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Computed tomography of the abdomen in Saanen goats: II. Liver, spleen, abomasum, and intestine

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Summary

This study describes the results of computed tomography (CT) of the liver, spleen, abomasum, small intestine and large intestine in 30 healthy Saanen goats. CT examination and anatomical slice preparation postmortem were performed as described in the first communication. After subjective evaluation of the CT images, various variables including the length/size, volume and density of the liver, spleen and gallbladder, the wall thickness of the abomasum, small intestine and large intestine and the diameter of the intestine were measured. The liver, spleen, abomasum, small intestine and large intestine could be accurately visualised using CT.

Keywords: computed tomography, goats, liver, spleen, abomasum, small intestine, large intestine

Computertomographische Untersuchung von Leber, Milz, Labmagen und Darm bei Saanenziegen

In der vorliegenden Arbeit werden die computertomographischen Befunde an Leber, Milz, Labmagen und Darm von 30 gesunden Ziegen beschrieben. Die CT-Untersuchung und die post mortem durchgeführte anatomische Schnittpräparation erfolgten wie in der ersten Mitteilung beschrieben. Im Anschluss an die subjektive Beurteilung der CT-Bilder wurden verschiedene Parameter, wie die Ausdehnung, das Volumen und die Dichte von Leber, Gallenblase und Milz bestimmt sowie die Wanddicke von Labmagen, Dünn- und Dickdarm und die Durchmesser dieser Därme gemessen. Die Untersuchungen zeigten, dass Leber, Milz, Labmagen, Dünn- und Dickdarm computertomographisch exakt dargestellt werden können. Die Topographie der CT-Bilder und der anatomischen Schnittpräparate stimmten sehr gut überein.

Schlüsselwörter: Computertomographie, Ziege, Leber, Milz, Labmagen, Dünndarm, Dickdarm

Introduction

The goal of the present paper was to describe the CT appearance of the normal liver, abomasum, intestines and spleen in 30 healthy Saanen goats and to compare the CT images to postmortem findings.

Animals, Material and Methods

See communication I.

Measurement of organs

The evaluation of the liver and gallbladder was carried out in 25 of the 30 goats. Five goats had livers with abnormal ultrasonographic or postmortem findings and were excluded from further analysis. The craniocaudal length of the liver was determined in the sagittal plane. This was achieved by first determining the sagittal plane in which the liver appeared furthest cranially. Then the plane in which the liver appeared furthest caudally was determined, and the distance in the sagittal plane between the cranial and caudal

border of the liver was termed the craniocaudal length of the liver. The liver volume was determined in the transverse plane. First, the surface area of the liver was marked on every third transverse slice and measured electronically, and then the volume was calculated electronically (OsiriX Open Source™ 3.2.1. Syngo CT 2007S, OsiriX Foundation, Geneva, Switzerland). The liver volume was related to body weight and expressed as cm^3 per kg body weight. The density of the liver parenchyma was expressed as Hounsfield units (HU) and determined in the transverse plane at the level of the 10th thoracic vertebra, excluding the hypodense hepatic vessels. The parenchymal density was determined in a 20-cm^2 area at the centre of the liver and then in a 1-cm^2 area at the periphery. The length and width of the gallbladder were measured in the plane where the gallbladder appeared the largest. The density of the gallbladder content was expressed in HU and determined in 1-cm^2 areas in the dorsal and ventral thirds of the gallbladder, a minimum of 5 mm from the wall.

Measurements of the spleen were carried out as described for the liver. The dorsoventral length, volume (using the surface area determined from the transverse slices) and density of the spleen at its centre and periphery were determined.

The thickness of the wall of the spiral colon and caecum adjacent to intraluminal gas, as well as the abomasal wall at the level of the omasum, was determined. The diameters of the jejunum and spiral colon were measured at three different locations and the largest diameter of the caecum was recorded.

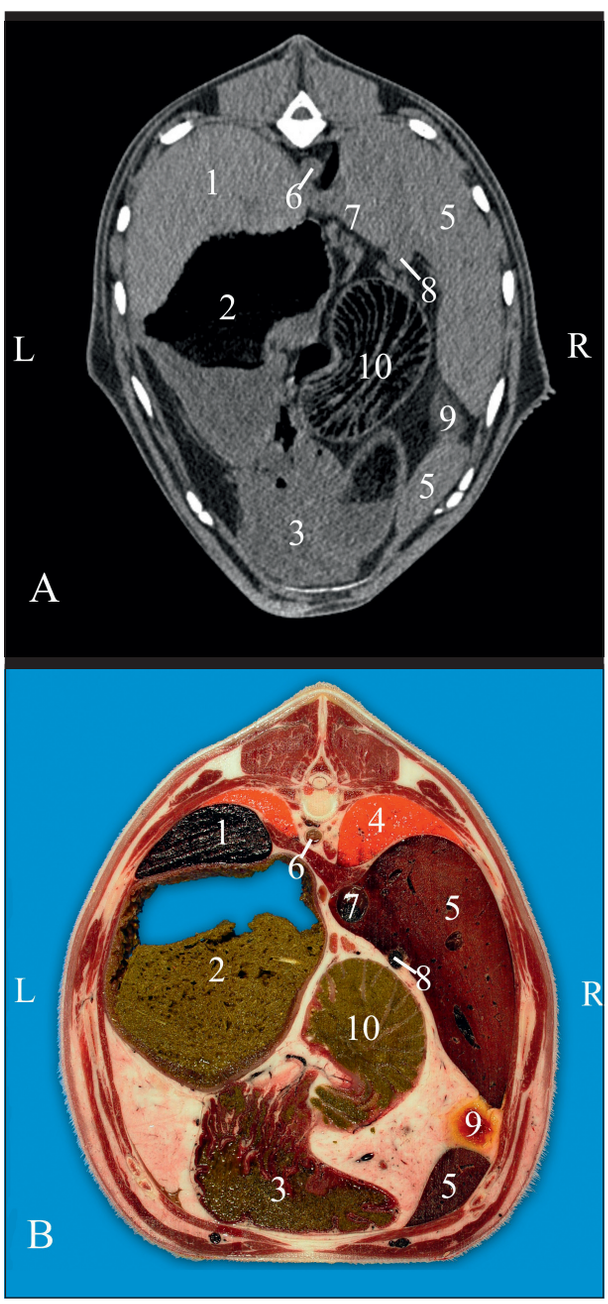

Figure 1: Comparison of the soft tissue window (A) and anatomical slice (B) at the level of the 11th thoracic vertebra in a Saanen goat. 1 Spleen, 2 Cranial dorsal blind sac of the rumen, 3 Abomasum, 4 Lungs, 5 Liver, 6 Aorta, 7 Caudal vena cava, 8 Portal vein, 9 Gallbladder, 10 Omasum, L Left, R Right.

Results

In all animals, the liver, spleen, abomasum and intestine could be identified on all anatomic sections and the corresponding CT images (Fig. 1).

Figure 2: CT image of the liver, spleen, reticulum and omasum in the transverse plane at the level of the 11th thoracic vertebra in a Saanen goat. 1 Liver, 2 Spleen, 3 Cranial dorsal blind sac of the rumen, 4 Reticulum, 5 Omasum, 6 Lungs, L Left, R Right.

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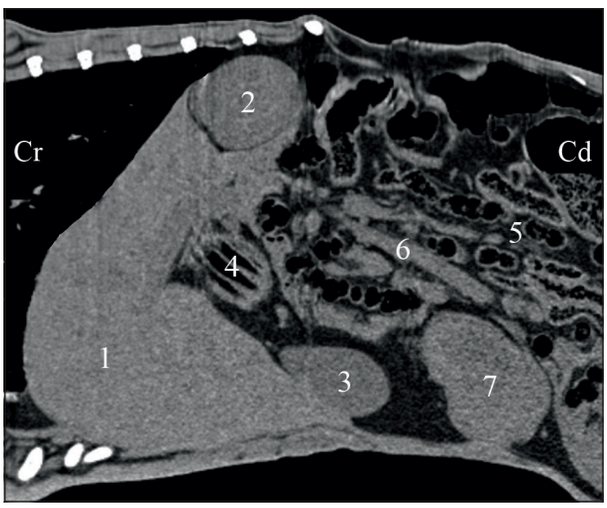

Figure 3: CT image of the liver, gallbladder, right kidney, abomasum, omasum and intestinal tract in the sagittal plane at the level of the right kidney in a Saanen goat. 1 Liver, 2 Right kidney, 3 Gallbladder, 4 Omasum, 5 Intestinal tract, 6 Portal vein, 7 Abomasum, Cr Cranial, Cd Caudal.

Liver and gallbladder

The liver was visualised from the 5th thoracic to the 1st lumbar vertebra, and was seen between the 9th and 12th thoracic vertebra in all the goats (Fig. 2–4). It was located immediately adjacent to the right abdominal wall and extended from the diaphragm next to the lungs to the sternum. Medially the reticulum was located adjacent to the liver from the 6th to 9th intercostal spaces, and the omasum, rumen and abomasum further caudally. In the sagittal plane, the right kidney was seen embedded in the renal impression of the liver. Medial to the liver, the caudal vena cava was seen dorsally, and, more ventral, the portal vein. The hepatic blood vessels appeared as hypodense bands.

The mean craniocaudal length of the liver was 20.4 cm and the mean liver volume 1280.9 cm^3, which was 21.5 cm^3/kg body weight. The mean density of the liver parenchyma at the periphery was 60.6 HU and was significantly greater than that at the centre (51.7 HU, $P < 0.01$). The gallbladder could be visualised in 24 of 25 goats, but was not seen in any of the three planes in one animal. It was most readily seen in the transverse plane and appeared as a round to pear-shaped structure extending beyond the ventral edge of the liver (Fig. 1, 3). The mean length of the gallbladder was 6.9 cm and its width 3.4 cm. The mean density of the gallbladder content was 17.2 HU dorsally and 28.3 HU ventrally, which was a significant difference ($P < 0.01$). Sediment was not seen in the gallbladder of any of the goats.

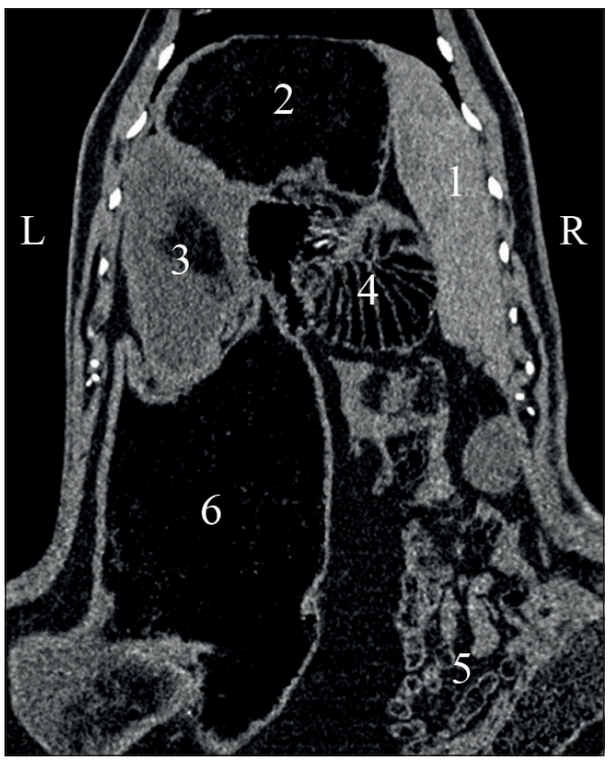

Figure 4: CT image of the liver, reticulum, abomasum and intestine in the dorsal plane at the level of the abomasum in a Saanen goat. 1 Liver, 2 Reticulum, 3 Abomasum, 4 Omasum, 5 Intestinal tract, 6 Rumen, L Left, R Right.

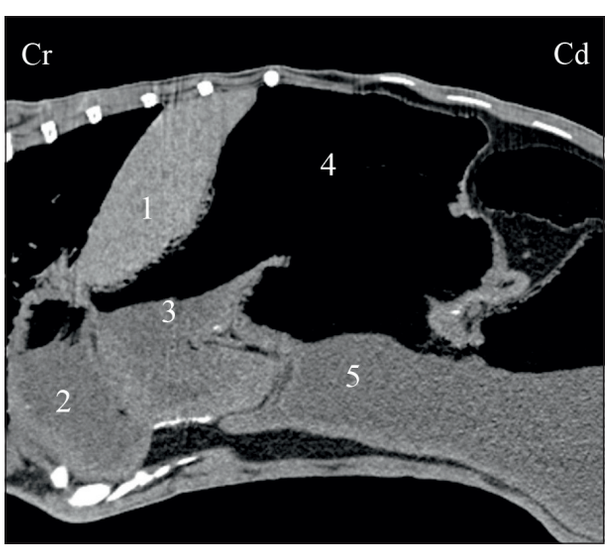

Figure 5: CT image of the spleen, reticulum, rumen and its anterior dorsal blind sac in the sagittal plane at the level of the left lung in a Saanen goat. 1 Spleen, 2 Reticulum, 3 Anterior dorsal blind sac of the rumen, 4 Dorsal sac of the rumen, 5 Ventral sac of the rumen, Cr Cranial, Cd Caudal.

Spleen

The spleen was visualised from the 8th thoracic to the 2nd lumbar vertebra, and was seen between the 10th and 13th thoracic vertebra in all the goats. In the transverse plane, the spleen appeared triangular with rounded borders, resting against the costal part of the abdominal wall dorsally. The dorsal sac of the rumen or its anterior blind

sac was located medial to the spleen (Fig. 2). In the sagittal and dorsal planes, the spleen appeared as a round to trapezoid-shaped structure between the diaphragm and rumen, and was easily differentiated from the surrounding organs (Fig. 5–6). The maximum dorsoventral size of the spleen was 7.2 cm and the volume 613.5 cm³, which was 9.9 cm³ per kg body weight. The density of the splenic parenchyma was 70.7 HU at the periphery, which was significantly greater ($P < 0.01$) than that at the centre (62.4 HU).

Abomasum

The abomasum was seen from the 8th thoracic to the 5th lumbar vertebra, and was observed between the 10th and 13th thoracic vertebra in all the goats (Fig. 4, 7–8). The cranial part of the abomasum was seen as a sac-like structure lying on the ventral abdominal wall between the reticulum and rumen. Caudoventrally and towards the liver, the abomasum narrowed before it ascended toward the pylorus, which transformed into the duodenum at the level of the gallbladder. The mucosal folds were vague and difficult to differentiate from the liquid ingesta. The abomasal wall was 0.2 to 0.3 cm thick. An accumulation of hyperdense material consisting of sand and small stones was seen in the abomasum of 29 goats (Fig. 9).

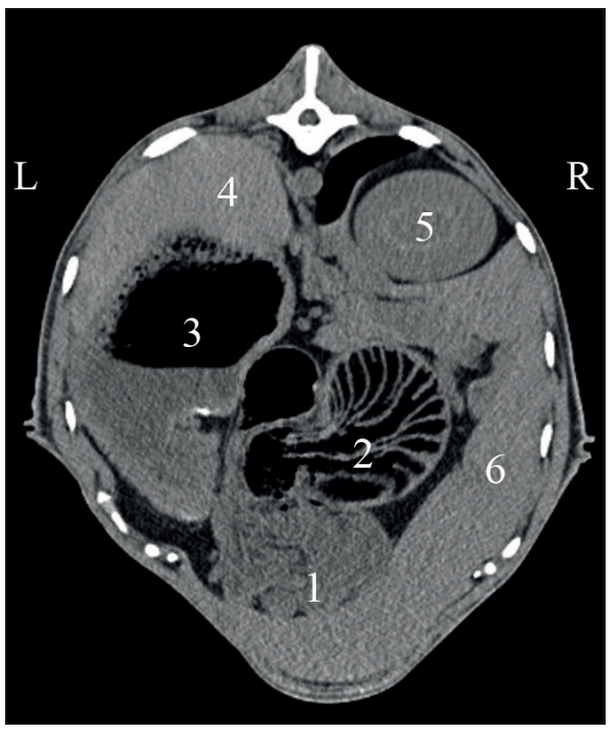

Figure 7: CT image of the abomasum, omasum, anterior dorsal blind sac of the rumen, spleen, right kidney and liver in the transverse plane at the level of the 12th thoracic vertebra in a Saanen goat. 1 Abomasum, 2 Omasum, 3 Anterior dorsal blind sac of the rumen, 4 Spleen, 5 Right kidney, 6 Liver, L Left, R Right.

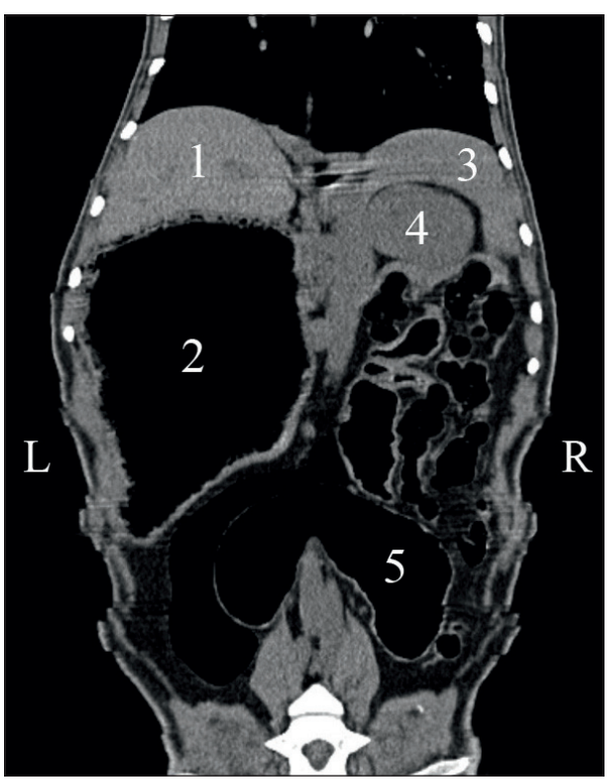

Figure 6: CT image of the spleen, rumen, liver, right kidney and large intestine in the dorsal plane at the level of the right kidney in a Saanen goat. 1 Spleen, 2 Dorsal sac of the rumen, 3 Liver, 4 Right kidney, 5 Large intestine, L Left, R Right.

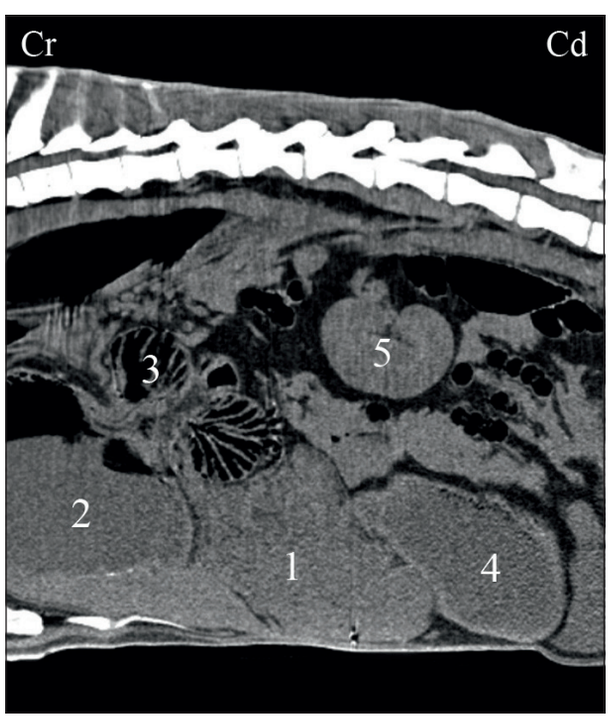

Figure 8: CT image of the abomasum, reticulum, omasum, rumen and left kidney in the sagittal plane at the level of the left kidney in a Saanen goat. 1 Abomasum, 2 Reticulum, 3 Omasum, 4 Ventral sac of the rumen, 5 Left kidney, Cr Cranial, Cd Caudal.

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Intestine

Simultaneous viewing of images taken in all three planes was required to follow the course of the intestine. Differentiation of small and large intestine was straightforward. The contents of the small intestine were liquid and homogenous and isodense relative to the intestinal wall, whereas the large intestine contained gas (black), which allowed differentiation of the intestinal wall. The wall of the small intestine could be differentiated from the luminal contents only at the cranial part of the duodenum.
The small intestine was located in the caudoventral region of the abdomen, adjacent to the ventral and dorsal sacs of the rumen and the right lateral abdominal wall (Fig. 10–11). In several goats, the cranial part of the duodenum with its sigmoid flexure could be seen next to the caudal border of the liver. The duodenum, jejunum and ileum could not be clearly differentiated. The small intestine had a mean diameter of 1.2 cm. The loops of the spiral colon were located dorsal to or between loops of the jejunum (Fig. 10–12). Parts of the proximal loop of the ascending colon were seen dorsally on the right. The caecum was easily identified caudodorsally. However, the remainder of the intestine could be differentiated in only a few cases. The mean diameter of the loops of the spiral colon was 1.4 cm, and the thickness of the wall varied from 0.1 to 0.3 cm. The mean diameter of the caecum was 6.1 cm, and the thickness of the caecal wall varied from 0.2 to 0.5 cm.

Figure 9: CT image of sediment and stones (arrow) in the abomasum of a Saanen goat. The image was taken in the transverse plane at the level of the 2nd lumbar vertebra. 1 Abomasum, 2 Rumen, 3 Large intestine, L Left, R Right.

Table 1: CT measurements on liver, gallbladder, spleen, abomasum and intestine in 30 Saanen goats.

Organ	Valuable	Mean ± sd	Range
Liver	Length (cm)	20.4 ± 2.03	16.9 – 24.6
	Volume (cm³)	1280.9 ± 206.19	966.7 – 1732.3
	Volume/kg body weight (cm³)	21.5 ± 4.03	15.2 – 30.5
	Density of the parenchyma at the periphery (HU)	60.6 ± 7.92	47.2 – 76.5
	Density of the parenchyma at the centre (HU)	51.7 ± 7.3	38.1 – 65.5
Gallbladder	Length (cm)	6.9 ± 1.23	3.9 – 9.3
	Width (cm)	3.4 ± 0.61	2.1 – 4.4
	Density of gallbladder content dorsally (HU)	17.2 ± 6.95	2.2 – 35.8
	Density of gallbladder content ventrally (HU)	28.3 ± 7.3	10.5 – 46.1
Spleen	Dorsoventral size (cm)	7.2 ± 1.14	5.5 – 10.2
	Volume (cm³)	613.5 ± 285.19	221.9 – 1448.2
	Volume/kg body weight (cm³)	9.9 ± 4.06	5.1 – 13.4
	Density of the parenchyma at the periphery (HU)	70.7 ± 8.54	49.7 – 81.5
	Density of the parenchyma at the centre (HU)	62.4 ± 9.46	32.4 – 77.8
Abomasum	Wall thickness (cm)	0.2 ± 0.04	0.2 – 0.3
Intestine	Diameter of the loops of the small intestine (cm)	1.2 ± 0.19	0.8 – 1.8
	Diameter of the loops of the spiral colon (cm)	1.4 ± 0.23	1.1 – 2.0
	Wall thickness of the spiral colon (cm)	0.2 ± 0.04	0.1 – 0.3
	Diameter of the caecum (cm)	6.1 ± 1.25	3.9 – 9.2
	Wall thickness of the caecum (cm)	0.3 ± 0.08	0.2 – 0.5

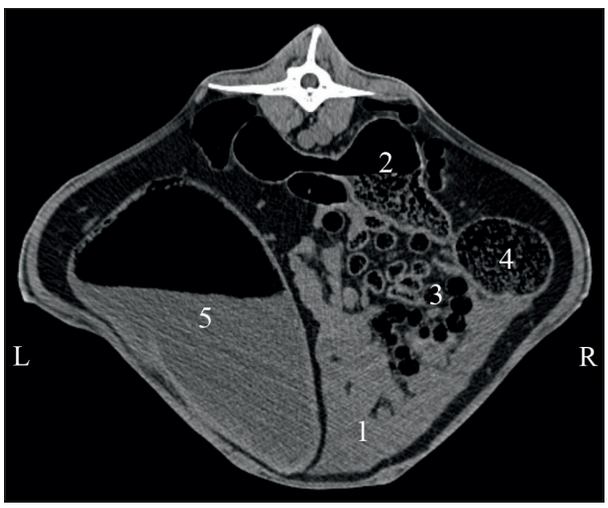

Figure 10: CT image of the small and large intestine in the transverse plane at the level of the 13th thoracic vertebra in a Saanen goat. 1 Jejunum, 2 Proximal loop of ascending colon, 3 Spiral loop of colon, 4 Caecum, 5 Ventral blind sac of the rumen, L Left, R Right.

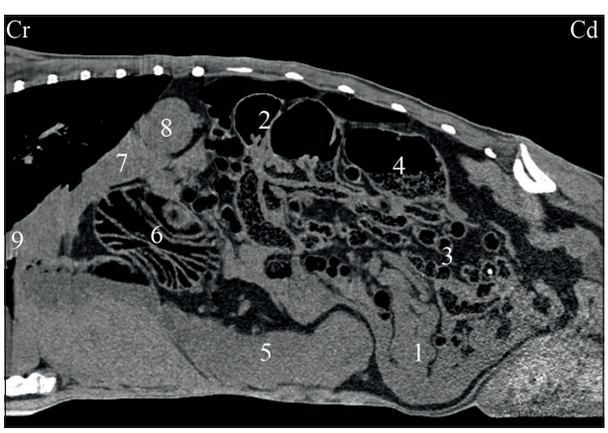

Figure 11: CT image of the small and large intestine in the sagittal plane at the level of the caudal vena cava in a Saanen goat. 1 Jejunum, 2 Proximal loop of ascending colon, 3 Spiral loop of colon, 4 Caecum, 5 Abomasum, 6 Omasum, 7 Liver, 8 Right kidney, 9 Caudal vena cava, Cr Cranial, Cd Caudal.

Discussion

Together with the rumen and spleen, the liver occupied a major part of the cranial abdomen. The mean volume of the liver was 1280.9 cm³, which is larger than that of sheep at 912 cm³ (Kayaalp et al., 2002). CT was also assumed to be the most accurate reference method of determining liver volume in sheep, and probably in goats as well. However, the liver volume varied widely among individual goats, similar to results in dogs (Stieger et al., 2007); this finding led to the liver volume being expressed in relation to body weight in the latter (Stieger et al., 2007). The liver volume in goats was 21.5 ± 4.03 cm³ per kg body weight, which was similar to the reported 24 ± 5.6 cm³ per kg body weight in dogs. Liver volume has been used to characterise dogs with portosystemic shunts, in which the liver was approximately 40 per cent smaller than in healthy dogs (Stieger et al., 2007). Recently, portosystemic shunt was proposed in two goat kits, presented for periodic neurologic deficits, seizures and a general loss of body condition (Wilkerson et al., 2008). Further studies in goats with liver disease are needed to determine the clinical significance of measuring CT-based liver volume in this species. The density of the liver parenchyma at the centre of the organ ranged from 38.1 to 65.5 HU in healthy goats, which is comparable to that in human liver (45 to 65 HU) (Mortele et al., 2002).

The gallbladder could be easily differentiated from the liver based on its shape, location caudoventral to the liver and liquid homogeneous contents. The large variation in the size of the gallbladder was attributable to its function as a storage organ for bile. Moreover, in cases with cholestasis, the gallbladder enlarges beyound the normal range. The increased density of the gallbladder contents ventrally was due to sedimentation of sludge. In herbivores, such as cattle, goats and sheep, sludge is infrequently seen by ultrasonography.

The spleen appeared grey on CT images similar as the liver. It was a prominent organ in the cranial abdomen and was located dorsolateral to the rumen. The measurements of the spleen, especially the thickness and volume, varied greatly among the goats. The size of the spleen as a blood storage and immunological organ depends on a number of factors, including stress, age, the administration of drugs and anaesthetics. The variable

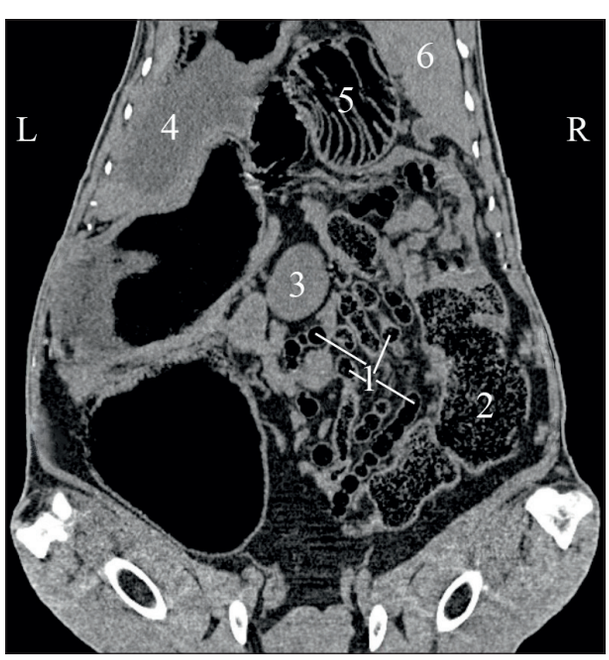

Figure 12: CT image of the large intestine in the dorsal plane at the level of the left kidney in a Saanen goat. 1 Spiral loop of colon, 2 Caecum, 3 Left kidney, 4 Abomasum, 5 Omasum, 6 Liver, L Left, R Right.

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size was considered normal. In dogs, measurements that exceed the reference range are indicative of splenomegaly particularly when accompanied by swollen and rounded edges (Thrall, 2007). In goats, splenomegaly occurs e. g. in acute septic processes with bacteraemia and toxaemia, in lymphoma, in congestive heart disease and in trypanosomiasis (Dargantes et al., 2005; Valli, 2007).
There was little contrast between the abomasum and surrounding structures, especially where it contacted the ventral abdominal wall. The abomasal mucosal folds also appeared vague because of the liquid nature of the luminal contents. However, hyperdense abomasal foreign bodies were easily differentiated from the surrounding ingesta. There was little to no contrast between the contents and wall of the small intestine, making them impossible to differentiate. The differentiation of the wall and contents of the large intestine, on the other hand, was relatively easy because of gas in the intestinal lumen. Overall the thickness of the wall of the forestomachs and intestine was rather uniform, in agreement with findings in dogs and cats (Penninck, 2002).

References

See communication III.

Examen tomodensitométrique du foie, de la rate, de la caillette et de l'intestin chez 30 chèvres de Gessenay

Dans le présent travail, on décrit les constatations tomodensitométriques faites sur le foie, la caillette et l'intestin de 30 chèvres en bonne santé. L'examen tomodensitométrique et la préparation de coupe anatomique post mortem ont été réalisés comme décrit dans une première présentation (Braun et al., 2010). Après l'examen subjectif des images tomodensitométriques, divers paramètres, comme l'extension, le volume et la densité du foie, de la vésicule biliaire et de la rate ont été déterminés; l'épaisseur de la paroi de la caillette, de l'intestin grêle et du gros intestin ainsi que le diamètre de ces intestins a été mesuré. Les examens montrent que le foie, la rate, la caillette, l'intestin grêle et le gros intestin se laissent représenter exactement par tomodensitométrie. La topographie des images tomodensitométriques et les coupes anatomiques présentent une très bonne congruence.

Esame tomografico computerizzato (CT) di fegato, milza, abomaso e intestino in 30 capre Saanen

In questo studio vengono descritti i risultati dell'esame CT di fegato, milza, abomaso e intestino in 30 capre sane. Come descritto nella precedente informazione (Braun et al. 2010) sono stati effettuati esami CT e post mortem seguiti da preparati istologici anatomici. In seguito alla valutazione soggettiva delle immagini CT sono stati calcolati vari parametri quali dilatazione, volume e spessore del fegato, cistifellea e milza e lo spessore delle pareti dell'abomaso, dell'intestino tenue e crasso e il loro diametro. Gli esami hanno mostrato che fegato, milza, abomaso, intestino tenue e crasso si possono rappresentare con precisione grazie al CT. La topografia delle immagini CT e gli esami istologici coincidevano molto bene.

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