Radiographic anatomy of the thorax and abdomen in captive caracals (*Caracal caracal*)

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SUMMARY

The caracal (*Caracal caracal*) also known as *Simbamangu* is widely distributed in Africa. Captive caracals commonly present with similar infectious and non-infectious diseases of the thorax and abdomen as domestic cats. The aim of this study was to describe the normal radiographic anatomy of the thorax and abdomen in captive caracals as a reference for clinical use. Radiography of the thorax and abdomen was performed in two healthy adult caracals during their annual health examinations. The thoracolumbar spine had 20 vertebrae. Pairs of ribs were 13, which corresponded to the number of thoracic vertebrae. The last pair of ribs was floating. The sternum was fairly straight and consisted of manubrium sterni, xiphoid process and six sternebrae. Clavicles were seen. Hypaxial muscles were conspicuous in all animals. The trachea was seen with mineralised cartilage rings in all animals. The cardiac silhouette was elongated and more horizontally positioned in the oldest animal (8.8 years). The spleen was clearly seen on the ventrodorsal view. The length of kidneys was approximately two times the length of the second lumbar vertebra (L2). Bunching of small intestines in the right central abdomen was seen in the heaviest caracal (14.8 kg). The diameter of the small intestine was approximately 0.7 times the height of L2. For the large intestine the diameter was approximately 1.7 and 0.7 times the height and length of L2, respectively. Knowledge of the normal radiographic anatomy of the thorax and abdomen of the caracal may be useful in the diagnosis of diseases and in routine health examinations.

Keywords: anatomy, abdomen, caracal, *Caracal caracal*, radiography, thorax

INTRODUCTION

The caracal (*Caracal caracal*) also known as *Simbamangu* belongs to order; Carnivora and family; Felidae (Avgan *et al.,* 2016). It is widely distributed in Africa, Central Asia and South-West Asia (Avgan *et al.,* 2016). In Africa, it is distributed throughout with the exception of the Democratic Republic of Congo, dense forests of equatorial West Africa and the Sahara and Namib deserts (Sunquist and Sunquist, 2002). The caracal occupies a wide variety of habitats; however it prefers drier woodlands and savannah regions with some cover and lower rainfall (Avgan *et al.,* 2016). In Tanzania, the caracal may be seen in the Serengeti ecosystem, on the open grassland around Semetu, Seronera, Ndutu, Naabi Hill and Five Hills track (Foley *et al.,* 2014). Occasionally it is seen in Mkomazi National Park (Foley *et al.,* 2014). The caracal may also be seen as a free-roaming wild animal (Makungu *et al.*,

2012). It is one of the species commonly kept in zoos (Makungu *et al.,* 2012; Tordiffe *et al.,* 2012). The caracal preys on variety of animals such as small mammals, birds and invertebrates (Palmer and Fairall, 1988).

Radiography is commonly used as the first diagnostic imaging modality for various health problems. Knowledge of the normal radiographic anatomy of individual species is important for accurate diagnosis of various diseases. The normal radiographic anatomy of the thorax and abdomen of domestic cats and dogs is well documented (Thrall and Robertson, 2011), which serves as guidance for diagnosis of thoracic and abdominal diseases. Several authors (Eshar *et al.,* 2013; Martins *et al.,* 2013; Makungu *et al.,* 2016; 2018) have described the normal radiographic anatomy of the thorax and abdomen of wild animal species, which serve as a reference for diagnosis of diseases and in routine health examinations.

Captive caracals are presented to zoo veterinarians with infectious and non-infectious diseases similar to domestic cats involving the thorax and abdomen and radiography may be used as the first diagnostic imaging modality. Diseases such as urolithiasis, renal failure, lymphoma, metabolic bone disease and fractures have been reported in caracals (Livingston, 2009; Aitken-Palmer *et al.,* 2011; Turk, 2011; Makungu *et al.,* 2012; Tordiffe *et al.,* 2012). The aim of this study was to describe the normal radiographic anatomy of the thorax and abdomen in captive caracals as a reference for clinical use.

MATERIALS AND METHODS

Radiography of the thorax and abdomen was performed in two adult healthy caracals (*Caracal caracal*) from the Johannesburg (JHB) zoo during their annual health examinations. The healthy status of the caracals was evaluated based on history, physical and clinical examination, faecal examination, kidney and liver function tests, complete blood count and peripheral blood smear evaluation. The mean weight of the animals was 13.8 ± 1.41 kg (range: 12.8 kg – 14.8 kg). The minimum and maximum age of the animals were 5.3 yrs and 8.8 yrs, respectively (mean: 7.05 ± 2.47 yrs) (Table 1).

Table 1. Sample population of caracals (*Caracal caracal*) used for radiography

Identification	Weight (kg)	Age (yrs)
Caracal I	12.8	5.3
Caracal II	14.8	8.8

Radiography was performed under general anaesthesia. Animals were fasted overnight, but water was given *adlibitum* until shortly before anaesthesia. Anaesthesia was induced by intramuscular injection of medetomidine hydrochloride (Domitor, Pfizer Laboratories) at a mean dosage of 0.05 ± 0.01 mg/kg and ketamine hydrochloride (Kyron Laboratories) at a mean dosage of 4.4 ± 0.45 mg/kg and was maintained using isoflurane (Isofor, Safeline pharmaceuticals).

Radiographs were made with an EVA-HF525 (Comed Medical System Company) x-ray machine at a source to image distance (SID) of 95 cm. A table top technique was used with a film-screen system. Right lateral (RL) and dorsoventral (DV) views of the thorax were taken at the end of inspiration. For the abdomen, RL and ventrodorsal (VD) views were taken at the end of expiration. Exposed films were processed by an automatic x-ray film processor model CP-345 (ELK Corporation). Radiographic images were

digitalised using a digital camera CANON PC1192 (Canon Inc.). Previous radiographs of the thorax and abdomen of one caracal (caracal II), which were taken at the age of 1.2 yrs were retrieved and evaluated.

Visibility, number, shape, location and size of thoracic and abdominal organs were recorded. On the RL view, the length of vertebral bodies was measured at the mid-body (Lehmkuhl *et al.,* 1997). The dorsoventral height of the second lumbar vertebral body (L2) was measured on the RL view along a line that extended between the craniodorsal and cranioventral borders of the cranial end-plate (Adams *et al.,* 2010). Additionally, the length of L2 was also measured on the VD view from the cranial end-plate to the caudal end-plate along the sagittal plane of the vertebra (Eshar *et al.,* 2013).

The ratio of the trachea diameter (TD) to the width of the third rib was calculated as previously described in domestic cats on the RL view (Hammond *et al.,* 2011). The TD was measured at the level of the second intercostal space, whereas the width of the third rib was measured at the proximal third (Hammond *et al.,* 2011). The diameter of the caudal vena cava (CVC) not overlapping the diaphragm and cardiac silhouette was measured perpendicular to the long axis of the CVC on the RL view (Lehmkuhl *et al.,* 1997). Additionally, the diameter of the CVC was compared with the length of the thoracic vertebral body (VL) above the tracheal bifurcation (Lehmkuhl *et al.,* 1997).

On the VD view, the length and width of kidneys were measured and compared with the length of L2 as described in ferrets (Eshar *et al.,* 2013). The diameter of the small and large intestines were measured and also compared with the height of L2 on the RL view (Adams *et al.,* 2010). Additionally, the diameter of the large intestine was also compared with the length of L2 on the RL view (Wagner and Kirberger, 2005).

Data were analysed using Microsoft Office excel. Mean, range and standard deviation (SD) were calculated. Data are expressed as mean ± SD. This study was approved by the Johannesburg (JHB) Zoo Research Committee.

RESULTS

Radiographic measurements and ratios of thoracic and abdominal organs in caracals are indicated in Table 2.

Musculoskeletal system

The thoracolumbar spine had slender vertebrae (Figures 1 and 2). The thoracic spine was fairly concave (Figure 1). All caracals had 13 thoracic vertebrae with the thoracic vertebra 11 (T11) being an anticlinal vertebra (Figure 1). The spinous processes of thoracic vertebrae were long except for T11 to T13 (Figure 1). All animals had 13 pairs of ribs of which the last pair was floating (Figure 1). The sternum was fairly straight with slender sternebrae and sloped from cranial to caudal (Figure 1). In all caracals, the sternum consisted of manubrium sterni, xiphoid process and six sternebrae (Figure 1). The lumbar spine was straight with seven vertebrae (Figure 2). The spinous and transverse processes of the lumbar vertebrae were directed cranially (Figure 2). The sacrum consisted of three fused segments. The clavicles were seen in all animals (Figure 3A). On the VD view of the abdomen, the hypaxial muscles were conspicuous in all animals (Figure 3B). On the RL view of the abdomen, accumulation of a large amount of abdominal fat in the

heaviest animal (caracal II) was seen in the cranioventral abdomen ventral to the liver and in the retroperitoneal space (Figure 2).

Respiratory system

The trachea was seen with mineralised cartilage rings in all caracals (Figures 1 and 4). On the RL view, the carina was located at the level of the sixth rib and sixth intercostal space in caracal II and caracal I, respectively (Figure 4). On the DV view, the trachea was running slightly to the right of the spine (Figure 3A). On the RL view, the caudodorsal lung border diverged from the spine in all caracals (Figure 1). The tip of the dorsocaudal lung lobes was located either at the level of T13 or L1 on the RL view (Figure 1).

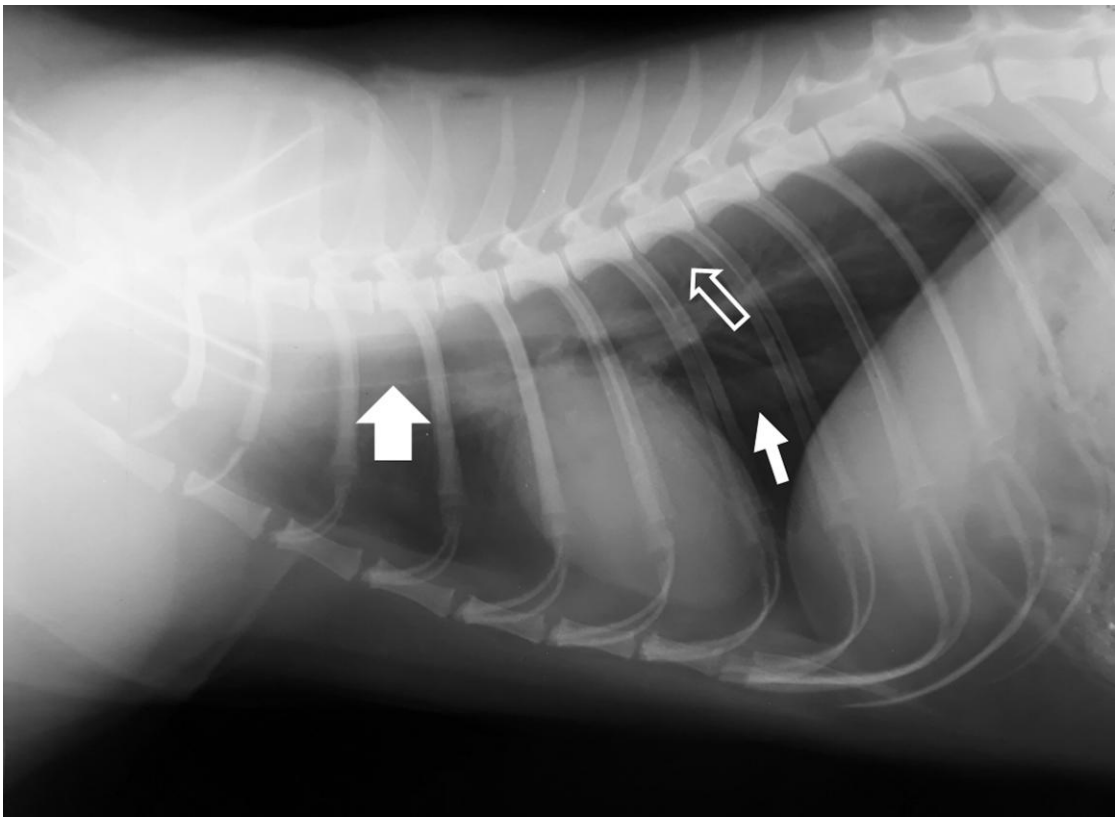

Figure 1. Right lateral (RL) thoracic radiograph of caracal II at the age of 1.2 years. The thoracic spine consists of 13 thoracic vertebrae with relatively long spinous processes. Pairs of ribs are 13 with the last pair floating. The sternum is fairly straight sloping from cranial to caudal and consists of six sternebrae, manubrium sterni and xiphoid process. The cardiac silhouette is not in contact with the diaphragm. The carina is seen at the level of the sixth rib. The trachea, descending aorta and caudal vena cava are indicated by a thick white arrow, open white arrow and thin white arrow, respectively.

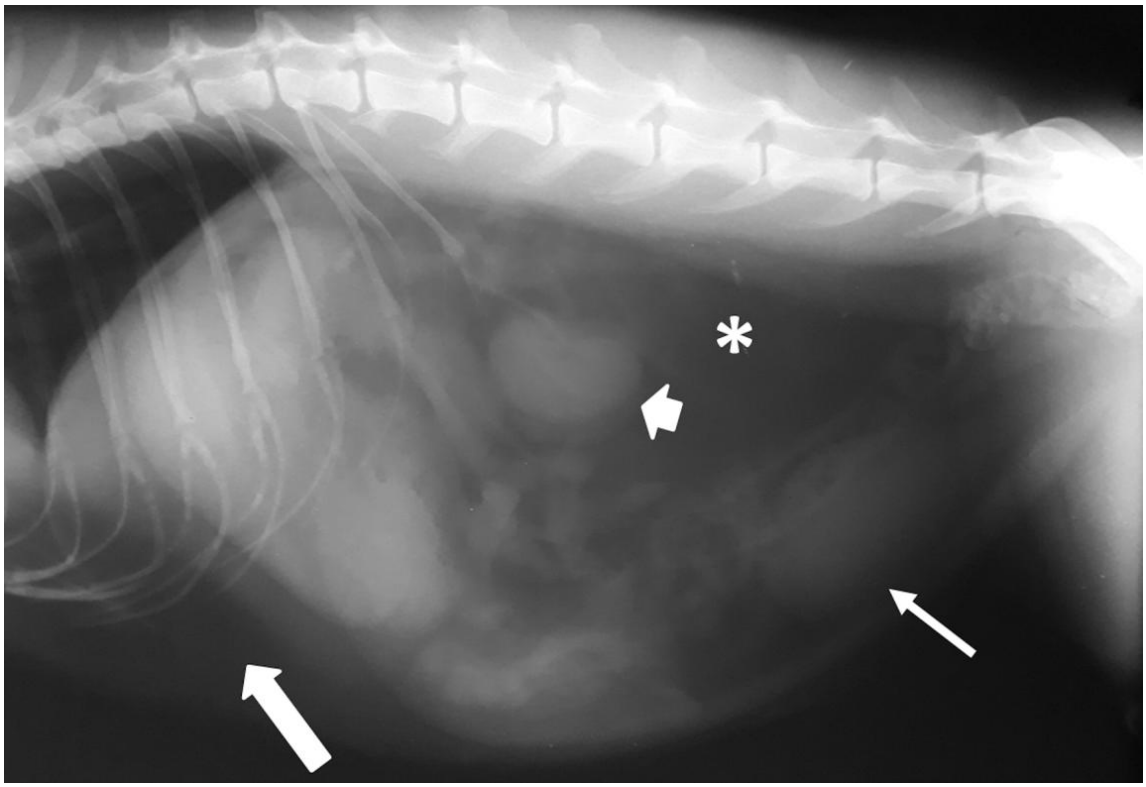

Figure 2. Right lateral (RL) abdominal radiograph of caracal II (14.8 kg; 8.8 yrs). The lumbar spine is almost straight with seven vertebrae. Accumulation of large amount of fat is seen in the cranioventral abdomen ventral to the liver (long thick arrow) and in the retroperitoneal space (*****). Note the bunching of small intestines in the central abdomen. The kidneys and urinary bladder are indicated by a short thick arrow and a thin arrow, respectively.

Circulatory system

On the RL view, the cardiac silhouette was ovoid and obliquely positioned in all animals (Figures 1 and 4). There was no contact between the cardiac silhouette and the diaphragm (Figures 1 and 4). The size of the cardiac silhouette was approximately 2½ to 3 intercostal spaces (Figure 4). The aorta and caudal vena cava were seen in all animals (Figure 4). The aortic arch was elongated (redundant) in the oldest animal (caracal II) (Figure 4B). On the DV view, the cardiac silhouette was ovoid and the apex was positioned in the left hemithorax (Figure 3A). The left lateral border of the descending aorta was seen in all animals (Figure 3A). The spleen was clearly seen in all animals on the VD view of the abdomen (Figure 3B). It was triangular located adjacent to the left abdominal wall between the left kidney and gastric fundus (Figure 3B).

Urinary system

The bean-shaped kidneys were identified on RL and VD views (Figures 2 and 3B). On the VD view, the right kidney's cranial pole was positioned more cranial than the

left kidney's cranial pole (Figure 3B). The right and left kidney's length were approximately two times the length of L2 (Figure 3B). Further, the right and left kidney's width were approximately 1.4 times the length of L2 (Figure 3B). The oblong urinary bladder was identified in all animals (Figures 2 and 3B).

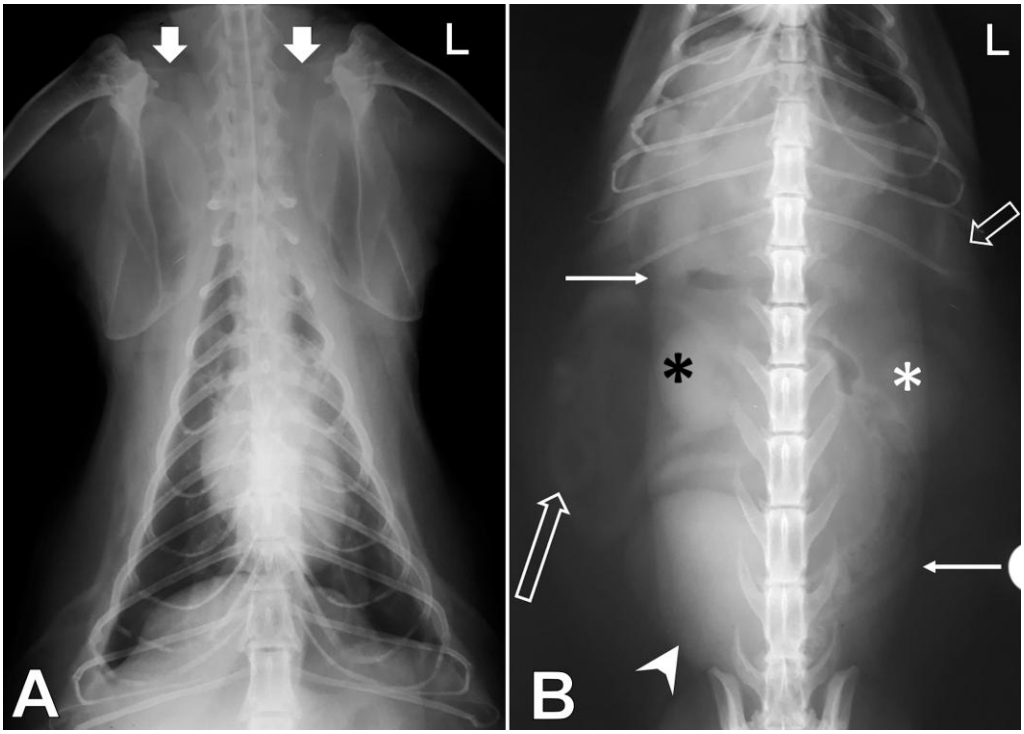

Figure 3. A: Dorsoventral thoracic radiograph of caracal I (12.8 kg; 5.3 yrs). **B:** Ventrodorsal abdominal radiograph of caracal II (14.8 kg; 8.8 yrs). **A:** The apex of the cardiac silhouette is positioned in the left hemithorax. The clavicles are indicated by thick white arrows. **B**: Hypaxial muscles are conspicuous (long white arrows). The right kidney (black asterisk) is more cranial than the left kidney (white asterisk). Note the bunching of small intestines in the right abdomen (long white open arrow). The spleen and urinary bladder are indicated by a short white open arrow and white arrow head, respectively. L= left.

Digestive system

The large intestine could be distinguished from the small intestines in all animals (Figure 2). The contents of the small intestines had mainly soft tissue opacity (Figure 2). Bunching of small intestines in the right central abdomen was seen in the heaviest animal (caracal II) (Figures 2 and 3B). The diameter of the small intestine was approximately 0.7 times the height of L2 (Figure 2). For the large intestine, the diameter was approximately 0.7 and 1.7 times the length and height of L2, respectively (Figure 2).

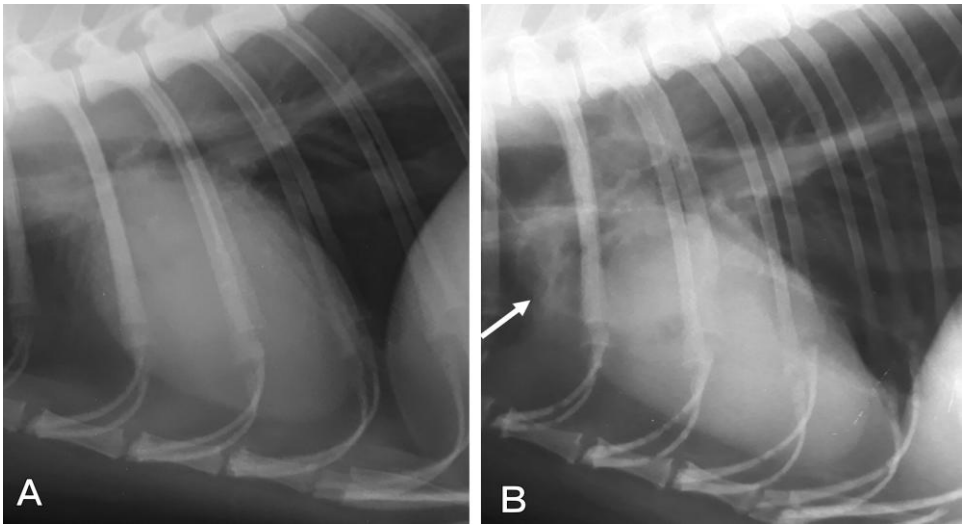

Figure 4. Close-up right lateral (RL) thoracic radiographs of caracal II at the age of 1.2 years (**A**) and 8.8 years (**B**). Note the elongated and more horizontally positioned cardiac silhouette in **B** compared with **A**. The redundant aortic arch is indicated by a white arrow. The trachea is seen with mineralised cartilage rings and the carina is located at the level of the sixth rib.

Table 2. Radiographic measurements in two captive caracals (*Caracal caracal*)

Variables	No.	Mean ± SD	Range
TD (cm)	2	1.4 ± 0.00	1.4-1.4
Third rib width (cm)	2	0.4 ± 0.00	0.4-0.4
TD: Third rib width (cm)	2	3.5 ± 0.00	3.5-3.5
CVC diameter (cm)	2	0.95 ± 0.07	0.9-1.0
VL above carina (cm)	2	1.5 ± 0.14	1.4-1.6
CVC: VL	2	0.65 ± 0.07	0.6-0.7
HL2 RL (cm)	2	1.2 ± 0.00	1.2-1.2
LL2 RL (cm)	2	2.8 ± 0.00	2.8-2.8
LL2 VD (cm)	2	2.7 ± 0.07	2.6-2.7
Small intestinal diameter (SID) (cm)	2	0.8 ± 0.14	0.7-0.9
SID: HL2	2	0.7 ± 0.12	0.6-0.8
Large intestinal diameter (LID) (cm)	2	2.0 ± 0.00	2.0-2.0
LID: HL2	2	1.7 ± 0.00	1.7-1.7
LID: LL2	2	0.7 ± 0.00	0.7-0.7
Left kidney			
Length [cm]	2	5.3 ± 0.28	5.1-5.5
L:LL2	2	2.0 ± 0.1	1.96-2.04
Width [cm]	2	3.7 ± 0.28	3.5-3.9
W:LL2	2	1.4 ± 0.09	1.35-1.48
Right kidney			
Length [cm]	2	5.6 ± 0.42	5.3-5.9
L:LL2	2	2.1 ± 0.11	2.04-2.19
Width [cm]	2	3.8 ± 0.28	3.6-4.0
W:LL2	2	1.4 ± 0.07	1.38-1.48

DISCUSSION

Caracals had slender thoracolumbar vertebrae and sternebrae similar to the domestic cat (Kirberger, 2005). Further, the fairly concave thoracic spine, which has been observed in this study, is similar to the domestic cat (Kirberger, 2005). The number of thoracolumbar spine (20) and fused sacral vertebrae (3) seen in caracals is similar to the domestic cat (Kirberger, 2005). Caracals had 13 pairs of ribs, which is similar to the domestic cat (Llabrés-Diaz *et al.,* 2008). However, the last pair of ribs was floating, which is different from the domestic cat in which the last two pairs of ribs are usually floating (Llabrés-Diaz *et al.,* 2008). The fairly straight sternum seen in caracals is also similar to the domestic cat (Llabrés-Diaz *et al.,* 2008). Conspicuousness of hypaxial muscles on the VD view in caracals is the result of pronounced retroperitoneal fat, which provides contrast to the margins of the hypaxial muscles and should not be confused with an abdominal mass. Similar finding has been observed in domestic cat (Thrall and Robertson, 2011).

The visualisation of the trachea with mineralised cartilage rings in all caracals is different from domestic cats (Hayward *et al.,* 2008) and should not be misinterpreted as an incidental finding or aging change. The ratio of the tracheal diameter to the width of the third rib observed in caracals (3.5) is larger than the reported ratios (1.59 and 1.71) in domestic cats (Hammond *et al.,* 2011). In all caracals the caudodorsal lung border diverged from the thoracic spine similar to the domestic cat (Thrall and Robertson, 2011). The divergence of the caudodorsal lung border from the thoracic spine on the RL view, in this species is the result of increased mass of the hypaxial muscles (Thrall and Robertson, 2011) and should not be confused with the pleural effusion. Further, the location of the tip of the dorsocaudal lung lobes at the level T13 to L1 observed in caracals is almost similar to the domestic cat (Thrall and Robertson, 2011).

In all caracals, the cardiac silhouette was obliquely positioned similar to the domestic cat (Buchanan, 2000). Additionally, the more horizontally positioned cardiac silhouette and redundant aortic arch, which were observed in the oldest animal (caracal II) in this study, have also been documented in older domestic cats (Moon *et al.,* 1993). These changes should not be interpreted as pathologic rather are associated with age related changes in thoracic conformation (Johnson *et al.,* 2008). The radiographic identification of the triangular spleen mainly on the VD view of the abdomen in caracals is similar to the domestic cats (Thrall and Robertson, 2011).

In this study, the length of the kidneys in caracals were approximately two times the length of L2, which is within the reported range (2.1-3.2) in the domestic cats (Larson, 2009). The bunching of small intestines in the right central abdomen, which was observed in the heaviest caracal (caracal II), has also been reported in obese domestic cats (Lee and Leowijuk, 1982; Thrall and Robertson, 2011) and should not be misinterpreted as an abdominal mass effect (Lee and Leowijuk, 1982) or linear foreign body (Thrall and Robertson, 2011). The ratio of the small intestinal diameter to the height of L2 obtained in this study (0.7) is lower than the median value (1.3) reported in domestic cats (Adams *et al.,* 2010). Moreover, the ratio of the large intestinal diameter to the height of L2 in this species (1.7) was lower than the median value (2.79) reported in domestic

cats (Adams *et al.*, 2010). Accumulation of a large amount of fat in the retroperitoneal space and in the cranioventral abdomen ventral to the liver, which was observed in the heaviest caracal (caracal II), has also been reported in obese domestic cats (Thrall and Robertson, 2011).

Majority of organs of clinical importance in caracals were seen on radiographic examination. Knowledge of the normal radiographic anatomy of the thorax and abdomen of the caracal may be useful in the diagnosis of diseases and in routine health examinations.

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