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Original Research Article

COMPUTED TOMOGRAPHIC, LAPAROSCOPIC AND SECTIONAL ANATOMY OF THE LIVER AND SPLEEN IN GOATS (*CAPRA HIRCUS*)

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Abstract: The present study was carried out on nine apparently healthy goats of both sexes, females were non-pregnant and non-lactating. Their weight and age ranged from 28-35 kg and 17 to 24 months, respectively. These goats were divided into three groups; 1) Three were subjected to frozen sagittal section technique, 2) Three underwent computed tomography followed by frozen cross section techniques, and 3) Three were used for laparoscopy. With the aid of these techniques, this study focused on liver and spleen to detect their position, shape and relation with other abdominal organs. Sagittal sectional anatomy was done using right paramedian, left paramedian and midline sagittal sections on the abdomen of goats. The frozen cross sections were compared with CT images at the same level. Laparoscopy was accomplished at three positions; dorsal recumbency, right flank and left flank laparoscopy. The obtained results were presented in plates and anatomical structures of clinical importance were identified and labelled to establish a comprehensive guide for specialists in anatomy, surgery, radiology and veterinary education.

Key words: frozen sections; CT; faparoscopy; *hepar*; *lien*; small ruminants

Introduction

Goats have been established as a model for biomedical research, teaching and surgical training. Because, they are relatively clean and small sized they can be maintained in small areas and handled with ease (1,2).

Computed tomography (CT) images are created by using both X-rays and computer processing (3). It provides a higher contrast and resolution of soft tissues than normal radiography, with the ability to reconstruct images of areas under investigation (4). It is now established as good standard diagnostic procedure in human medicine, as it is non-invasive and can be performed frequently. However, only in the last decade, it became available in veterinary profession, but with limited use as it requires anaesthesia and high costs (5).

Laparoscopy represents a technique for visual examination of the abdominal cavity and its contents. It is a minimally invasive technique that requires the distension of the abdominal cavity with gas (a process called: induced pneumo-peritoneum), this results in improved visualization and facilitated instrumental and visceral manipulation (6). In addition, it provides live visual examination of the abdominal contents using an illuminated tele-

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scope (7). Therefore, it is very useful to display the organs in a natural colour, and so it offers an advantage over other techniques such as ultrasonography or radiography (8,9).

Laparoscopy allows surgeons to access the abdomen without making large incisions in the abdominal wall, an advantage over laparotomy. in addition to reducing tissue trauma, reducing postoperative adhesions and infections, fast recovery, stimulation of the immunity, better cardiovascular stability and lower pain scores (10,11).

Literature lacks adequate information on goat's liver and spleen anatomy using both CT and laparoscopy; besides formalin fixed samples are becoming less and less used in anatomical education. Therefore, this study was conducted to provide the normal anatomy, topography and morphometry of liver and spleen in goats, using laparoscopy and computed tomography compared to standard sectional anatomy procedure. In addition, we aimed to provide photographs that will be of essential importance for veterinary anatomists, radiologists, surgeons and clinicians.

Material and methods

The present study was performed on nine apparently healthy goats of both sexes; females were non-pregnant and non-lactating. Their weight ranged from 28 to 35 kg and their age ranged from 17 to 24 months. The study was approved by the Committee of Animal Welfare and Research Ethics, Faculty of Veterinary Medicine, Zagazig University.

Three techniques were carried out to describe the liver and spleen in goats; Frozen sections technique, Computed tomography and Laparoscopy. Study design and methodology described herein followed the guidelines of Faculty of Veterinary Medicine Research Ethics Committee. The nomenclature used in this study was adopted following *Nomina Anatomica Veterinaria*, 2012 (12).

Frozen sections technique

The goats were sedated with intravenous injection of Xylazine HCl 2% (0.1 mg/kg, Xyla-Ject®, ADWIA, Egypt), followed by slaughtering and complete bleeding. The two fore limbs were removed, and the cadavers were put in a deep freezer (-20°C) in sternal or lateral recumbency position.

After complete freezing of the cadavers (3 days or more), three cadavers, were longitudinally sectioned using electrical band saw through midline, right para-median and left para-median sections (supplementary plate 1/A). The paramedian sections passed through the edge of the first lumbar transverse process parallel to the midline on each side. While, another three cadavers (after CT scanning) were transversely sectioned into serial transverse sections (approximately three cm apart; to cut in each vertebra) starting from the level of the 5^{th} thoracic vertebra and perpendicular to the longitudinal axis of the goat's trunk (supplementary plate 1/B). Each cut section was immediately photographed, and the obtained photos were compared with the corresponding CT images.

Computed tomography (CT)

The CT scan was carried out at a private CT centre, El-Sharkia Governorate, Egypt. A third-generation multi-slice helical CT scanner (GE LightSpeed Ultra 8 system, General Electric Company, USA) was used with eight body slices per rotation and soft tissue window width of 500 HU (Hounsfield unit); its features were 53.2 KW generator, 6.3 MHU tube size and rotation time of 0.5 seconds (supplementary plate 1/C). The CT scan was performed following previously described protocol with slight modifications (13). For this part of the study, three goats were used (after that, the same goats were used for frozen cross sections technique described in point 2.1.).

The CT images were obtained without using contrast material and only soft tissue window was used to detect the location, homogeneity, shape and morphometry of both liver and spleen. After fasting for 24 hours, the goats were sedated with intravenous injection of Xylazine HCl 2% (0.1 mg/kg, Xyla-Ject®, ADWIA, Egypt), then the goats were positioned in sternal recumbency during scanning time. A scout view of the goat was obtained before beginning of the scanning as shown in (supplementary plate 1/D). The

abdomen was scanned with a layer thickness of one mm interval with an exposure of 120 kV and 270 mA. The captured images were compared with their corresponding cross sections at the same level.

Laparoscopic technique

Laparoscopy was carried out using SOPRO-COMEG laparoscope (Germany, supplementary Plate 1/F) at the laparoscopy unit of the Surgery Department, Faculty of Veterinary Medicine, Zagazig University, Egypt. The procedure followed published guidelines (6,10,14).

Results and discussion

The present work focused mainly on the liver and spleen in goats, using different anatomical techniques. With a final goal of improving our understanding and interpretation of clinically important information, provided either as CT scans or laparoscopic images, for a broad range of research and education professionals.

Frozen sectional anatomy

Sagittal sectional findings: Three sagittal sections were obtained; the midline, right paramedian and left paramedian sections.

Liver (*Hepar*): The liver was present in the right paramedian sagittal section (Plate 1/A). It extended from the level of the sixth to last thoracic vertebrae. Its shape resembled a narrow elongated triangular strip. Both right (*Lobus hepatis dexter*) and caudate (*Lobus caudatus*) lobes of the liver were identified. The latter lobe was seen capping the cranial pole of right kidney and its perirenal fat (Plate 1/A). Parietally, the liver was related to diaphragm. Its visceral surface was related to the reticulum, omasum, pancreas, portal vein and dorsal ruminal sac. While, the liver was seen in midline sagittal section as a small narrow slice related dorsally to the ruminal atrium (Plate 1/B). These findings are similar to previously reported findings in sheep and goat (15).

Spleen (*Lien*): The longitudinal section of the spleen appeared as a small fusiform elongated mass in the left paramedian sagittal section. In this aspect, it prolonged from the level of the ninth to last thoracic vertebrae. It was dark red in colour and rested on the dorsal surface of the dorsal ruminal sac and related to the vertebral column and the diaphragm (Plate 1/C). These findings are in accordance with previous descriptions in small ruminants (15–17).

Cross sectional findings: In this part of study, each cross section was identified and described within the topography of the main regions of the abdomen. Appearance of the liver and spleen in each section is tabulated in (Table 1).

Table 1: Liver and spleen in studied goats appearing in frozen cross sections (FCS) and in computed tomography (CT) studies, in relation to thoracic vertebrae number

Organs \ No. of vertebrae	Thoracic vertebrae															
	6th		7th		8th		9th		10th		11th		12th		13th	
	FCS	CT	FCS	CT	FCS	CT	FCS	CT	FCS	CT	FCS	CT	FCS	CT	FCS	CT
• Liver	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
○ Gallbladder	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-
○ Caudal vena cava	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
○ Portal vein	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-
• Spleen	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-

(+) = visible, (–) = not visible.
Highlighted cells in grey indicate differences between FCS & CT

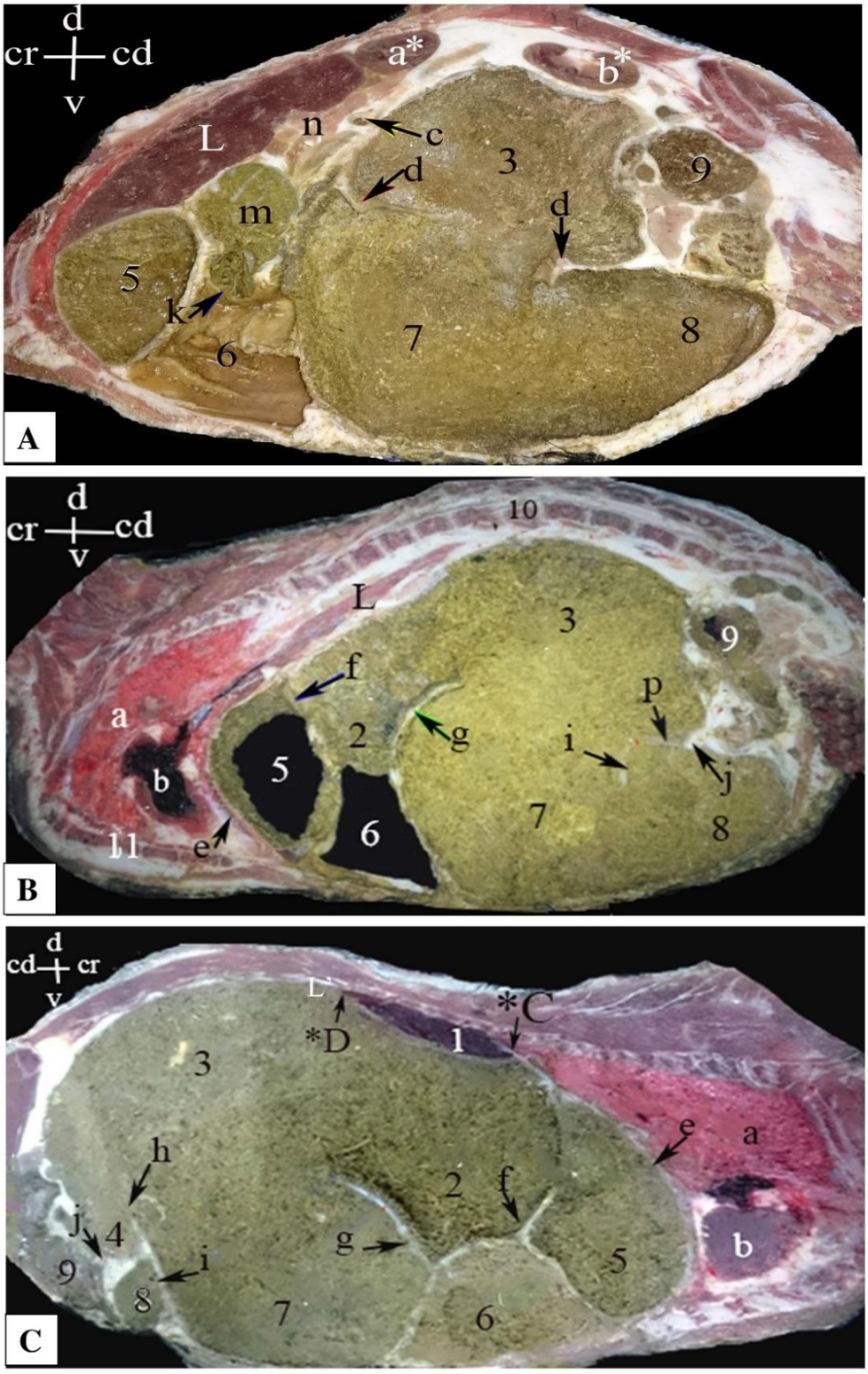

Plate 1: Photomacrographs showing representative frozen longitudinal sections of goat aged 21 months, right paramedian sagittal section (A), midline sagittal section (B) and left paramedian sagittal section (C). 1- Spleen, 2- Ruminal atrium, 3- Dorsal ruminal sac, 4- Dorsal caudal blind sac, 5- Reticulum, 6- Abomasum, 7-Ventral ruminal Sac, 8- Ventral caudal blind sac, 9- Intestine, 10- Vertebral column, 11- Sternum, a- Left lung, b- Heart, c- Portal vein, d- Right longitudinal pillar, e- Diaphragm, f- Rumino-reticular fold, g- Cranial transverse pillar, h- Dorsal coronary pillar, i- Ventral coronary pillar, j- Caudal pillar, k- Omaso-abomasal orifice, L- Liver, L'- Caudate lobe of the liver, m- Omasum, n- Pancrea, p- longitudinal pillar, a*- Right kidney, b*- Left kidney and *C, *D – the extension of the spleen

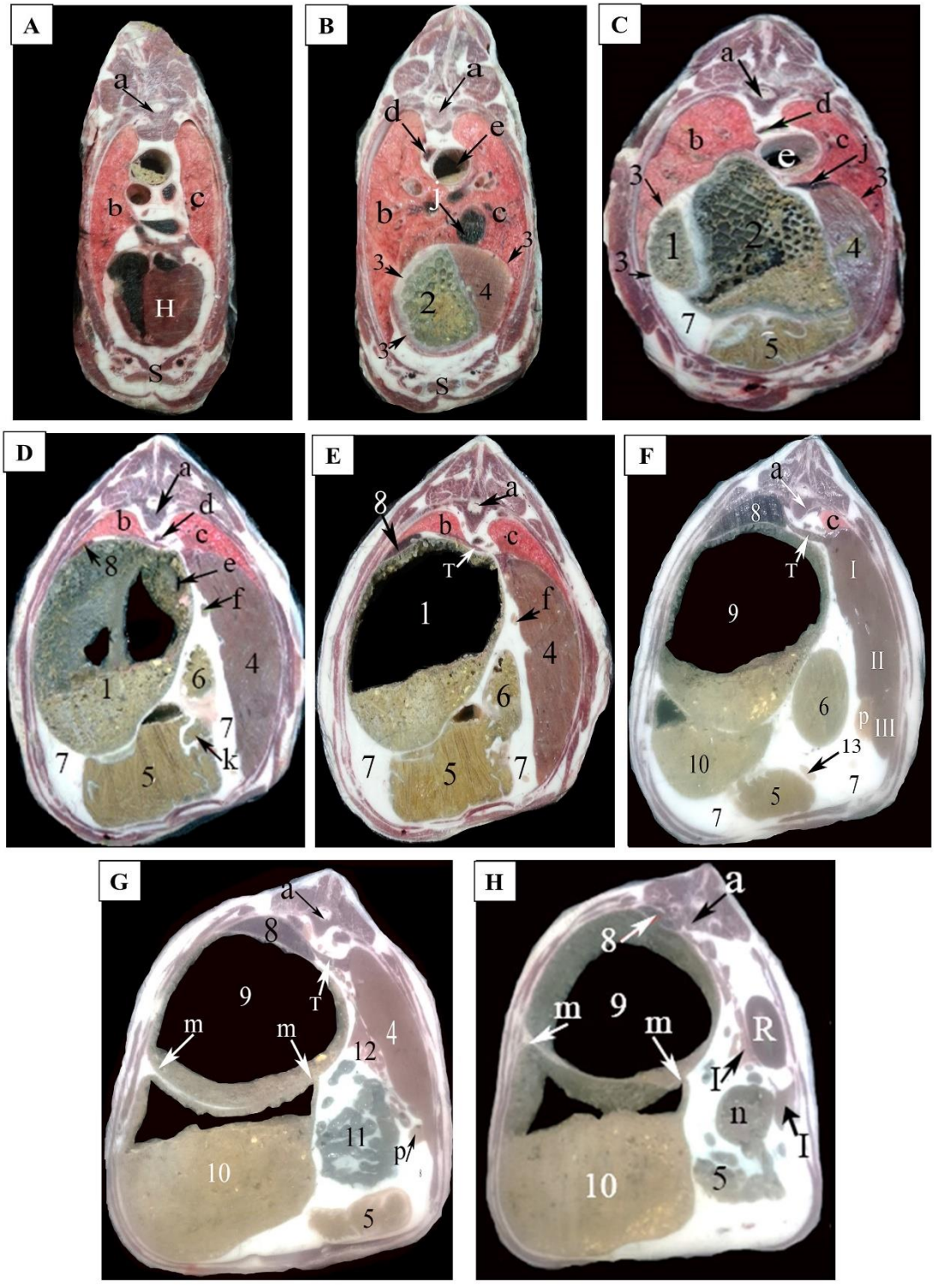

Plate 2: Photomacrographs showing representative frozen cross-anatomical sections, of goats aged between 17-24 months, at the level of fifth (A), sixth (B), seventh (C), eighth (D), ninth (E), tenth (F), eleventh (G) and twelfth (H) thoracic vertebrae.1- Ruminal atrium, 2- Reticulum, 3- Diaphragm, 4- Liver (I- Caudate lobe of liver, II- Right lobe of liver, III- Quadrate lobe of liver), 5- Abomasum, 6- Omasum, 7- Greater omentum, 8- Spleen, 9- Dorsal ruminal sac, 10- Ventral ruminal sac, 11- Intestine (Jejunum), 12- Pancreas, 13- Abomasal lymph node , a- Vertebra, b, c- Left and right lungs, d- Aorta, e- Oesophagus, f- Portal vein, H- Heart, J- Caudal vena cava, k- Omaso-abomasal orifice, m- Right and Left longitudinal pillars, n- Caecum, P- Gallbladder, R- Right kidney, S- Sternum, T- Lumbar part of diaphragm (Root)

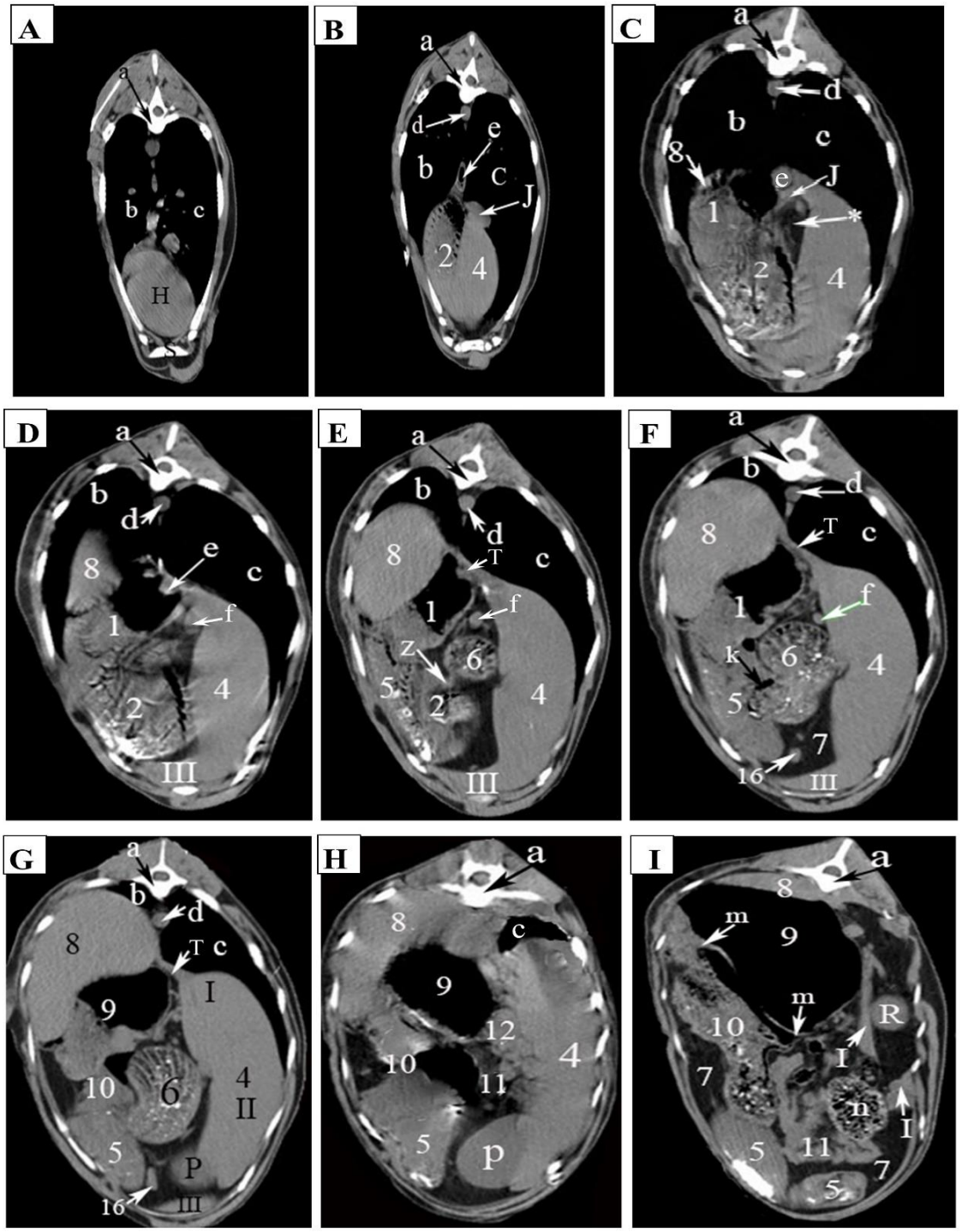

Plate 3: Photomacrographs showing representative CT images, of goats aged between 17-24 months, at the level of fifth (A), sixth (B), seventh (C), eighth (D and E), ninth (F), tenth (G), eleventh (H) and twelfth (I) thoracic vertebrae. 1- Ruminal atrium, 2- Reticulum, 3- Diaphragm, 4- Liver (I- Caudate lobe of liver, II- Right lobe of liver and III- Quadrate lobe of liver), 5- Abomasum, 6- Omasum, 7- Greater omentum, 8- Spleen, 9- Dorsal ruminal sac, 10- Ventral ruminal sac, 11- Intestine (Jejunum), 12- Pancreas, 16- Abomasal lymph node, a- Vertebra, b, c- Left and right lungs, d- Aorta, e- Oesophagus, f- Portal vein, H- Heart, J- Caudal vena cava, k- Omaso-abomasal orifice, m- Right and Left longitudinal pillar, n- Cecum, P- Gallbladder, R- Right kidney, S- Sternum, T- Lumbar part of diaphragm (Root), Z- Reticulo-omasal orifice, and *- Porta hepatis

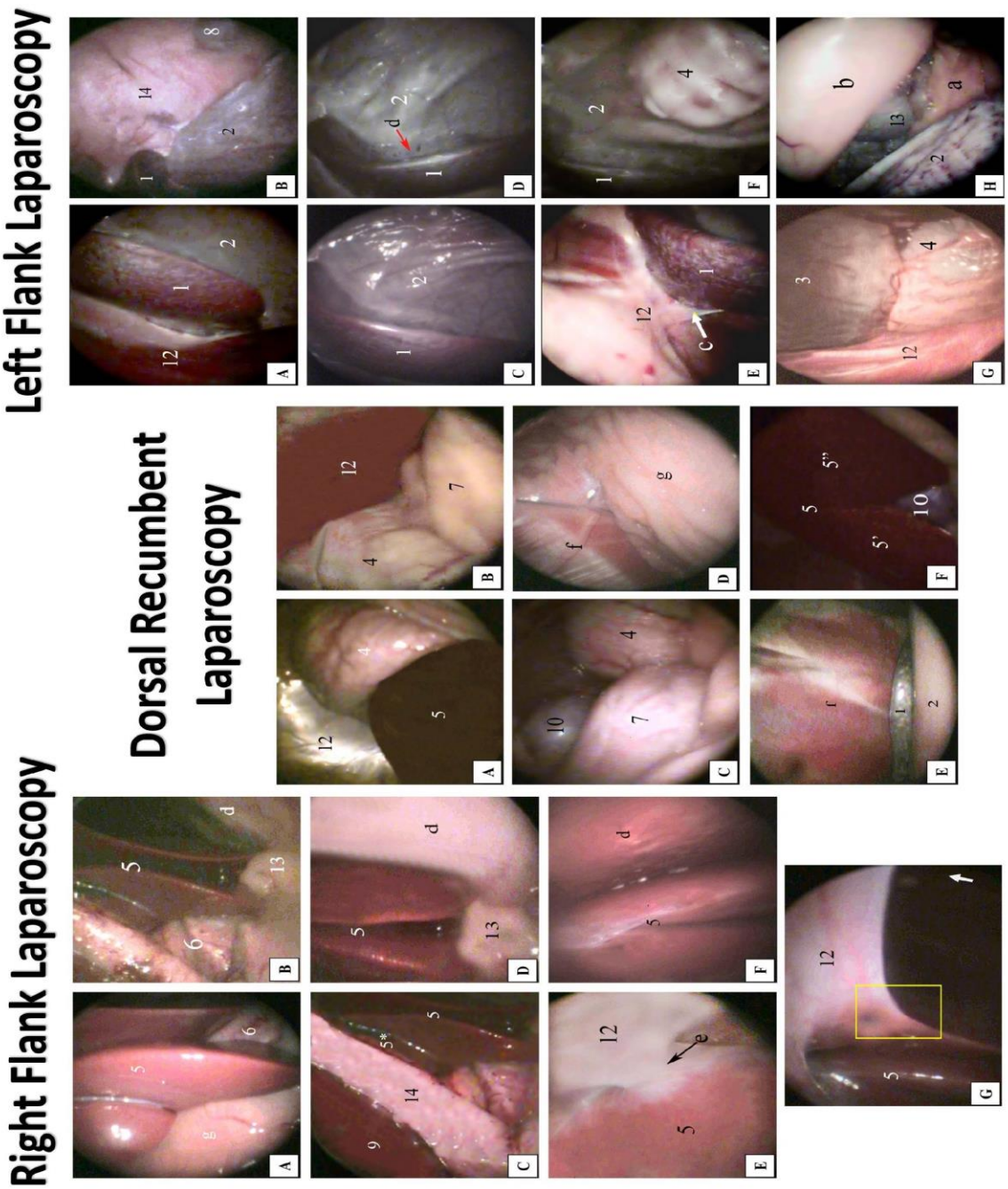

Plate 4: Representative photomacrographs of Right flank laparoscopy, of goats aged between 17-24 months. Note: the telescope was inserted to the right side of the abdomen till reaching the level of the liver. Showing: 5- Liver, 5*- caudate lobe of the liver, 6- Omasum, 9- Right kidney, 12- Diaphragm, 13- Intestine (duodenum), 14- Peri-renal fat, d- Right abdominal wall, g- Greater omentum, e- Coronary ligament, and Yellow rectangle- Right triangular ligament. Dorsal recumbency laparoscopy. Note: the telescope was directed dorsally and to the right side of the abdomen till reach the liver (A), ventral to show reticulum and abomasum (B and C) and caudally till the caudal abdominal region (D). Showing: 1- Spleen, 2-Dorsal ruminal sac, 4- Reticulum, 5- Liver, 5'- Right lobe of the liver, 5"- Quadrate lobe of the liver, 7- Abomasum, 10- Gallbladder, 12- Diaphragm, f: Left abdominal wall, and g: Greater omentum. Left flank laparoscopy. Note: the telescope was directed dorsally till reaching the level of the dorsal ruminal sac and spleen (A, B, C, E, F and H) and directed ventrally to the left side till reach the reticulum (D and E). Showing: 1- Spleen, 2- Dorsal ruminal sac, 3- Ventral ruminal sac, 4- Reticulum, 8- Left kidney, 12- Diaphragm,13- Intestine (colon), 14- Peri-renal fat, a- Intra-abdominal fat, b- Dorsal abdominal wall, c- Phrenico-splenic ligament, and d- Gastro-splenic ligament

Liver: Sequence examination of the frozen sections from the level of the fifth to twelfth thoracic vertebrae (Plate 2) revealed that the liver was entirely located to the right half of the intrathoracic part of abdominal cavity. It was dark red in colour. At the level of sixth thoracic vertebra (Plate 2/B), it had a triangular shape in cross section and was related to the reticulum medially, right abdominal wall laterally and diaphragm dorsally. Also, at the level of seventh thoracic vertebra (Plate 2/C), it was related to diaphragm dorsally, reticulum and abomasum medially right abdominal wall laterally. While, at the level of eighth and ninth thoracic vertebrae (Plates 2/D and 2/E), the liver was related to the right abdominal wall and diaphragm parietally and ruminal atrium, omasum, abomasum, greater omentum, and portal vein viscerally. At the level of the tenth thoracic vertebra (Plate 2/F), the shape of liver changed to elongated oval in outline and it was related medially to the dorsal ruminal sac, greater omentum, omasum and gallbladder, laterally to right abdominal wall and dorsally to the root (lumbar part) of diaphragm. In addition, at the level of eleventh thoracic vertebra (Plate 2/G), the liver was related medially to pancreas, intestine, greater omentum and dorsal ruminal sac, laterally to right abdominal wall and dorsally to the lumbar part of diaphragm. Finally, at the level of the twelfth thoracic vertebra (Plate 2/H), a small part of the caudate lobe of the liver was visible capping the right kidney and its peri-renal fat. There is not much difference between these and previous data in sheep and goat (15,16), and in ruminants in general (17,18).

The portal vein (*V. portae*) appeared as a circular structure on the visceral surface of the liver, at the level of the eighth and ninth thoracic vertebrae, as shown in (Plate 2/D and 2/E). Its location is ventro-lateral to the caudal vana cava (*Vena cava caudalis*). While, the latter vein was detected dorsal to the parietal surface of the liver at the level of the sixth and seventh thoracic vertebrae (Plate 2/B and 2/C). In addition, larger hepatic veins (*Vv. hepaticae*) were distinguishable within the hepatic parenchyma.

Through examining sections at the level of tenth and eleventh thoracic vertebrae, the gallbladder (*Vesica fellea*) was seen as a fluid filled vesicle rested at the ventral part of the visceral surface of liver (Plate 2/F and 2/G). Others observed it at the level of tenth or eleventh rib (16,17). Meanwhile, no relation was detected between the gallbladder and the right abdominal wall, in contrast with information provided by Getty and Nickel and co-workers (18,19).

Spleen: Examined sections at the level from eighth to twelfth thoracic vertebrae, spleen was detected at the left side of the abdomen just ventral to the vertebral column & ribs (Plate 2/D : 2/H). The spleen appeared as a triangular organ that is related to dorsal ruminal sac viscerally, diaphragm and left abdominal wall parietally. Its relations to the vertebral column, dorsal ruminal sac and diaphragm were as previously described in ruminants (17). However, it was shown to be related to the reticulum, in ruminants, (18) and the pancreas, in sheep, (16), but it was not feasible to detect these relations in the present cross or even longitudinal sections (in point 3.1.1.2).

Frozen sections technique described herein, is in accordance with previous anatomical texts and research describing position, size and relation of liver and spleen in ruminants, particularly in goats. However, some findings did not match with the previously reported information such as in the portal vein and gallbladder, which highlight either differences in ruminant subspecies used or the physiological condition, and highlight the need for more revised versions of the currently available information.

Computed tomography (CT)

Detailed examination of soft structures viewed using soft tissue window, the location, relation; homogeneity and shape of each organ under investigation were observed. During this process, each transverse CT image was matched with the conforming frozen cross-section at the same level. The bones (thoracic and lumbar vertebrae, ribs and sternum) were used as landmarks for detecting soft tissue structures. The structures were identified

according to their radiodensity, shape and location. The visible organs in CT scanning with their extension are tabulated in (Table 1).

Abdominal CT in study goats demonstrated most of the typical anatomical findings which appeared in frozen cross-sections. What is more, it shows advantages over regular radiography, since it provides soft tissue structures without superimpositions or artefacts. In addition, its information is diagnostic without the need for contrast materials (20).

Liver: The liver was apparent as homogenous soft tissue density at the right side of the epigastric region from the level of sixth to twelfth thoracic vertebrae (Plates 3/B : 3/I), but, in another goat study its extension was between the fifth thoracic and eleventh lumbar vertebrae (13). Meanwhile, in Holstein-Friesian calves, it extended from the seventh thoracic to the first lumbar vertebrae (21). In another small ruminant species; Jebeer gazelles (22), the liver extended from the eighth thoracic further till the level of second lumbar vertebra (22). This highlights an obvious extension differences between ruminant species.

It was elongated in shape and prolonged from the diaphragm dorsally to the sternum and ventral abdominal wall ventrally. At the levels from eighth to tenth thoracic vertebrae (Plate 3/D: 3/G) but not at the fifth (Plate 3/A), the quadrate lobe was revealed as a small tapered lobe on the ventral abdominal wall. This lobe could be clearly recognized from the right medial hepatic lobe by the gallbladder at the level of tenth thoracic vertebra (Plate 3/G). The right and left lobes were distinguishable by their side location on the CT image. The liver was observed between right abdominal wall, diaphragm, rumen, reticulum, omasum, abomasum and sternum. These relations and the three distinguishable liver lobes were previously reported in goats (13,23).

The hepatic portal (*Porta hepatis*) was seen as a hypodense area medial to the liver at the level of seventh thoracic vertebrae (Plate 3/C). Also, the portal vein was visible medial to the liver as a hypodense band at the level of eighth and ninth thoracic vertebrae (Plate 3/D: 3/F). While, the caudal vena cava was found as a hypodense irregular band dorsal to the visceral surface of liver at the level of sixth and seventh thoracic vertebrae (Plate 3/B and 3/C). Meanwhile, the hepatic veins could not be identified. All this was in agreement with previous reports in goats (13).

The gallbladder was visible as pear-shaped structure at the level of tenth and eleventh thoracic vertebrae (Plate 3/G and 3/H). It was seen to the right side of the ventral part of the visceral surface of the liver with hypodensity (noticeably less density compared to hepatic density); as it was filled with bile. At the level of the tenth thoracic vertebra (Plate 3/G), it was seen between the quadrate and right hepatic lobes. These findings were in a line with those previously mentioned in goats (23) and in Holstein-Friesian calves (21). However, in Jebeer gazelles, the gallbladder was at the level of thirteenth thoracic and first lumbar vertebrae (22). This difference is mainly due to the difference in the caudal extension of the liver between both species.

Spleen: The spleen was shown at the left cranial abdominal region from the level of seventh to the level of twelfth thoracic vertebrae (Plate 3/C: 3/I). However, in another study on goats, it appeared from the eighth thoracic to the second lumbar vertebrae (13). While, in Jebeer gazelles the spleen extended between the ninth thoracic and second lumbar vertebrae (22). Whether these variations in extension are merely due to the state of fullness of the rumen or due to anatomical differences it is not clear in any of the studies and requires further investigation.

The spleen was present between the diaphragm and left abdominal wall dorsally and the dorsal ruminal sac ventrally. It appeared as a large organ with rounded angles and hypodense homogenous soft tissue density; started oval then triangular and finally crescentic in shape depending on the section number. Its homogenous soft tissue density, similar to liver's density, was previously confirmed in goats (13,23) and bovine (21).

Computed tomography, was highly comparable to findings reported in frozen cross sections with the added advantage of ability to perform frequent scanning and follow-up, in addition it is completely non-invasive and no

need to sacrifice the animal under investigation. There were slight variations in CT scans compared to frozen cross sections. For example, this study showed variation in the size and extension of the spleen noted between CT and frozen cross-sections. This could be due to the fact that study goats were live and only sedated, and not bled. Also, slight movement and/or respiration during CT scanning could have participated in such variations, but this needs further investigation.

Laparoscopic study

Laparoscopic study was done on both standing and dorsal recumbent (reverse Trendelenburg) positions. Access through the right flank region showed the liver and its relation with other organs. The left flank approach exposed the spleen and its relations, while, the dorsal recumbency position identified both liver and spleen. The liver and spleen were feasibly characterized by their normal anatomical shape, position and relation.

Liver: Thorough laparoscopic examination of goats showed that, the parietal surface of the liver was viewed in the right epigastric region in standing position (Plate 4). This finding is in agreement with previous reports in goats, horses and ruminants (10,24–27). The liver was also detected in dorsal recumbency approach towards the right side of the cranial abdominal region. This was previously reported in caprine (9), in horses (27–29) and in adult cattle (26).

It had a bright red to brown red colour with smooth surface and sharp edges, as previously shown in small animals (14). But in llama, another small ruminant, the ventral border was fimbriated (30). The hepatic lobation was clearly visible; mainly the left lobe, right lobe, quadrate and caudate lobes. The latter was related to the right kidney dorsally, but it was practically impossible to show the renal impression or hepatorenal ligament due to extensive amount of peri-renal fat (Plate 4/C), so we were unable to observe these structures.

In dorsal recumbent goat, the quadrate lobe was separated from the right hepatic lobe by the gallbladder (Plate 4/F), also this was in agreement with previous findings (9). The left hepatic lobe made a lateral relation with the reticulum in the right side of dorsal recumbent goats, similar finding was observed in bovine (24). Meanwhile, in dogs and cats (31) and in horses (25,27) the left lobe was only visible through the left lateral/paralumbar laparoscopy.

In right flank region, the liver was medially related to the cranial part of duodenum, greater omentum and omasum, laterally to right abdominal wall (Plate 4). The right triangular ligament was viewed in right flank laparoscopy and located between the right lobe of the liver and diaphragm (Plate 4/G), in a line with previous reports in llama (30) and in equine (32). The coronary ligament could be revealed also between the parietal surface of the liver and tendinous part of diaphragm (Plate 4/E), also reported in equines (32) but no details were found in ruminants in the literature. Meanwhile, the left triangular ligament was difficult to examine in the studied goats, in contrary to equines where it could be observed through left flank laparoscopy (32).

In dorsal recumbency laparoscopy, the gallbladder had a pear-shape with a bluish colour and was (embedded between the right and quadrate hepatic lobes (Plate 4/F), these matched previous results in goats (9,14). It was related medially to the reticulum and abomasums (Plate 4/C). It was difficult to identify in standing goats due to omental covering, plus we did not use tissue forceps in our laparoscopic approach, this also was reported previously in large ruminants (24,25).

Spleen: The spleen had a smooth surface with a bluish red colour with white dotted areas giving it a mottling appearance, as previously reported in goats (14), in llama (30), in horse and cattle (25,26,29,32). This characteristic anatomical appearance and position help surgeons identify the spleen to plan surgical interventions, such as splenectomy.

It was present in the left side of the intrathoracic part of abdominal cavity in standing and dorsal recumbent goats between the dorsal ruminal sac viscerally and the abdominal wall parietally (Plates 4/E and 4/A: 4/F), which was also confirmed by previous reports in goats (9), in horse and cattle (10,25–27,29). However, another study on horses

reported that it could be detected through both right and left sides of abdomen (32).

The spleen attached to the dorsal ruminal sac by gastro-splenic ligament medially along the visceral surface of the spleen (Plate 4/D) and to the tendinous part of diaphragm by the phrenico-splenic ligament (Plate 4/E). While, in goats, previous studies gave no observation to the gastro-splenic ligament, only the ventral extremity of the spleen was seen related to the ventral ruminal sac (9). In equines, this ligament was visible between the stomach and visceral surface of spleen (32). There was no direct relation between the spleen and the left kidney (Plate 4/B), other that the spleen was cranial to the left kidney, this was also previously described in goats (14).

Laparoscopy is ideal for real-time monitoring of internal organs as liver and spleen, and for obtaining biopsies or guiding internal injections. We showed for the first time the coronary ligament of the liver through right flank laparoscopy. However, laparoscopy is slightly invasive, requires local and/or general anaesthesia and shows a risk for postoperative complications which can be very costly in veterinary practice.

Conclusions

This study compared CT scanning with frozen cross sections in addition to abdominal laparoscopy, focusing mainly on the liver and spleen of goats. We provided comprehensive serial cross-sectional and CT images, in addition to laparoscopic images from different approaches with the final goal of updating our current knowledge about the anatomical shape, position and relations of liver and spleen in goats. Data and images provided in this study will be of immense value for specialists in anatomy, surgery, radiology and veterinary education.

Conflict of interest

The authors declare no conflict of interest.

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Supplementary data

The supplementary data file is available upon reasonable request by e-mailing the corresponding author. The file contains detailed methodology used herein in addition to supplementary plates and tables.

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