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Computed tomography of the abdomen in Saanen goats: I. Reticulum, rumen and omasum

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Summary

Computed tomography (CT) of the reticulum, rumen and omasum was carried out in 30 healthy goats and the images were compared to corresponding body sections obtained at postmortem. A multidetector CT was used to examine goats in sternal recumbency. A setting of 120 KV and 270 mA was used to produce 1.5-mm transverse slices from the fifth thoracic vertebra to the sacrum. Soft tissue structures were assessed in a soft tissue with a window width (W) of 400 Hounsfield Units (HU), and a window level (L) of 40 HU. The layering of the ruminal contents was assessed in an ingesta window with a W of 1500 HU and an L of 30 HU. After subjective evaluation, the size of the rumen and omasum, the thickness of the walls of the reticulum, rumen and omasum and the height of the gas cap and fibre and liquid phases of the rumen were measured. Fifteen goats were euthanised after CT examination, placed in sternal recumbency and frozen at –18 °C for three to 10 days. Thirteen goats were then cut into 1.0- to 1.5-cm-thick transverse slices. One goat was cut in dorsal-plane slices and another in sagittal slices. The structures in the CT images were identified by using the corresponding anatomical slices.

Keywords: computed tomography, goat, reticulum, rumen, omasum

Computertomographische Untersuchung von Haube, Pansen und Psalter bei Saanenziegen

In der vorliegenden Arbeit werden die computertomographischen Befunde an Haube, Pansen und Psalter von 30 gesunden Ziegen beschrieben und mit den Befunden der postmortalen Untersuchung verglichen. Die Ziegen wurden mit einem Mehrschicht-Computertomographen in sternaler Position untersucht. Die Untersuchung erfolgte mit einer Exposition von 120 kV und 270 mA in Transversalschnitten vom fünften Brustwirbel bis zum Sakrum bei einer Schichtdicke von 1.5 mm. Die Weichteilstrukturen wurden in einem definierten Weichteilfenster (Breite [W] 400 Hounsfield Units [HU], Lage [L] 40 HU) betrachtet und ausgewertet. Die Beurteilung der Pansenschichtung erfolgte in einem eigens dafür definierten Fenster, dem sogenannten Ingestafenster (W 1500 HU/L 30 HU). Im Anschluss an die subjektive Beurteilung wurden verschiedene Strukturen, wie die Ausdehnung von Pansen und Psalter, die Dicke von Hauben-, Pansen- und Psalterwand sowie die Ausdehnung der gasförmigen, flüssigen und festen Ingestaphase im Pansen bestimmt. 15 Ziegen wurden im Anschluss an die CT-Untersuchung euthanasiert und während 3 bis 10 Tagen bei –18 °C in sternaler Position tiefgefroren. Danach wurden 13 davon transversal in 1.0 bis 1.5 cm dicke Scheiben gesägt. Je eine weitere Ziege wurde in Dorsal- bzw. Sagittalschnitten gesägt. Die Schnitte wurden den CT-Bildern der entsprechenden Lokalisation gegenübergestellt, um die abgebildeten Strukturen zu identifizieren.

Schlüsselwörter: Computertomographie, Ziege, Haube, Pansen, Psalter

Introduction

Diseases of the abdominal organs are common in goats. A number of recent studies have shown that goats suffer from diseases that may require in depth diagnostic work-up (Tschuor et al., 2007; Braun et al., 2008a, 2008b, 2009a, 2009b). The methods used to diagnose disorders of these organs include physical examination, haematologic and serum biochemistry analyses, faecal analysis, radiography and ultrasonography (Steininger, 2009; Braun und Steininger, 2010; Jacquat, 2010). With the exception of one case (Braun et al., 2009a), CT was not used until now to examine goats. The expectations and willingness of owners to pay for more expensive procedures have increased over the years because many goats are kept as pets, although they have traditionally been raised for milk, meat and hair production. However, accurate interpretation of CT images necessitates a thorough knowledge of the normal appearance of organs and tissues. Thus, the goal of the present study was to establish CT reference values for the reticulum, rumen and omasum based on the examination of 30 healthy goats.

Animals, Material and Methods

Animals

Thirty, clinically healthy, non-lactating, female, Saanen goats, which were 2.5 to 6.5 years old (mean, 4.1 years) and weighed 42 to 86 kg (mean, 61.3 kg), were used. The goats were not pregnant and had similar body conditions. They originated from two farms and had been sold for slaughter. After purchase, all of the goats were deemed healthy based on the results of various clinical and laboratory examinations (Becker-Birck, 2009).

CT examination and imaging processing

The animals were fasted for 24 hours and deprived of water for 2 hours prior to anaesthesia. Each goat was sedated by use of xylazin (0.1 mg/kg) (Xylazin, Streuli Pharma, Uznach, Switzerland), then, anaesthesia was induced with ketamine (3 mg/kg) (Ketanarkon 100, Streuli Pharma, Uznach, Switzerland), and maintained with 2–2.5 % isoflurane (Isoflo, Abbott, Baar, Switzerland) delivered in oxygen through an endotracheal tube. The goats were examined in sternal recumbency using a multidetector CT machine (Somatom Sensation Open, Siemens, Erlangen, Germany). Total scan time for the entire abdomen was 7 to 9 s. A detailed description can be found in the dissertation published by Irmer (2010). Transverse slices, 5 mm in thickness, were taken from the fifth thoracic vertebra to the sacrum using 120 kV and 270 mA. The images were reconstructed to a thickness of 1.5 mm using a soft-tissue algorithm. Multiplane reconstruction also allowed visualization of the structures in the sagittal and dorsal (horizontal) planes. The CT findings and measurements were analysed using an image processing and analysis program (OsiriX Open Source™ 3.2.1 Syngo CT 2007S, OsiriX Foundation, Geneva, Switzerland). Soft tissue structures were assessed in a soft tissue with a window width (W) of 400 Hounsfield Units (HU), and a window level (L) of 40 HU. The evaluation of the ruminal layering was carried out in an ingesta window (W 1500 HU/L 30 HU).

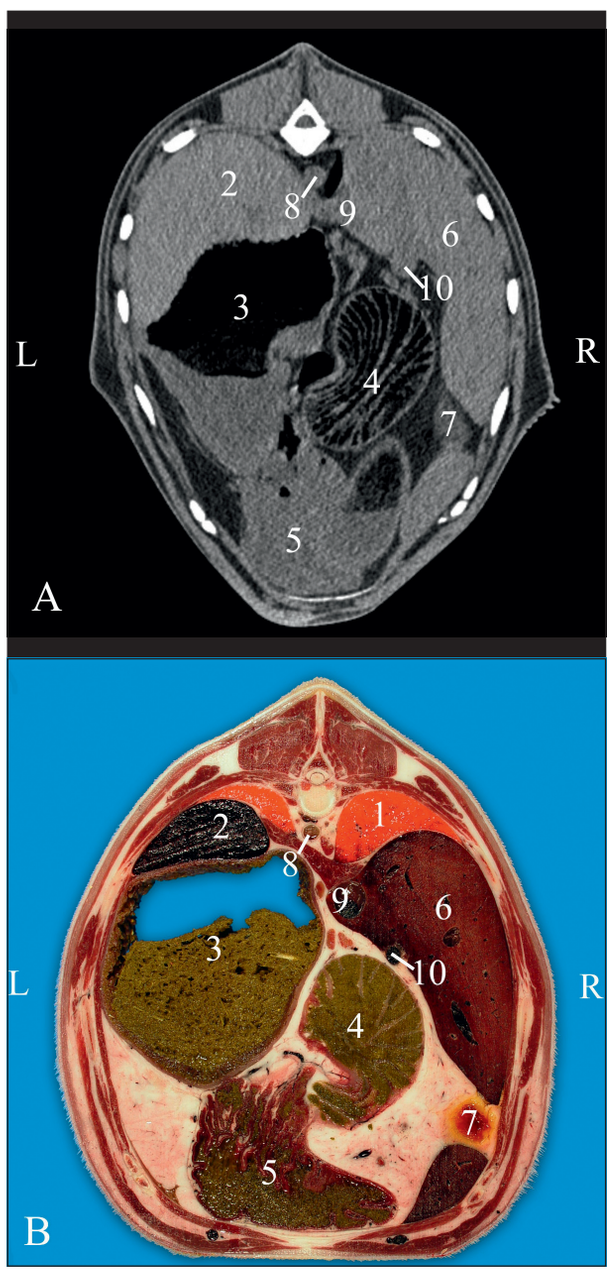

Figure 1: Comparison of the soft-tissue window (A) and transverse postmortem body section (B) at the level of the 11th thoracic vertebra in a Saanen goat. 1 Lungs, 2 Spleen, 3 Anterior blind sac of rumen, 4 Omasum, 5 Abomasum, 6 Liver, 7 Gall bladder, 8 Aorta, 9 Caudal vena cava, 10 Portal vein, L Left, R Right.

Measurements of organs

After subjective evaluation, the various structures were measured using a window that provided the best visualisation. The thickness of the reticular wall was determined on the medial side of the reticulum. The maximum craniocaudal dimension (length) of the rumen was determined in the sagittal plane. This was achieved by measuring the distance between the cranial and caudal apexes of the rumen. The maximum height and width of the rumen were determined in the transverse plane. The thickness of the wall of the dorsal and ventral blind sacs of the rumen was measured at the level of the left kidney. The layering of the ruminal contents was evaluated in the transverse plane at the maximum height of the rumen using an ingesta window. That location and width of window allowed optimal resolution and differentiation of gas, fluid and solid contents. The size of the omasum was determined in the plane that offered the best visualisation, and the thickness of its wall was measured on the greater curvature without inclusion of the omasal leaves.

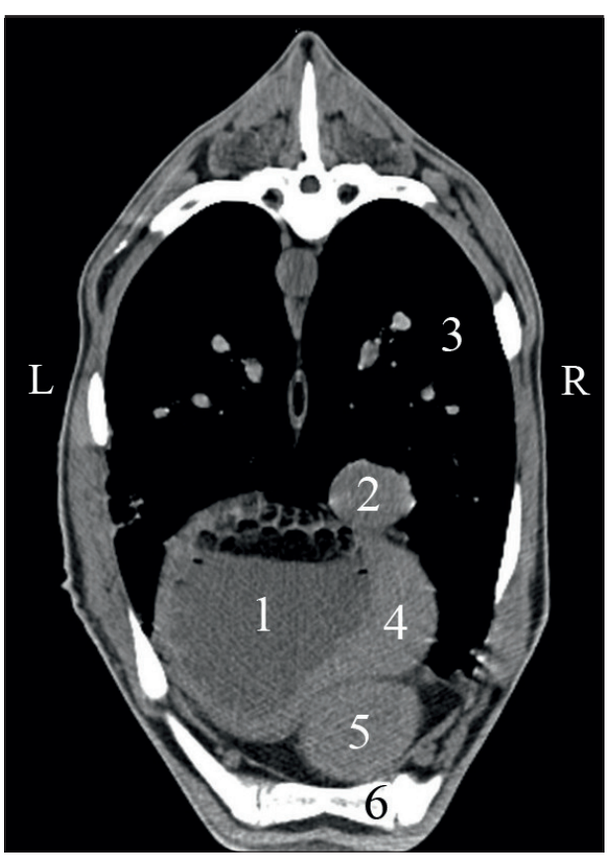

Figure 2: CT image of the reticulum in the transverse plane at the level of the 7th thoracic vertebra using a soft-tissue window in a Saanen goat. 1 Reticulum, 2 Caudal vena cava, 3 Lungs, 4 Left liver lobe, 5 Apex of heart, 6 Sternum, L Left, R Right.

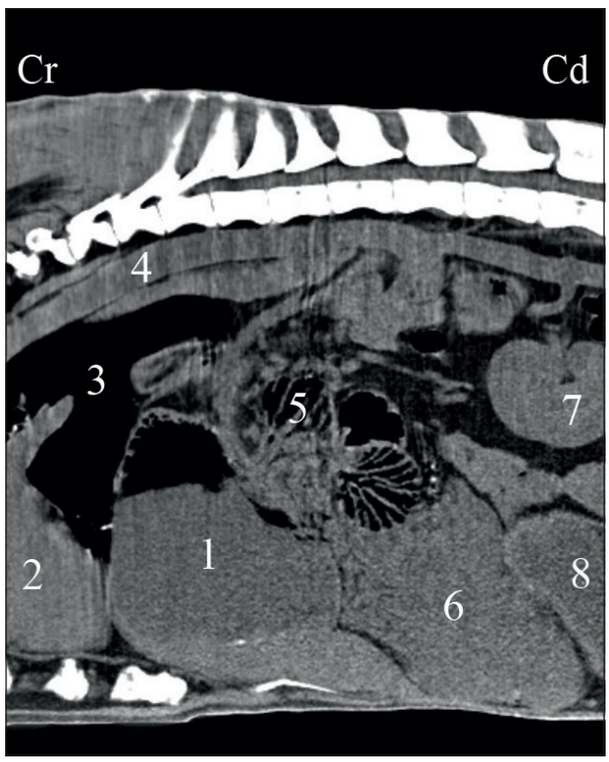

Figure 3: CT image of the reticulum in the sagittal plane in the region of the aorta using a soft-tissue window in a Saanen goat. 1 Reticulum, 2 Heart, 3 Lungs, 4 Aorta, 5 Omasum, 6 Abomasum, 7 Right kidney, 8 Ventral sac of the rumen, Cr Cranial, Cd Caudal.

Postmortem examination and anatomical slice preparation

The goats were either slaughtered (n = 15) or euthanised (n = 15) after the CT examination. The organs of the slaughtered animals were examined macroscopically. Anatomical slices in the transverse, sagittal and horizontal planes were obtained from the goats that were euthanised. The internal organs were examined on these sections. Those goats were placed in sternal recumbency, analogous to the position used for CT scanning, and stored at –18 °C for 3 to 10 days. Transverse slices, 1.0 to 1.5 cm thick, were obtained by cutting the goats along the longitudinal body axis with a band saw. One goat was cut in the median plane and also in a sagittal plane at the level of the caudal vena cava. One other goat was cut in two horizontal (dorsal) planes, one at the level of the presternum and one at the level of the trachea. The transverse slices were photographed from caudal, the horizontal slices from dorsal and the sagittal slices from the left using a digital camera. The slices were compared with the CT images to identify the various structures shown in the images. The labelling of the anatomical structures and the comparison of CT images and anatomical slices were carried out using the program Adobe Photoshop (Adobe Systems, Munich, Germany).

Table 1: CT measurements on reticulum, rumen and omasum in 30 Saanen goats.

Organ	Valuable	Mean ± sd	Range
Reticulum	Wall thickness (cm)	0.2 ± 0.03	0.2 – 0.3
Rumen	Length (cm)	47.1 ± 4.73	37.2 – 55.9
	Width (cm)	20.9 ± 5.96	11.3 – 35.5
	Height (cm)	25.5 ± 2.49	19.6 – 32.2
	Wall thickness of the dorsal blind sac (cm)	0.2 ± 0.04	0.2 – 0.3
	Wall thickness of the ventral blind sac (cm)	0.3 ± 0.06	0.2 – 0.4
	Height of dorsal gas cap (cm)	2.9 ± 2.58	0.0 – 8.9
	Height of middle fibre layer (cm)	15.9 ± 4.52	6.3 – 26.3
	Height of ventral fluid layer (cm)	6.7 ± 2.98	0.0 – 11.7
	Height of dorsal gas cap (%)	11.1 ± 9.4	0.0 – 33.6
	Height of middle fibre layer (%)	62.5 ± 17.4	25.5 – 93.7
	Height of ventral fluid layer (%)	25.9 ± 11.4	0.0 – 47.3
Omasum	Size (cm)	11.6 ± 1.37	8.7 – 14.4
	Wall thickness (cm)	0.2 ± 0.03	0.2 – 0.3

Statistical analysis

Frequencies, means and standard deviations of the measured variables were calculated using a software program (StatView 5.1, SAS Institute, Cary, USA).

Results

In all animals, the reticulum, rumen and omasum could be identified on all anatomic sections and the corresponding CT images (Fig. 1).

Reticulum

The reticulum and rumen could be seen between the fifth thoracic vertebra and the sacrum; both organs were consistently seen between the eighth thoracic vertebra and the fifth lumbar vertebra in all the goats. In the transverse plane, the reticulum appeared as a round structure and was almost completely filled with ingesta except for an area of gas in the dorsal aspect (Fig. 2). The reticular structure of the mucosa was seen in the gas-filled dorsal region of the reticulum. The mean thickness of the reticulum wall was 0.2 cm (Tab. 1). The reticulum bordered the lungs via the diaphragm (not visible) craniodorsally, the left lobe of the liver on the right and the apex of the heart cranioventrally. In the sagittal plane the reticulum and heart, separated by the diaphragm, were seen immediately adjacent to each other over a distance of a few centimetres (Fig. 3), and dorsal to this area of contact were the lungs. The reticulum was bordered caudally by the abomasum and caudodorsally by the omasum.

Rumen

Identification of the individual compartments of the rumen was straightforward in all the goats because of the landmarks provided by the ruminal grooves and pillars. The longitudinal groove of the rumen separated the dorsal and ventral sacs (Fig. 4) and the vertical grooves di-

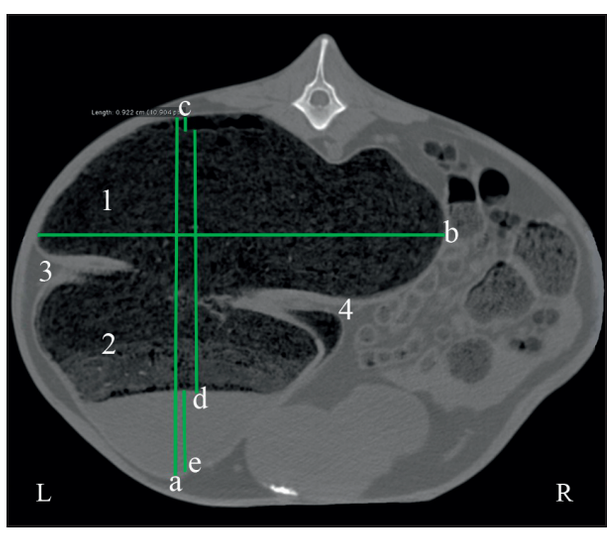

Figure 4: CT image of the rumen in the transverse plane at the level of the 3rd thoracic vertebra using an ingesta window in a Saanen goat. The green line shows the height (a) and width (b) of the rumen as well as the size of the gas cap (c), fibre layer (d) and fluid layer (e) of the contents of the rumen. 1 Dorsal sac of the rumen, 2 Ventral sac of the rumen, 3 Lateral longitudinal groove, 4 Medial longitudinal groove, L Left, R Right.

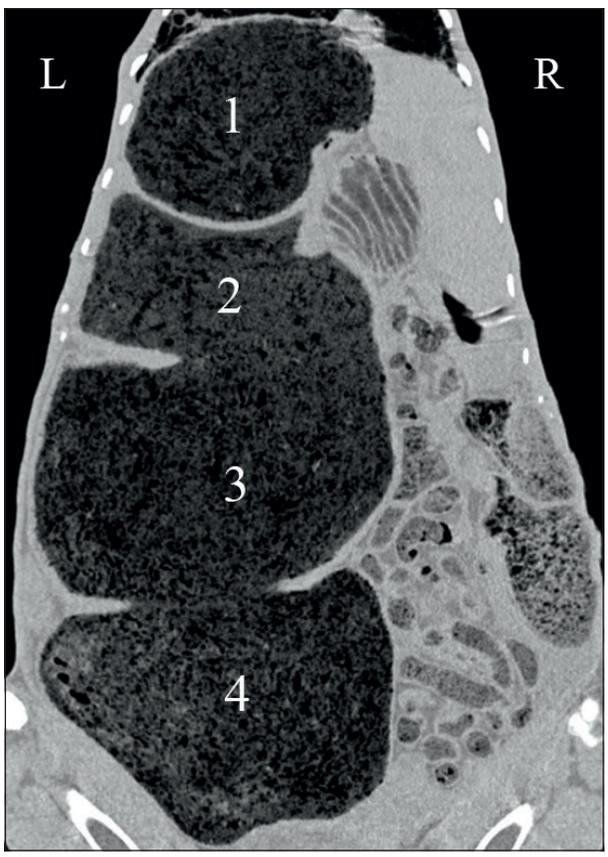

Figure 5: CT image of the rumen in the dorsal plane at the level of the omasum using an ingesta window in a Saanen goat. 1 Reticulum, 2 Anterior blind sac of the rumen, 3 Ventral sac of the rumen, 4 Posterior ventral blind sac of the rumen, L Left, R Right.

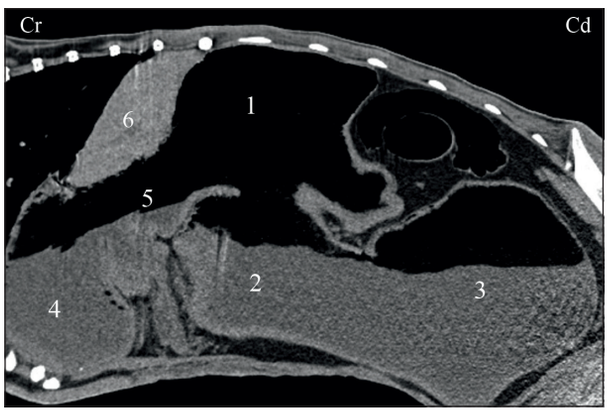

Figure 6: CT image of the rumen in the sagittal plane near the spleen in a Saanen goat. The reticulum and anterior blind sac and ventral sac of the rumen contain ingesta. 1 Dorsal sac of rumen, 2 Ventral sac of rumen, 3 Posterior ventral blind sac of rumen, 4 Reticulum, 5 Anterior sac of rumen, 6 Spleen, Cr Cranial, Cd Caudal.

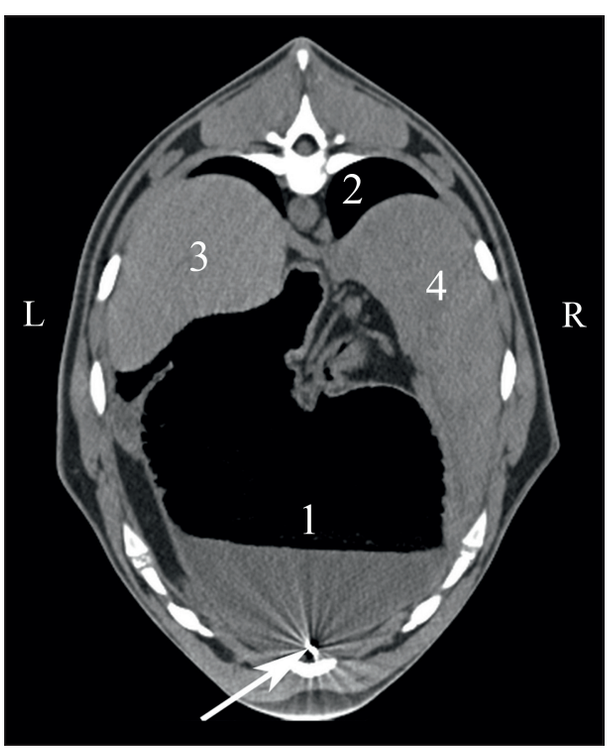

Figure 7: CT image of a metal foreign body (arrow) in the reticulum of a Saanen goat. The image was taken in the transverse plane at the level of the 9th thoracic vertebra. The radiodense lines radiating from the metal foreign body are called streaking artifact. 1 Reticulum, 2 Lungs, 3 Spleen, 4 Liver, L Left, R Right.

vided the anterior and the two posterior blind sacs from the remaining main part of the rumen (Fig. 5). The craniocaudal extent of the rumen was best evaluated in the sagittal plane (Fig. 6). In this plane, the transitions from the reticulum to the anterior blind sac and from there to the ventral ruminal sac were clearly visible. The mean length of the rumen from the cranial border of the reticulum to the end of the posterior blind sacs was 41.7 cm, the maximum width 20.9 cm and the height 25.5 cm (Tab. 1). The wall thickness of the dorsal blind sac of the rumen was 0.2 cm and that of the ventral blind sac 0.3 cm. The layering of the contents of the rumen was best seen using an ingesta window (Fig. 4). The dorsal gas cap was on average 2.9 cm in height, the middle fibre layer 15.9 cm and the ventral fluid layer 6.7 cm. The middle fibre layer was the largest and comprised on average 62.5 % of the dorsoventral dimension of the ruminal cavity, followed by the fluid layer that comprised 25.9 % and the gas cap that comprised 11.1 %. Metal foreign bodies were seen in the reticulum or in the anterior blind sac of the rumen in nine of 30 goats (Fig. 7).

Omasum

The omasum was seen between the 8th thoracic vertebra and the 1st lumbar vertebra, and was consistently seen at the level of the 10th and 11th thoracic vertebra in all the goats. Because of its unmistakable appearance,

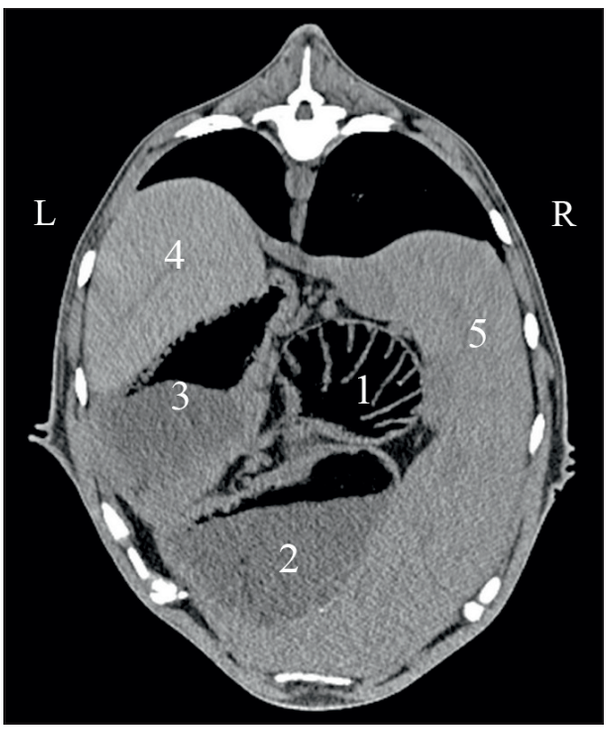

Figure 8: CT image of the omasum, using a soft-tissue window, in a Saanen goat. The image is in the transverse plane at the level of the 10th thoracic vertebra. 1 Omasum, 2 Reticulum, 3 Anterior blind sac of the rumen, 4 Spleen, 5 Liver, L Left, R Right.

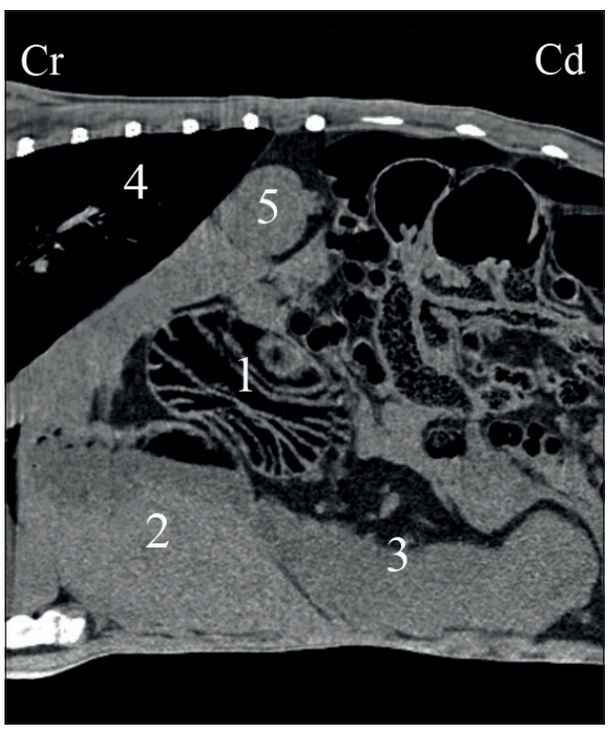

Figure 9: CT image of the omasum, using a soft-tissue window, in a Saanen goat. The image was taken in the sagittal plane at the level of the right kidney. 1 Omasum, 2 Reticulum, 3 Abomasum, 4 Lungs, 5 Right kidney, Cr Cranial, Cd Caudal.

the omasum was easily differentiated from the rest of the forestomachs. In transverse section, it had a spherical soccer-ball appearance (Fig. 8) and an elongated rugby-ball appearance in sagittal section (Fig. 9). The omasal leaves appeared as light grey septa, originating from the omasal wall and protruding into the lumen. The leaves varied in size and hypodense ingesta were seen between them. The omasum was located between the rumen and liver and rested in the *impressio omasica* of the latter (Fig. 8). The size of the omasum was best assessed in the sagittal and dorsal planes and was 11.6 cm on average (Tab. 1); the thickness of its wall was 0.2 cm.

Postmortem examination

Postmortem examination of the reticulum, rumen and omasum of the examined goats revealed no abnormal findings.

Discussion

The contours of the reticulum and rumen were clearly seen because of the contrast between the wall of these organs and the surrounding fat as well as the luminal contents, which consisted of gas, fluid and ingesta. The walls appeared hyperdense (light to moderate grey) relative to the fat and intestinal contents. This contrast was particularly prominent in the reticulum because of the honey-comb-like structure of its mucosa. The wall of the omasum and its leaves could also be easily differentiated from the luminal contents that were markedly hypodense (black) using the soft tissue window. The soft-tissue was not suitable for viewing the layering of the ruminal contents; the best images were obtained with a setting of W1500 HU/ L30 HU. Because of the positioning of the goats on the CT table, the abdomen including the rumen might have been somewhat distorted and therefore the measurements obtained for the layers of ruminal contents may not have corresponded exactly to the physiological situation. However, the thickness of the layers was also calculated as a percentage of the total height of the rumen, and the results were in agreement with published values (Bostedt and Dedié, 1996). The relative thickness of the layers can be affected by ruminal tympany, acidosis, atony or overload.

The various sections of the goats allowed the accurate identification of organ structures seen in the CT images. They provided the topographical relationship of the various organs to one another as well as structural differences. The sagittal sections were useful because they allowed longitudinal measurements.

The radiodense foreign bodies in the reticulum were seen as distinct entities in the ingesta. Diseases caused by ingested foreign bodies are uncommon in goats because of their selective eating habits. However, goats are curious creatures and may occasionally ingest a foreign body (Bostedt and Dedié, 1996; Navarre and Pugh, 2002). The metal foreign bodies and sediment in the reticulum of nine goats in the present study were not associated with clinical signs and were therefore assumed to be incidental findings.

References

See communication III.

Examen tomodensitométrique du bonnet, de la panse et du feuillet chez 30 chèvres de Gessenay

Dans le présent travail, on décrit les constatations tomodensitométriques faites sur le bonnet, la panse et le feuillet de 30 chèvres en bonne santé et leur comparaison avec l'examen post mortem. Les chèvres ont été examinées en position sternale dans un scanner multi coupes. L'examen a utilisé une exposition de 120 kV et de 270 mA en réalisant des coupes transversales d'une épaisseur de 1.5 mm de la 5e vertèbre thoracale jusqu'au sacrum. Les structures molles ont été examinées et mesurées dans une fenêtre spécifique (largeur [W] 400 Hounsfield Units [HU], Position [L] 40 HU) L'examen de la panse a été réalisé dans une fenêtre définie à cette intention appelée fenêtre d'ingesta. (W1500 HU/L 30HU). Après un examen subjectif, les différentes structures comme l'extension de la panse et du feuillet, l'épaisseur des parois du bonnet, de la panse et du feuillet ainsi que l'extension des phases gazeuses, liquides et solides de l'ingesta dans la panse ont été déterminés. Quinze chèvres ont été euthanasiées après l'examen tomodensitométrique et congelées pendant 3 à 10 jours à –18 °C en position sternale. Treize d'entre elles ont été ensuite sciées dans le plan transversal en tranches de 1 à 1.5 cm d'épaisseur. Les deux dernières chèvres ont été sciées dans le plan dorsal respectivement sagittal. Les coupes ont été comparées aux images tomodensitométriques correspondant à leur localisation afin d'identifier les structures représentées sur l'image.

Esame tomografico computerizzato (CT) di reticolo, rumine e omaso in 30 capre Saanen

In questo studio vengono descritti i risultati dell'esame CT di reticolo, rumine e omaso in 30 capre sane e vengono paragonati i risultati delle analisi post mortem. Le capre sono state esaminate in posizione sternale con un CT a più strati. L'esame è stato condotto con un'esposizione di 12 kV e 270 mA in sezioni trasversali della quinta vertebra toracica fino al sacro con uno spessore di 1.5 mm. Le strutture dei tessuti molli sono state definite e valutate in una finestra per parti molli (larghezza [W] 400 Hounsfield Units [HU], posizione [L] 40 HU). La valutazione della stratificazione del rumine è stata definita in una finestra speciale, la cosiddetta «finestra ingesta» (W 1500 HU/L 30 HU). In seguito alla valutazione soggettiva sono state definite varie strutture come la dilatazione del rumine e dell'omaso, lo spessore della parete del reticolo, del rumine e dell'omaso, infine la dilatazione della fase ingesta gassosa, liquida e solida del rumine. Alla fine dell'esame CT, 15 capre sono state soppresse e congelate per un periodo di 3 fino a 10 giorni, a –18 °C in posizione sternale. Dopo di ciò, 13 sono state segate trasversalmente a strati spessi tra gli 1.0 e i 1.5 cm. Un'altra capra è state segata in posizione dorsale e sagittale. Le sezioni sono state confrontate alle immagini CT della posizione corrispondente alfine di individuare le strutture raffigurate.

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