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Ultrasonographic examination of the small intestine, large intestine and greater omentum in 30 Saanen goats

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ABSTRACT

The small and large intestine of 30 healthy Saanen goats were examined ultrasonographically using a 5.0 MHz-linear transducer. The goats were examined on the right side, from the eighth rib to the caudal aspect of the flank. The small and large intestine could be easily differentiated. The descending duodenum could be imaged in 19 goats, and the jejunum and ileum seen in all goats. The jejunum and ileum were most often seen in cross-section and rarely in longitudinal section in the ventral region of the right flank. The intestinal contents were usually homogenously echoic, and active motility was observed in all the goats. The diameter of the small intestine was 0.8–2.7 cm (1.6 [0.33] cm). The spiral ansa of the colon was imaged in all the goats, and in 21 the caecum was also seen. Both these sections of large intestine were most commonly seen in the dorsal region of the right flank. The spiral ansa of the colon was easily identified by its spiral arrangement of centripetal and centrifugal gyri, which had a garland-like appearance. Because of intraluminal gas, only the wall of the colon closest to the transducer could be imaged. The diameter of the spiral colon ranged from 0.8 to 2.0 cm (1.1 [0.24] cm). Usually only the wall of the caecum closest to the transducer could be imaged and it appeared as a thick, echoic, slightly undulating line. The greater omentum could be seen in all the goats.

Introduction

In cattle, ultrasonographic examination of the small intestine (Marmier, 1993; Braun and Marmier, 1995) and large intestine (Amrein-Schneider, 1999; Braun and Amrein, 2001) has been described in healthy cows and in cows with ileus of the duodenum, ileum and jejunum (Braun et al., 1995, 2010; Braun, 2003, 2005; Nuss et al., 2006; Streeter and Step, 2007; Lejeune and Lorenz, 2008) and caecal dilatation (Braun et al., 2002). Evaluation of the contents of the small intestine in cattle is usually straightforward. Because there is generally no gas, the intestinal wall closest to the transducer as well as the intestinal contents and the wall furthest from the transducer can be visualised. The different parts of the small intestine can be clearly differentiated. The cranial part of the duodenum is easily identified because it starts at the abomasum and is in close contact with the liver and gallbladder. The descending duodenum can almost always be imaged and is identified as a horizontal structure running caudally between the two serosal layers of the greater omentum immediately adjacent to the abdominal wall. The jejunum and ileum cannot be differentiated ultrasonographically and represent the longest part of the small intestine. In most healthy cows, using a 3.5 MHz-linear transducer with a penetration depth of 17 cm, more than 10 loops of small intestine are seen, usually in cross-section but sometimes in longitudinal section, in the flank and 9th–12th intercostal spaces.

Intraluminal gas is usually a differentiating feature of the large intestine (Amrein-Schneider, 1999; Braun and Amrein, 2001). Because of the gas, often only the wall of the large intestine closest to the transducer can be imaged and it appears as a thick echoic line. Parts of the proximal ansa, caecum and spiral ansa of the colon can usually be seen. The proximal ansa and caecum appear as a thick echoic continuous and slightly curved line. The spiral ansa of the colon looks like an echoic garland because of the concentric arrangement of the loops of intestine. To the authors' knowledge, there is no information on the ultrasonographic appearance of the intestinal tract in goats. Reasons for this most likely are economic; the value of individual goats is generally low and ultrasound equipment is expensive. However, because ultrasound machines are widely available in general veterinary practice, and because owners of sick pet goats or expensive show animals are often willing to pay for an extensive diagnostic work-up, it is expected that the use of ultrasonography in goats, as in other small ruminants, will become more widespread. Ileus and caecal dilatation attributable to various causes occur frequently in cattle and to a lesser extent in goats. Transrectal palpation can be used to detect dilated loops of intestine or a dilated caecum in many bovine

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patients but this is not possible in goats for anatomical reasons. Instead, a tentative diagnosis of ileus or caecal dilatation may be based on the absence of faeces in the rectum or the presence of blood, mucus or fibrin in the faeces. Failure to diagnose either of these conditions may result in conservative rather than surgical treatment, which results in prolongation of the disorder and perhaps irreparable lesions. Abdominal ultrasonography appears to be a promising tool for rapid diagnosis of ileus or caecal dilatation in goats. However, diagnosis of these conditions requires a thorough knowledge of the ultrasonographic appearance of the normal large and small intestines in goats. Thus, the goal of the present study was to document the ultrasonographic findings of the small and large intestines in 30 healthy Saanen goats.

Materials and methods

The study was approved by an ethical committee of the canton of Zurich, Switzerland.

Animals

Thirty, clinically healthy, non-lactating, female, Saanen goats, which were 2.0–6.5 year (mean [sd] 4.9 [1.10] years) old and weighed 42–86 kg (61.8 [9.95] kg), were used. The goats were not pregnant. 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 a thorough clinical examination, a complete blood cell count, biochemical profile, urinalysis, and examination of rumen juice and faeces. The results of these examinations have been described in detail (Becker-Birck, 2009).

Ultrasonographic examination of the small intestine and large intestine

A real-time ultrasound machine (EUB 8500, Hitachi Medical Systems) with a 5.0 MHz-linear transducer with a penetration depth of 9 cm (EUP-L53 Linear) was used to examine the standing, non-sedated goats. The right side of each goat, from the dorsal midline of the back to the linea alba and from the eighth rib to the caudal aspect of the flank, was clipped. The 8th–12th intercostal spaces were examined from dorsal to ventral with the transducer held parallel to the ribs. The right flank was examined from dorsal to the linea alba with the transducer held perpendicular to the longitudinal axis of the body. For optimal localisation of the various parts of the intestine, the flank was divided into four quadrants using a vertical line at the level of the fifth lumbar vertebra and a horizontal line at the level of the patella (Fig. 1a).

Small intestine

Ultrasonographic evaluation of the small intestine was carried out as described for cattle (Marmier, 1993; Braun and Marmier, 1995; Braun, 2003) and goats (Steininger, 2009). The appearance, contents and intestinal motility were subjectively assessed. The diameter and the thickness of the intestinal wall were determined using the in-built cursor system once the image was frozen. Visualisation of the cranial, descending and ascending parts of the duodenum was then attempted (Fig. 1b). The jejunum and ileum were evaluated in the 9th–12th intercostal spaces on the right flank. No attempt was made to differentiate between the jejunum and the ileum, as such a differentiation is not possible in cattle (Braun and Marmier, 1995; Braun, 2003). The intercostal space and abdominal quadrant in which loops of intestine could be visualised were determined. Then at each location, the number of loops seen in cross and longitudinal section, the intestinal diameter and the appearance of the intestinal contents were recorded.

Large intestine

Ultrasonographic examination of the large intestine was carried out as described for cattle (Amrein-Schneider, 1999; Braun and Amrein, 2001; Braun, 2003) and goats (Steininger, 2009). The size of the large intestine was determined in the 10th–12th intercostal spaces and in the flank (Fig. 1). Attempts were made to differentiate the proximal loop of the colon, the spiral loop of the colon and the caecum. The contents, thickness and various layers of the wall and motility of the large intestine were evaluated. The diameter of the spiral loop of the colon and the caecum were also determined.

Ultrasonographic examination of the greater omentum

The greater omentum was evaluated in the 8th–12th intercostal spaces and in the right flank. The thickness of the omentum was measured electronically using the two cursors.

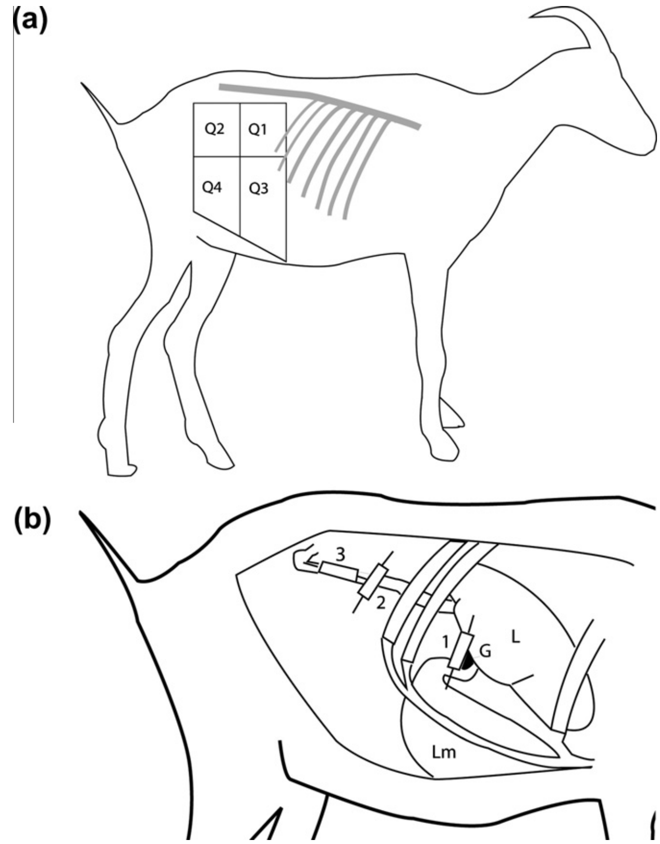

Fig. 1. (a) Division of the flank region into four quadrants for localisation of intestine during ultrasonographic examination. Q1 – Craniodorsal quadrant, Q2 – Caudodorsal quadrant, Q3 – Cranioventral quadrant, Q4 – Caudoventral quadrant. (b) Position of the linear transducer for the ultrasonographic examination of the various parts of the duodenum. 1 – Position for the examination of the cranial part of the duodenum, 2 – Position for examination of the descending part of the duodenum in cross-section, 3 – Position for the examination of the duodenum in longitudinal section, L – Liver, G – Gall bladder (black area), Lm – Abomasum.

Postmortem examination

After examination, the goats were slaughtered ($n = 14$) or euthanased ($n = 16$). A macroscopic postmortem examination of the intestines was carried out in the slaughtered goats. The euthanased goats, which were also used in other studies (Becker-Birck, 2009; Irmer, 2009), were frozen and cut into 1.0 to 1.5 cm-thick transverse sections. The intestine was examined on these sections.

Statistical analysis

The statistical software program StatView 5.1 (SAS Institute, Cary, USA) was used for analysis of the data. Frequencies, means and standard deviations were calculated.

Results

Duodenum

The cranial part of the duodenum could not be visualised in any of the goats because it was hidden by the liver (see also Fig. 1b), and the ascending part of the duodenum could not be seen because its distance from the abdominal wall exceeded the depth of penetration of the transducer. The descending duodenum could be distinctly differentiated from other parts of the small and large intestine in 19 goats. Similar to cattle (Braun and Marmier, 1995), the descending duodenum was recognised because of its location immediately adjacent to the abdominal wall and between the two serosal layers of the greater omentum (Fig. 2). Its contents

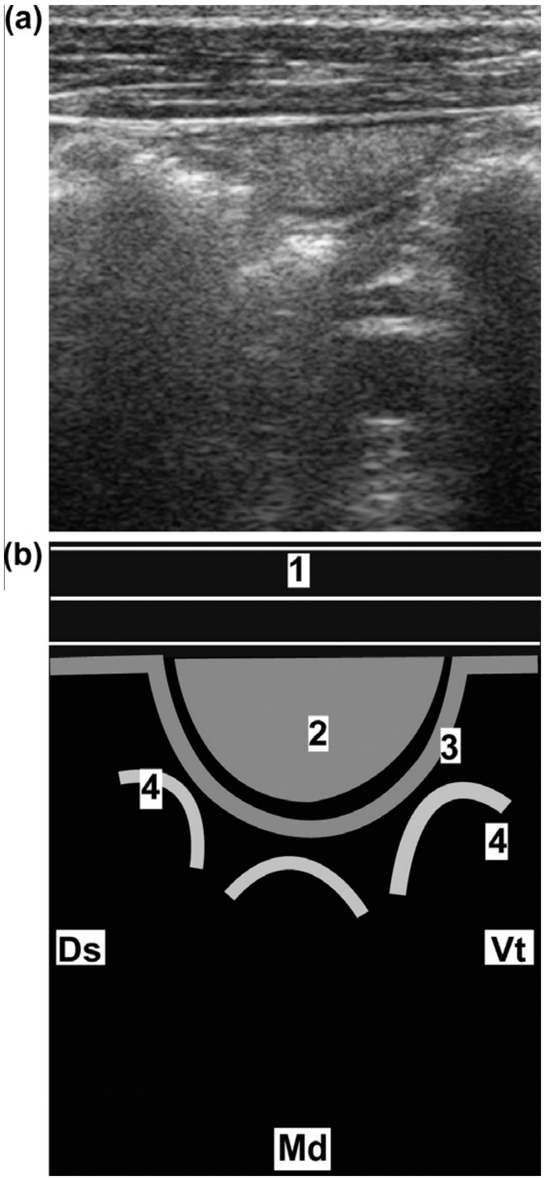

Fig. 2. Ultrasonogram and schematic of the descending duodenum in the craniodorsal quadrant (Q1) of a 4-year-old Saanen goat. 1 – Lateral abdominal wall, 2 – Descending duodenum, 3 – Greater omentum, 4 – Large intestine, Ds – Dorsal, Vt – Ventral, Md – Medial.

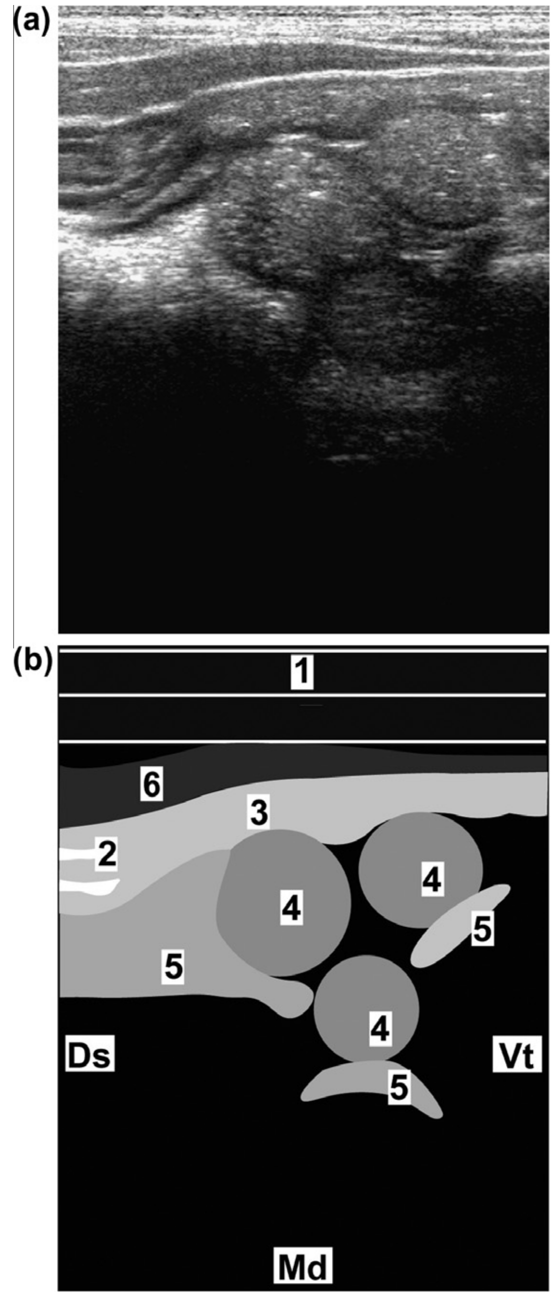

Fig. 3. Ultrasonogram and schematic of the jejunum in longitudinal and cross-section in the cranioventral quadrant (Q3) of a 3-year-old Saanen goat. 1 – Lateral abdominal wall, 2 – Empty intestine, 3 – Longitudinal section, 4 – Cross-section, 5 – Large intestine, 6 – Greater omentum, Ds – Dorsal, Vt – Ventral, Md – Medial.

were homogenously echoic. The descending duodenum could be imaged from one examination location in all the 19 goats and in two goats, it could be followed across several intercostal spaces. The descending duodenum was seen most often (n = 13) in the craniodorsal quadrant (Q1; Table 1). It was also seen in one to two goats in the 10th–12th intercostal spaces and quadrants 2 and 3. The thickness of the duodenal wall ranged from 0.5 to 1.7 mm. The largest diameter varied from 0.8 to 2.3 cm (1.3 [0.37 cm]), and there were one to eight duodenal contractions per minute (3.7 [2.05] contractions per minute).

Table 1
Visibility of the small and large intestine in the various abdominal quadrants and intercostal spaces in 30 Saanen goats (per cent in brackets).

Part of intestine	Intercostal spaces				Abdominal quadrants			
	9	10	11	12	1	2	3	4
Descending duodenum	0 (0.0)	1 (3.3)	2 (6.7)	2 (6.7)	13 (43.3)	2 (6.7)	2 (6.7)	0 (0.0)
Jejunum and ileum	4 (13.3)	12 (40.0)	8 (26.7)	7 (23.3)	2 (6.7)	1 (3.3)	29 (96.7)	29 (96.7)
Spiral colon	1 (3.3)	1 (3.3)	5 (16.7)	4 (13.3)	19 (63.3)	25 (83.3)	13 (43.3)	12 (40.0)
Caecum	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (26.7)	8 (26.7)	6 (20.0)	3 (10.0)

Jejunum and ileum

The jejunum and ileum could be seen in all the goats and were most often imaged ($n = 29$) in the ventral quadrants (Q3 and Q4) of the right flank (Table 1). They were less frequently seen ($n = 7–12$) in the ventral part of the 10th–12th intercostal spaces and only occasionally imaged in the dorsal flank region. Loops of jejunum and ileum were usually seen in cross-section and rarely longitudinally (Fig. 3). Although the number of intestinal loops seen in cross-section in both ventral quadrants (Q3 and Q4) ranged from one to nine, usually ($n = 16$) only four to six loops were seen (Fig. 4). Intestinal loops were seen in longitudinal section in five goats, with 1 ($n = 3$) or 3 ($n = 2$) sections being observed (Fig. 5). The intestinal loops were located immediately adjacent to one another with no free fluid between them. In a few goats, loops of empty intestine were seen between loops containing ingesta. Active intestinal motility was observed in all the goats. However, it was not possible to determine the frequency of contractions because the intestines were constantly in motion. The intestinal contents were usually homogenously echoic. The diameter of the small intestine ranged from 0.8 to 2.7 cm (1.6 [0.33] cm), although in the majority of goats it varied from 1.2 to 1.8 cm, and was rarely greater than 2.5 cm (Fig. 6). The thickness of the wall of the jejunum and ileum was 0.8–2.1 mm.

Large intestine

The large intestine was seen in all the goats, and in 21, the caecum could be imaged separately. These structures were most often seen in the dorsal region of the right flank (Q1 and Q2), sometimes in the ventral quadrants (Q3 and Q4) and rarely (spiral loop of colon) or never (caecum) in the 9th–12th intercostal spaces (Table 1).

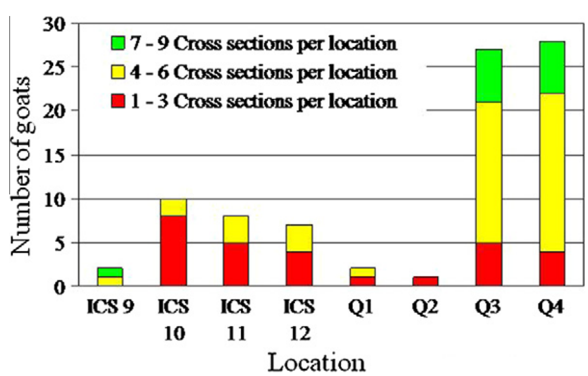

Fig. 4. Frequency distribution of the number of intestinal loops seen in cross-section in the various abdominal quadrants and intercostal spaces in 30 Saanen goats using a 5.0 MHz-linear transducer with a penetration depth of 9 cm. ICS Intercostal space, Q1 – Craniodorsal quadrant, Q2 – Caudodorsal quadrant, Q3 – Cranioventral quadrant, Q4 – Caudoventral quadrant.

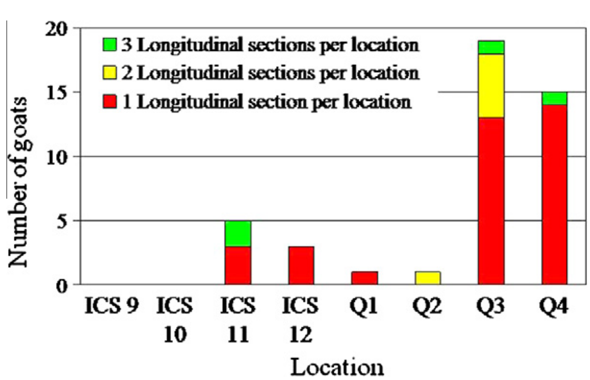

Fig. 5. Frequency distribution of the number of intestinal loops seen in longitudinal section in the various abdominal quadrants and intercostal spaces in 30 goats using a 5.0 MHz-linear transducer with a penetration depth of 9 cm. Key see Fig. 4.

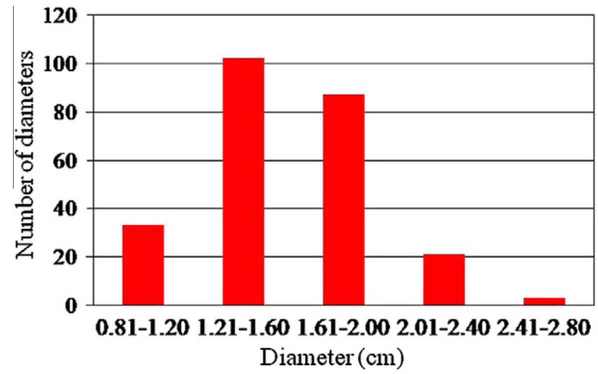

Fig. 6. Frequency distribution of the diameter of the jejunum and ileum in 30 Saanen goats (246 measurements).

The spiral loop of the colon was easily identified because of the centripetal and centrifugal arrangement of the intestine giving it an echoic garland-like appearance (Fig. 7). The spiral colon was often located medial to the small intestine and not immediately adjacent to the right abdominal wall. Because of intraluminal gas, only the wall of the large intestine closest to the transducer could be visualised. The wall of the large intestine furthest from the transducer and the intestinal contents could not be seen because of a distal acoustic shadow created by the gas. Parts of the proximal loop of the colon were usually seen during examination of the spiral loop of the colon. The thickness of the wall of the spiral loop of the colon ranged from 1.0 to 2.6 mm and its diameter was 0.8 to 2.0 cm (1.1 [0.24] cm).

Only the wall of the caecum closest to the transducer could be imaged. It appeared as a thick, echoic, slightly undulating line with a length of 5.6 to 8.0 cm (6.6 [0.69] cm; Fig. 8). The thickness of the caecal wall was 1.8–4.1 mm (3.0 [0.74] cm).

Greater omentum

The greater omentum was seen in all the goats and appeared as a homogenously echoic structure with small hypoechoic foci which corresponded to blood vessels. It was located immediately adjacent to the abdominal wall, and visualisation of the omentum increased from cranial to caudal. The greater omentum was seen in the 8th intercostal space in one goat and in the 9th–12th intercostal spaces in 3, 9, 12 and 15 goats, respectively. It was seen in the dorsal abdominal quadrants in 24 goats and in the ventral abdominal quadrants in 26 goats. The thickness of the greater omentum ranged from 0.2 to 2.9 cm (1.0 [0.51] cm).

Postmortem examination

Postmortem examination of the small intestine, large intestine and greater omentum of the examined goats revealed no abnormal findings.

Discussion

Ultrasonography has become a routine diagnostic tool in many domestic animal species including goats. Small ruminant practitioners should be familiar with the ultrasonographic anatomy of healthy animals so as to be able to interpret abnormal findings. The results of this study indicate that transabdominal ultrasonography is suitable for assessing the intestinal tract and differentiating

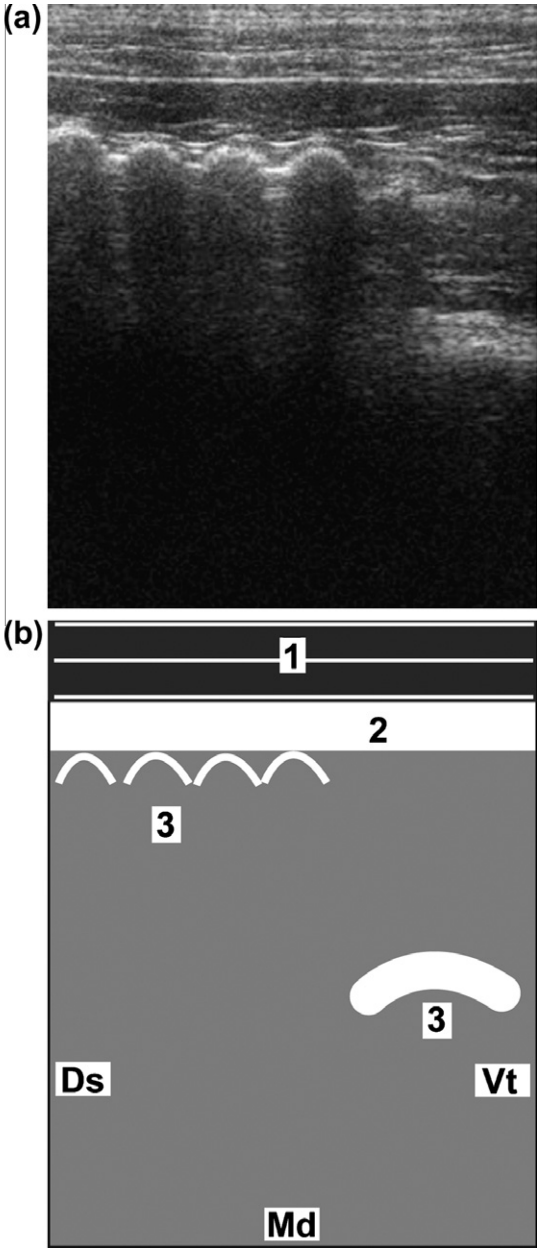

Fig. 7. Ultrasonogram and schematic of the spiral colon in the caudodorsal quadrant (Q2) of a 3-year-old Saanen goat. 1 – Lateral abdominal wall, 2 – Greater omentum, 3 – Spiral colon, Ds – Dorsal, Vt – Ventral, Md – Medial.

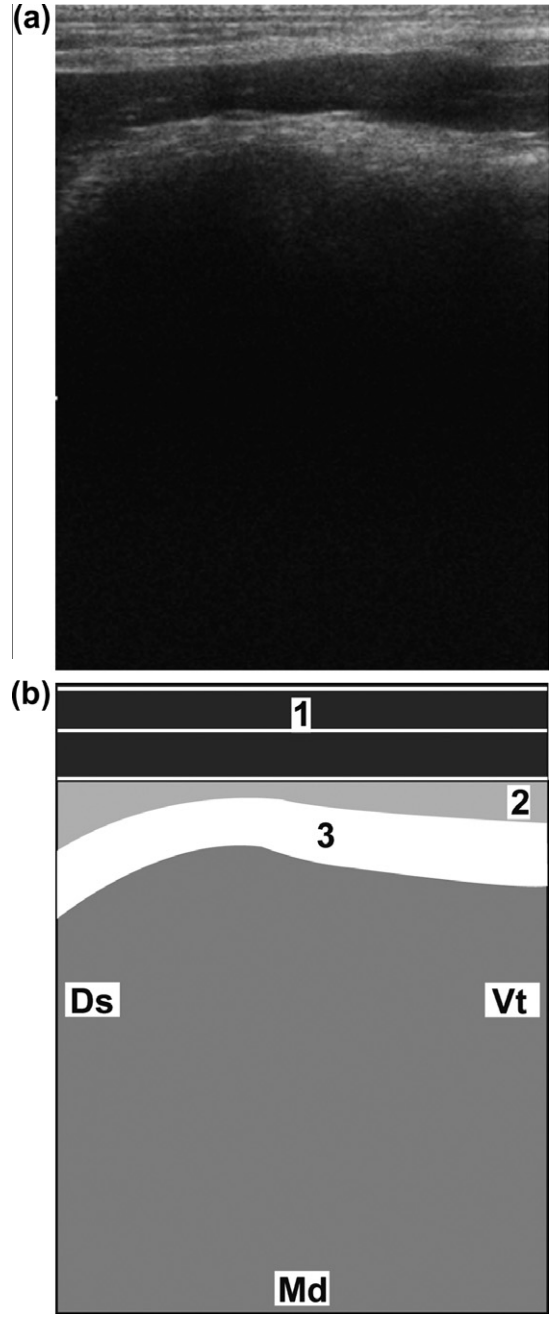

Fig. 8. Ultrasonogram and schematic of the caecum in the caudodorsal quadrant (Q2) of a 3-year-old Saanen goat. 1 – Lateral abdominal wall, 2 – Greater omentum, 3 – Caecum, Ds – Dorsal, Vt – Ventral, Md – Medial.

the small and large intestine in goats. Generally, our findings were similar to descriptions of the small (Marmier, 1993; Braun and Marmier, 1995) and large (Amrein-Schneider, 1999; Braun and Amrein, 2001) intestine in cattle. The descending duodenum was seen between the serosal layers of the omentum, similar to findings in cattle. However, the cranial part of the duodenum could not be imaged, which was in contrast to findings in cattle.

The jejunum and ileum were most often seen in the ventral region of the right flank and less frequently in the 9th–12th intercostal spaces. This is in contrast to cattle in which they were always seen in the 11th and 12th intercostal spaces (Braun and Marmier, 1995). The diameter of the jejunum and ileum ranged from 0.8 to 2.4 cm in 99% of the goats, whereas the diameter was 2.0–4.0 cm in 98% of cattle (Braun and Marmier, 1995). Other similarities to findings in cattle included imaging the loops in cross-section more often than longitudinally, and the active motility. Assessing intestinal diameter and motility is important for diagnosing ileus in cattle (Braun et al., 1995) and probably goats as well. Dilated, non-motile loops of intestine are suggestive of ileus (Braun, 2003; Braun et al., 1995).

Because of intraluminal gas, the large intestine could be easily differentiated from the small intestine in all the goats; this finding was similar to results in cattle (Braun and Amrein, 2001). Because of intraluminal gas, usually only the wall of the large intestine closest to the transducer could be imaged as a thick echoic line. Similar to findings in cattle, the spiral colon had the appearance of a garland.

The greater omentum was of special interest because in the majority of goats it was easily identified as a prominent echoic structure, up to 2.9 cm in thickness, immediately adjacent to the abdominal wall in the flank region. The greater omentum does not appear as prominently in sheep or cattle. In cattle, the greater omentum appears as a very thin structure mainly when the abdomen contains fluid (Braun et al., 2004). Visualisation of the greater omentum was excellent because in goats fat deposition occurs mainly in the abdomen, especially in the greater omentum (Warmington and Kirton, 1990; Liméa et al., 2009). Of all the ruminants, goats have the highest amount of fat in the greater omentum (Brandt et al., 1983). This also explains why the weight of the goats used in this study had such a wide variation despite the fact that their size was relatively uniform, and all belonged to the same breed. In contrast to other domestic animal species, goats generally deposit less fat subcutaneously, which is why the body conditions appeared similar despite the large variation in body weight (Warmington and Kirton, 1990; Liméa et al., 2009).

Conclusions

Ultrasonographic examination of the small and large intestine is a useful adjunct to the clinical examination and is an important tool for diagnosis of intestinal disorders. This imaging modality is a unique method for non-invasive evaluation of the location, diameter, motility, wall and intraluminal contents of various parts of the intestine. Furthermore, ultrasonography is a goat-side technique that can be carried out almost anywhere. Because many of the findings in goats were similar to those in cattle, it is likely that ileus can be diagnosed by ultrasonography in goats.

Conflict of interest statement

The authors of this paper have no financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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