

Thoracic radiographic anatomy in goats

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SUMMARY

The aim of this study was to describe the normal radiographic anatomy of the thorax of small East African goats as a reference for clinical use. Radiography of the thorax was performed under general anaesthesia in 10 healthy small East African goats. Right lateral (RL), left lateral (LL), dorsoventral (DV) and ventrodorsal (VD) views of the thorax were obtained at the end of inspiration. Reference ranges were established and ratios were calculated. The number of thoracic vertebrae ranged from 12 (1/10) to 13 (9/10). The mean number of sternbrae was 4.8 ± 0.42 . The cardiac silhouette was rounded (7/10) and angular shaped (8/10) on the DV and VD views, respectively. The mean vertebral heart score (VHS) on the RL view (10.02 ± 0.33) was significantly ($P < 0.0001$) larger than that of the DV view (8.21 ± 0.49). The trachea was narrow and the mean ratio of the trachea diameter (TD) to thoracic inlet distance (TID) was 0.11 ± 0.02 . On lateral views, the caudal vena cava (CVC) was frequently (9/10) clearly visible. The aorta was not clearly visible on lateral views. The mean ratio of the CVC diameter to the height of the fourth thoracic vertebral body (T4) was 1.08 ± 0.07 . Species-specific differences exist in the normal radiographic anatomy of the thorax. Knowledge of the normal thoracic radiographic anatomy of small East African goats should prove useful in the diagnosis of thoracic diseases.

Keywords: thorax, radiography, anatomy, goat, small East African goat

INTRODUCTION

Radiography is a non-invasive diagnostic imaging technique, which is used for the diagnosis of thoracic diseases (Olchoway *et al.*, 1996; Parish *et al.*, 1996; Rozear *et al.*, 1998; Mozaffari and Vosough, 2007; Schwarz and Johnson, 2008). It is commonly used as the first diagnostic imaging modality for thoracic diseases. Additionally, it is used to monitor the effectiveness of therapy in animals with cardiac, pulmonary, orthopaedic and oncologic disease (Owens and Biery, 1999).

Knowledge of the normal radiographic anatomy of the thorax is important for correct interpretation and diagnosis of

thoracic diseases (Berry and Thrall, 2007). Several authors (Farrow, 1981; Mattoon *et al.*, 2001; Nelson *et al.*, 2011; Thrall and Robertson, 2011) have documented the normal radiographic anatomy of the thorax in various species, which provide references for the diagnosis of thoracic diseases.

Goats are kept mainly for improving socio-economic status (Peacock, 2005). Additionally, they are used in biomedical research and teaching (Fulton *et al.*, 1994). Pneumonia is one of mostly reported lower respiratory tract disease conditions in goats (Aiello and Mays, 1998). Other thoracic conditions which have been reported in goats include; osteomyelitis (Altmaier *et al.*, 1994), diaphragmatic hernia (Tafti,

1998), calcinosis (Braun *et al.*, 2000), megaesophagus (Parish *et al.*, 1996; Mozaffari and Vosough, 2007), Ebstein's anomaly (Laus *et al.*, 2011) and neoplasia such as thymoma (Olchowy *et al.*, 1996; Parish *et al.*, 1996), extraskelatal osteosarcoma (Braun *et al.*, 2011), pulmonary lymphosarcoma (Rozear *et al.*, 1998) and pulmonary adenomatosis (Al-Dubaib, 2005).

The aim of this study was to describe the normal radiographic anatomy of the thorax in small East African goats as a reference for clinical use. To the best of the authors' knowledge it has not been published previously in small East African goats.

MATERIALS AND METHODS

Animals

Ten (5 females and 5 males) healthy small East African goats from the Sokoine University of Agriculture, Faculty of Veterinary Medicine, Animal Research Unit (ARU) were imaged in this study. Animals were considered healthy based on history, physical and clinical examinations. The age of the animals ranged from 10 to 48 months (mean: 22.80 ± 15.40 months). Their minimum and maximum weights were 13.20 kg and 24.50 kg, respectively, (mean: 17.54 ± 3.85 kg).

Radiography

Radiography of the thorax was performed under general anaesthesia. Animals were fasted for 24 hours but water was given *ad libitum* until two hours before general anaesthesia. Xylazine hydrochloride (KEPRO, Holland) at a dosage of 0.025 mg/kg was used as a sedative. Ketamine hydrochloride (ROTEXMEDICA, Germany) at a dosage of 2 mg/kg was used as a general anaesthetic. All drugs were injected intravenously (IV) through the

jugular vein. Ketamine hydrochloride was injected five minutes after xylazine hydrochloride.

Right lateral (RL), left lateral (LL), dorsoventral (DV) and ventrodorsal (VD) radiographic views of the thorax were taken at the end of inspiration. A source to image distance (SID) of 100 cm was used. Medium speed screen-type films (CARESTREAM, USA) were used in combination with regular (Green 400: KIRAN, India) intensifying screens. In all animals a grid was used. A kVp range of 72-86 was used for lateral views. For the DV and VD views a kVp range of 92-104 was used. In all radiographic views 2 mA (200 mA; 0.01s) was used. Exposed films were processed manually using Kodak (CARESTREAM, Belgium) developer and fixer. All radiographs were made using Roller 30 (SMAM X-ray equipments, Italy) X-ray machine.

Radiographic evaluation

The visibility, location, number, shape and size of thoracic organs and structures were recorded. The depth of the thorax (TDp) was measured on the RL view from the cranial edge of the xiphoid process to the ventral border of the vertebral column along a line perpendicular to the vertebral column (Buchanan and Bücheler, 1995). The width of the thorax (TW) was measured on the DV view as the maximum distance between the right and left pleural surfaces of the sixth ribs.

The ratio of the tracheal diameter (TD) to thoracic inlet distance (TID) was calculated on the RL view (Hayward *et al.*, 2008). The TID was measured from the ventral aspect of the vertebral column at the midpoint of the most cranial rib to the craniodorsal border of the manubrium sterni. The TD was measured between the internal surfaces of the tracheal wall

perpendicular to the tracheal long axis at the point where the TID crosses the midpoint of the tracheal lumen (Hayward *et al.*, 2008). The angle of divergence of the trachea from thoracic vertebrae was measured as the angle between the dorsal margin of the trachea at the thoracic inlet and the ventral margins of the third through the fifth thoracic vertebrae on the RL view (Nelson *et al.*, 2011). The position of the carina with respect to the thoracic vertebra was determined on the RL view (Makungu *et al.*, 2014). The crossing point of the diaphragmatic crura/crus to the thoracic vertebra on the RL view was recorded in relationship to the cranial thoracic vertebrae during inspiration (Makungu *et al.*, 2014).

The vertebral heart score (VHS) was measured on the RL, LL, DV and VD views as previously described in dogs (Buchanan and Bücheler, 1995). The cardiaphragmatic contact was measured from the cardiac apex to the dorsal point of intersection of the cardiac silhouette and diaphragm on lateral views (Nelson *et al.*, 2011). The cardiosternal contact was measured on lateral views from the cardiac apex to the point where the cranioventral margin of the cardiac silhouette diverges from the sternum (Nelson *et al.*, 2011). The ratio of the caudal vena cava (CVC) diameter to the height of the fourth thoracic vertebral body (T4) was calculated on the RL view (Nelson *et al.*, 2011). The height of T4 was measured along a line that extended between the cranioventral and craniodorsal borders of the vertebral body (Nelson *et al.*, 2011). The maximum diameter of the CVC was measured caudal to the cardiac silhouette and cranial to the diaphragm (Makungu *et al.*, 2014).

Data analysis

Data were analysed using Microsoft Office excel 2003. Mean, range and standard deviation (SD) were calculated. Student's *t*-test was used to compare the mean of VHS, cardiaphragmatic contact and cardiosternal contact on the RL view versus (vs.) LL view, DV view vs. VD view and RL view vs. DV view. Statistical significance was accepted at $P \leq 0.05$. Data are expressed as mean \pm SD.

RESULTS

Musculoskeletal system

Of the 10 animals, nine had 13 thoracic vertebrae (Figure 1) whereas one animal had 12 thoracic vertebrae. The mean number of thoracic vertebrae was 12.90 ± 0.32 . The sternum was fairly concave upward and consisted of *manubrium sterni*, four (2/10) or five (8/10) sternbrae and xiphoid process (Figure 1). The mean number of sternbrae was 4.80 ± 0.42 . Radiographic findings and measurements are summarised in Table 1.

Respiratory system

On lateral views the trachea was narrow (Figs. 1 and 2). The mean ratio of the TD to TID was 0.11 ± 0.02 . The carina (Figure 1) was seen in the majority of animals (7/10). It was frequently positioned at the level of the fifth thoracic vertebra (6/7) and rarely at the level of the fourth thoracic vertebra (1/7). The mean angle of divergence of the trachea from the thoracic vertebrae was $17.80 \pm 2.10^\circ$. In all animals the pulmonary cupula ended at the level of the first rib (Figs. 1 and 2). The diaphragmatic crura were seen to be parallel, Y-shaped or superimposed (Figs. 1 and 2).

On the VD view, the diaphragm was seen as a single dome (Figure 3A) in the

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majority of animals (9/10). In one animal the left and right crura were seen superimposed over the cupula giving a three-humped appearance. On the DV

view, the diaphragm was seen as a single dome in all animals (Figure 3B).

Table 1. Radiographic measurements and findings of the thorax not compensated for magnification in small East African goats

Variable	Number of animals	Mean \pm SD	Range (min – max)
TDp (cm)	10	15.29 \pm 1.53	14.00 - 19.00
TW (cm)	10	11.42 \pm 1.19	10.50 - 14.00
TDp:TW	10	1.34 \pm 0.05	1.28 - 1.43
TD (cm)	10	0.84 \pm 0.14	0.70 - 1.10
TID (cm)	10	7.58 \pm 0.65	7.00 - 9.00
TD:TID	10	0.11 \pm 0.02	0.09 - 0.14
Tracheal angle (°)	10	17.80 \pm 2.10	14.00 - 20.00
Position of the carina	7	4.90 \pm 0.38	4.00 - 5.00
Cranial crus	10	10.50 \pm 0.24	10.20 - 10.90
VHS (RL)	10	10.02 \pm 0.33	9.60 - 10.70
VHS (LL)	10	10.10 \pm 0.25	9.80 - 10.5
VHS (DV)	10	8.21 \pm 0.49	7.70 - 9.00
VHS (VD)	10	9.42 \pm 0.66	8.50 - 10.50
CDC (RL) cm	10	3.19 \pm 0.76	2.00 - 4.50
CDC (LL) cm	10	4.46 \pm 1.13	2.00 - 6.00
CSC (RL) cm	10	5.74 \pm 0.97	4.00 - 7.20
CSC (LL) cm	10	5.72 \pm 0.66	4.60 - 7.10
CVC diameter (cm)	9	1.42 \pm 0.13	1.20 - 1.60
Height of T4 (cm)	10	1.33 \pm 0.13	1.20 - 1.50
CVC diameter:Height of T4	9	1.08 \pm 0.07	1.00 - 1.17

CDC = cardiodiaphragmatic contact; CSC = cardiosternal contact

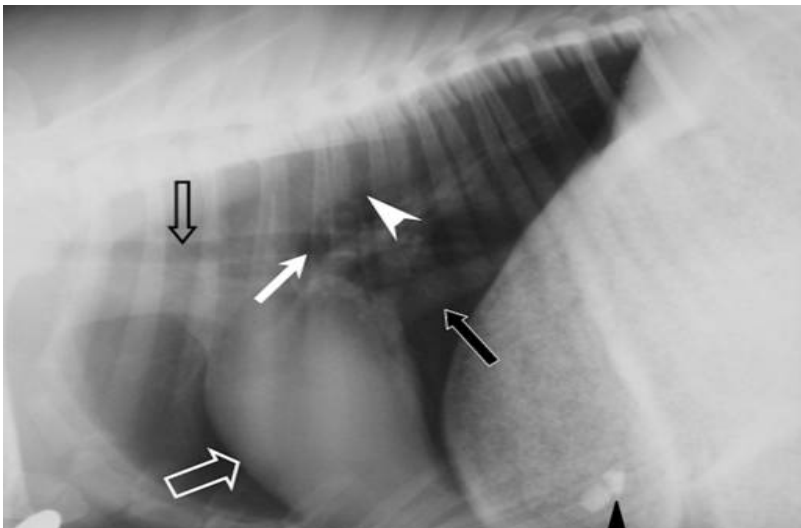


Figure 1. Right lateral thoracic radiograph of an 18.5 kg male small East African goat. Note the presence of 13 thoracic vertebrae and five sternbrae. Note also the visualisation of the carina (white arrow) and a narrow trachea (open black arrow). The cardiac silhouette (open white arrow) is ovoid. The caudal vena cava (black arrow) is clearly seen whereas the aorta (white arrow head) is not clearly seen. Gastroliths (black arrow head) are seen in the cranioventral abdomen.

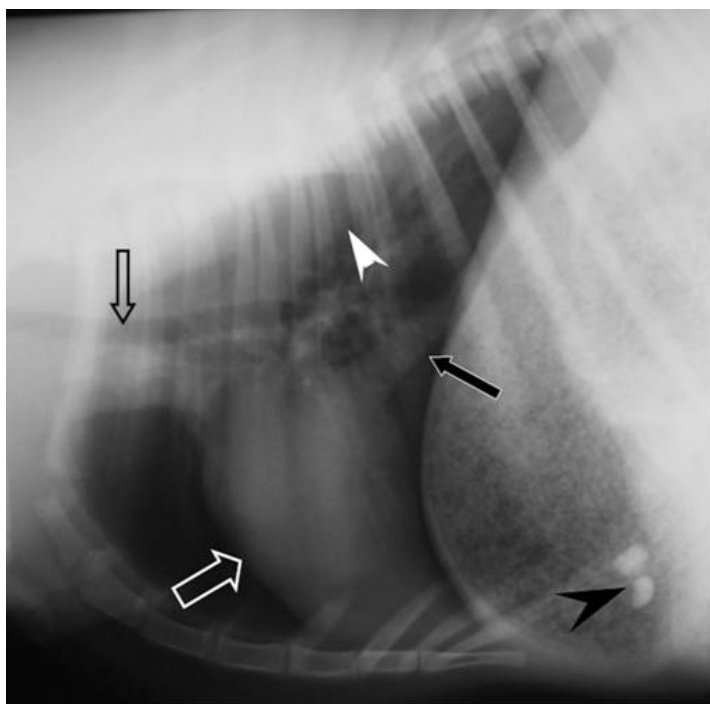


Figure 2. Left lateral thoracic radiograph of an 18.5 kg male small East African goat. The cardiac silhouette (open white arrow) is ovoid and the trachea (open black arrow) is narrow. The caudal vena cava (black arrow) is clearly seen whereas the aorta (white arrow head) is not clearly visible. Note the extensive cardiodiaphragmatic contact when compared to Figure 1. Gastroliths are indicated by black arrow head.

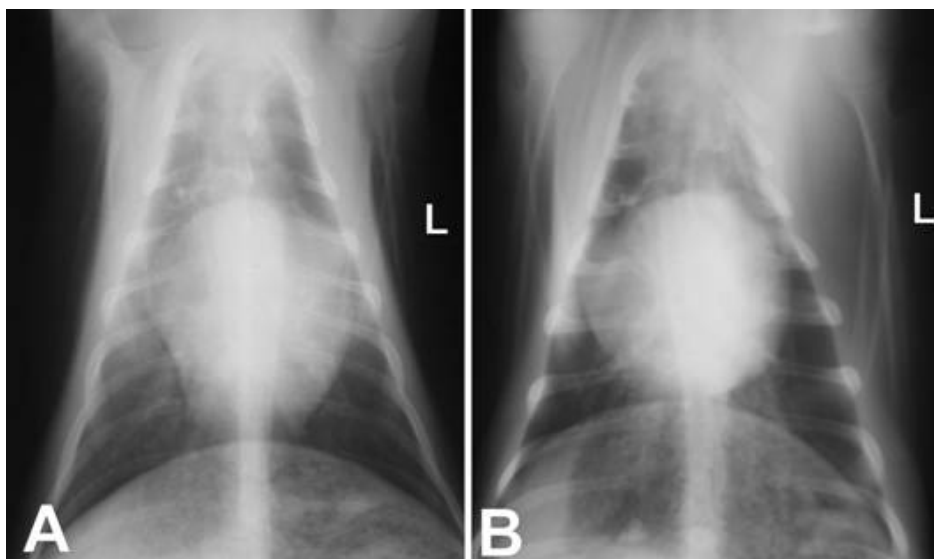


Figure 3. Ventrodorsal (A) and dorsoventral (B) radiographs of an 18.5 kg male small East African goat. The diaphragm is seen as a single dome. **A:** The cardiac silhouette is angular shaped and the cardiac apex is located at the midline. **B:** The cardiac silhouette is ovoid and the cardiac apex is located slightly to the left of the midline. L, left.

Cardiovascular system

On lateral views, the cardiac silhouette was ovoid (Figs. 1 and 2). The size of the cardiac silhouette was wider than two intercostal spaces, but did not exceed three intercostal spaces. The cranial border of the cardiac silhouette was located at the level of the third rib or third intercostal space, whereas the caudal border of the cardiac silhouette was located at the level of the sixth rib. There was no significant difference ($P = 0.3513$) in the mean VHS obtained on the RL (10.02 ± 0.33) and LL (10.10 ± 0.25) views. In all animals the cardiac silhouette was in contact with the diaphragm (Figs. 1 and 2). The mean cardiaphragmatic contact on the LL view (4.46 ± 1.13 cm) was significantly ($P = 0.0053$) larger compared to that of the RL view (3.19 ± 0.76 cm). There was no significant difference ($P = 0.9085$) in the mean cardiosternal contact obtained on the RL (5.74 ± 0.97 cm) and LL (5.72 ± 0.66 cm) views.

On the DV view, the cardiac silhouette was rounded (Figure 3B) in 7/10 animals and angular in 3/10 animals. Cardiaphragmatic contact was seen in 8/10 animals. On the VD view, the cardiac silhouette was angular (Figure 3A) in 8/10 animals and rounded in 2/10 animals. Cardiaphragmatic contact was seen in 6/10 animals. The cardiac apex was located at the midline (Figure 3A) or slightly to the left of the midline (Figure 3B). The mean VHS on the VD view (9.42 ± 0.66) was significantly ($P = 0.0002$) larger compared to that of the DV view (8.21 ± 0.49). Additionally, the mean VHS on the RL view (10.02 ± 0.33) was significantly ($P < 0.0001$) larger compared to that of the DV view (8.21 ± 0.49).

On lateral views, the aorta was not clearly visible in all animals (Figs. 1 and 2). The CVC was clearly visible in 9/10 animals

(Figs. 1 and 2). In one animal it was not clearly visible or not visible at all on the LL and RL views, respectively. The mean ratio of the CVC diameter to the height of T4 was 1.08 ± 0.07 .

DISCUSSION

Most of thoracic organs and structures of clinical importance were seen and evaluated radiographically in small East African goats. The mean ratio of TDp to TW obtained in this study (1.34) indicates a deep thoracic conformation (Buchanan and Bücheler, 1995) similar to the Saanen goat (Ohlerth *et al.*, 2012). The number of thoracic vertebrae (13) observed in the majority of animals in this study is similar to domestic cats and dogs (Llabrés-Díaz *et al.*, 2008). However, the mean number of sternbrae obtained in this study (4.8), is lower than the reported number in domestic cats and dogs (6) (Llabrés-Díaz *et al.*, 2008).

The rounded and angular shaped cardiac silhouette which was observed on the DV and VD views, respectively, in the majority of animals is similar to the reported study in the alpaca crias (Nelson *et al.*, 2011). The mean VHS obtained on the DV view (8.21) is similar to the reported mean VHS on the DV view in the alpacas crias (8.21) (Nelson *et al.*, 2011) and is within the normal values (mean: 8.0; range: 7.0-9.0) reported in Saanen goats on computed tomographic (CT) examination (Ohlerth *et al.*, 2012). The higher mean values of VHS obtained from lateral views than the DV view has also been observed in alpacas crias (Nelson *et al.*, 2011), which is contrary to the reported studies in domestic cats (Litster and Buchanan, 2000) and dogs (Buchanan and Bücheler, 1995). In domestic cats (Litster and Buchanan, 2000) and dogs (Buchanan and Bücheler, 1995) the mean value of VHS on lateral views

was reported to be lower than that for the DV view.

The mean diameter of the CVC obtained in this study (1.42 cm) is lower than the reported mean in Saanen goats (1.9 cm) (Ohlerth *et al.*, 2012). The difference in diameter of the CVC between small East African goats and Saanen goats is possibly attributed to the difference in body size. The mean weight of Saanen goats was 61.5 kg (Ohlerth *et al.*, 2012). The mean ratio of the CVC diameter to the height of the T4 obtained from RL view (1.08) was larger than the reported mean in alpaca crias (0.89) (Nelson *et al.*, 2011).

The narrow trachea observed in small East African goats is normal and should not be misinterpreted as tracheal hypoplasia or collapse. Similar finding has also been reported in Saanen goats on CT examination (Ohlerth *et al.*, 2012). The mean ratio of TD to TID obtained from this study (0.11) is similar to bull dogs (0.11) (Hayward *et al.*, 2008) and is within the normal values reported in Saanen goats (mean: 0.13; range: 0.08-0.19) on CT examination. The mean tracheal angle obtained in this study (17.80°) is almost similar to Saanen goats (16.5°) (Ohlerth *et al.*, 2012) and is within the range (10°-20°) reported in domestic cats and dogs (Hayward *et al.*, 2008).

In conclusion, species-specific differences exist in the normal radiographic anatomy of the thorax. Knowledge of the normal thoracic radiographic anatomy of small East African goats should prove useful in the diagnosis of thoracic diseases.

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