different cardiothoracic parameters for physio-anatomical and clinical applications.

5. References

1. Abd-Elbasset AE, El-Sayed A, Mohamed H, El-Bherey E, Nouh D. Computed tomographic, echocardiographic, radiographic and morphological anatomy of the heart in goats (*Capra hircus*). Zagazig Veterinary Journal. 2021;49(4):414-428. <https://doi.org/10.21608/zvjz.2021.98165.1159>
2. Abdelhakiem MAH, Khalphallah A, Al-lethie AA. Radiographic appearance and measurements of thoracic structures using four radiographic projections in goats. Alexandria Journal of Veterinary Sciences. 2020;64(1):34-46. <https://doi.org/10.5455/ajvs.65920>
3. Babicsak VR, Alves LS, Tsunemi MH, Vulcano LC. Radiographic measurements related with the cardiac size in young female Bergamasca sheep. Pesquisa Veterinária Brasileira. 2017;37(12):1526-1530. <https://doi.org/10.1590/S0100-736X2017001200027>
4. Bhargavi S, Kannan TA, Ramesh G, Sumathi D, Prasad AA. Vertebral heart score in indigenous dog breed of Tamil Nadu. Journal of Entomology and Zoology Studies. 2018a;6:1664-1666.
5. Bhargavi S, Kannan T, Ramesh G, Sumathi D, Prasad AA. Radiographic evaluation of heart using VHS method in Rajapalayam dog-Indigenous breed of Tamil Nadu. International Journal of Current Microbiology and Applied Sciences. 2019;8(2):1216-1220. <https://doi.org/10.20546/ijcmas.2019.802.141>
6. Birks R, Fine DM, Leach SB, Clay SE, Eason BD, Britt LG, Lamb KE. Breed-specific vertebral heart scale for the Dachshund. Journal of the American Animal Hospital Association. 2017;53(2):73-79. <https://doi.org/10.5326/JAAHA-MS-6474>
7. Buchanan JW, Bucheler J. Vertebral scale system to measure canine heart size in radiographs. Journal of the American Veterinary Medical Association. 1995;206(2):194-199. <https://doi.org/10.2460/javma.1995.206.02.194>
8. Diniz ADN, Da Silva Júnior JR, Ambrósio CE, De Sousa JM, De Sousa VR, Carvalho MA, Nascimento DM, Alves FR. Thoracic and heart biometrics of non-anesthetized agouti (*Dasyprocta prinnolopha* Wagler, 1831) measured on radiographic images. Pesquisa Veterinária Brasileira. 2013;33(3):411-416. <https://doi.org/10.1590/S0100-736X2013000300023>
9. Harada M, Koie H, Iwaki S, Sato T, Kanayama K, Taira M, Sakai T. Establishment of vertebral heart scale in the growth period of the Japanese macaque (*Macaca fuscata*). Journal of Veterinary Medical Science. 2010;72(4):503-505. <https://doi.org/10.1292/jvms.09-0328>
10. Jilintai N, Hashiyama S, Gonda Y, Ishikawa H, Sato M, Miyahara K. Radiographic evaluation of caudal vena cava size as a useful parameter for the diagnosis of heart disease in dairy cattle. Journal of Veterinary Medical Science. 2006;68(9):995-998. <https://doi.org/10.1292/jvms.68.995>
11. Kealy JK, McAllister H, Graham J. The thorax. In: Diagnostic Radiology and Ultrasonography of the Dog and Cat. Elsevier; St. Louis; 2011. p.199-349.
12. Kumar V, Purohit S, Pandey RP, Singh AK, Upadhyay A. Radiographic measurements related with the cardiac size in apparently healthy goats (*Capra hircus*). Journal of Animal Research. 2019a;9(4):589-596.
13. Lehmukhl LB, Bonagura JD, Biller DS, Hartman WM. Radiographic evaluation of caudal vena cava size in dogs. Veterinary Radiology & Ultrasound. 1997;38(2):94-100. <https://doi.org/10.1111/j.1740-8261.1997.tb00822.x>
14. Makungu M, Paulo P. Thoracic radiographic anatomy in goats. Tanzania Veterinary Journal. 2014;29(2):73-80.
15. Mattoon JS, Gerros TC, Brimacombe M. Thoracic radiographic appearance in the normal llama. Veterinary Radiology & Ultrasound. 2001;42(1):28-37. <https://doi.org/10.1111/j.1740-8261.2001.tb00900.x>
16. Mohan NH, Niyogi D, Singh HN. Analysis of normal electrocardiograms of Jamunapari goats. Journal of Veterinary Science. 2005;6(4):295-298.
17. Nelson NC, Mattoon JS, Anderson DE. Radiographic appearance of the thorax of clinically normal alpaca crias. American Journal of Veterinary Research. 2011;72(10).
18. Reddy CS, Rao CM, Harikrishna NV, Srinivas M. Radiographic appearance and measurement of thoracic structure in Nellore brown sheep. International Journal of Veterinary Science and Animal Husbandry. 2024;9(2):1043-1047.
19. Singh A, Pandey R, Purohit S, Kumar V, Upadhyay A. Measurement and comparison of vertebral heart size (VHS) in Muzaffarnagari sheep using two different methods. Journal of Entomology and Zoology Studies. 2020;8(3):834-837.
20. Sleeper MM, Buchanan JW. Vertebral scale system to measure heart size in growing puppies. Journal of the American Veterinary Medical Association. 2001;219(1):57-59. <https://doi.org/10.2460/javma.2001.219.57>
21. Swetha P, Kishore PVS, Nagamalleswari Y, Raghunath M. Computed radiographic studies on the vertebral heart score in pugs with haematological and serum [incomplete citation-page range missing].
22. Ulian CMV, Lourenco MLG, Inamassu LR, Souza PM, Mamprim MJ, Alfonso A, Chiacchio SB. Echocardiographic parameters and VHS in lambs during the neonatal period. Pesquisa Veterinária Brasileira. 2018;38(9):1869-1877.
23. Verma A, Sangwan V, Anand A, Kaur K. Comparative radiographic morphometry of thorax in up to one-month-old healthy buffalo and cow calves. Large Animal Review. 2022;28:255-263.