Available online at www.sciencedirect.com
SCIENCE DIRECT®
The Veterinary Journal 166 (2003) 112–124
The Veterinary Journal
www.elsevier.com/locate/tvjl

Review

Ultrasonography in gastrointestinal disease in cattle

U. Braun

Department of Farm Animals, University of Zurich, Winterthurerstrasse 260, CH-8057 Zurich, Switzerland

Accepted 28 October 2002

Abstract

Ultrasonography is an ideal diagnostic tool for investigating gastrointestinal disorders in cattle. It is performed on standing non-sedated cattle using a 3.5 MHz linear transducer. In animals with traumatic reticuloperitonitis, inflammatory fibrinous changes, and abscesses can be imaged; however, magnets and foreign bodies are difficult to visualize because of the gas content of the reticulum. Ultrasonography can be used to assess the size, position and contents of the abomasum. Percutaneous ultrasound-guided abomasocentesis can be performed to evaluate the nature and chemical composition of its contents. In left displacement of the abomasum, the abomasum is seen between the left abdominal wall and the rumen. It contains fluid ingesta ventrally and a gas cap of varying size dorsally. Occasionally, the abomasal folds are seen in the ingesta. In cattle with right displacement of the abomasum, the liver is displaced medially from the right abdominal wall by the abomasum, which has an ultrasonographic appearance similar to that described for left displacement. Motility and diameter of the intestine are the most important criteria for ultrasonographic assessment of ileus. However, the cause of the ileus is rarely determined using ultrasonography. In cases with ileus of the small intestine, there is at least one region of dilatation of the intestine and motility is reduced or absent. In cattle with caecal dilatation, the caecum can always be imaged from the right lateral abdominal wall. The wall of the caecum closest to the transducer appears as a thick, echogenic, semi-circular line.

Keywords: Ultrasonography; Cattle; Reticulum; Abomasum; Small intestine; Caecum

1. Introduction

Ultrasonography is an ideal diagnostic tool for the investigation of bovine gastrointestinal disorders, the most common of which include traumatic reticuloperitonitis, left and right displacement of the abomasum, ileus of the small intestine and dilatation and displacement of the caecum. An ultrasonographic examination is performed on non-sedated, standing cattle using a 3.5 MHz linear transducer[1] after the application of transmission gel. The hair is clipped from the area where the transducer is to be applied; for optimal transmission of ultrasound waves, remaining hair may be removed using a razor or depilatory cream.

2. Reticulum/rumen

2.1. Ultrasonographic examination of the normal reticulum

For ultrasonographic examination of the reticulum, the transducer is applied to the ventral aspect of the thorax on the left and right of the sternum as well as to the left and right lateral thorax up to the level of the elbow (Braun, 1997; Braun and Götz, 1994; Götz, 1992; Kaske et al., 1994). The reticulum is first examined from the left side and then from the right (Fig. 1). The normal reticulum appears as a half-moon-shaped structure with an even contour (Fig. 2). It contracts at regular intervals and, when relaxed, is situated immediately adjacent to the diaphragm and ventral portion of the abdominal wall. The different layers of the reticular wall usually cannot be imaged, and the honeycomb-like structure of the mucosa is not often seen clearly. Contents of the reticulum cannot be normally imaged because of their

E-mail address: ubraun@vetclinics.unizh.ch
[1] The figures in the manuscript were obtained using ultrasound scanners LSC7000 (Picker International), EUB-515A (Hitachi) and EUB-405 (Hitachi).

1090-0233/$ - see front matter © 2003 Elsevier Science Ltd. All rights reserved.
doi:10.1016/S1090-0233(02)00301-5

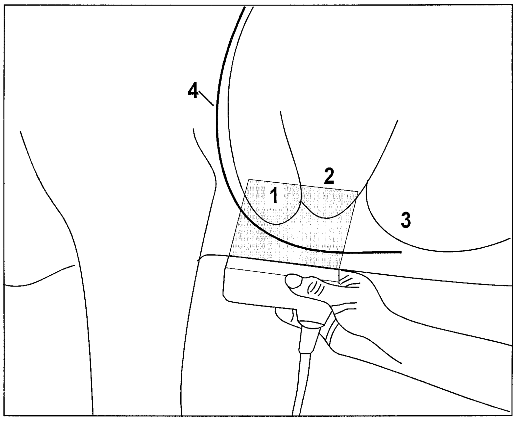

Fig. 1. Ultrasonographic examination of the left paramedian view of the reticulum. (1) Reticulum, (2) craniodorsal blind sac of the rumen, (3) ventral sac of rumen, (4) diaphragm (reproduced from Braun and Götz, 1994).

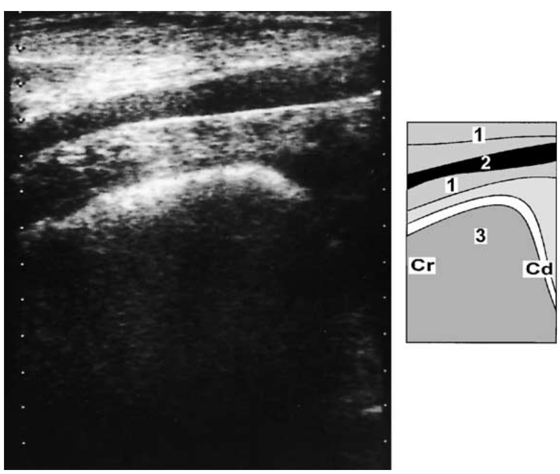

Fig. 2. Ultrasonogram of the normal reticulum viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) musculophrenic vein, (3) reticulum. Cr: cranial and Cd: caudal.

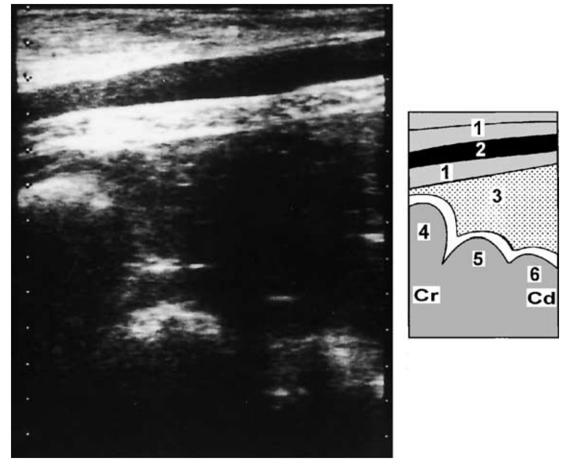

Fig. 3. Ultrasonogram of the normal reticulum, craniodorsal blind sac of the rumen, ventral sac of the rumen, and abomasum viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) musculophrenic vein, (3) abomasum, (4) reticulum, (5) craniodorsal blind sac of the rumen, (6) cranial part of the ventral sac of the rumen. Cr: cranial and Cd: caudal.

partly gaseous composition. Foreign bodies and magnets also cannot usually be seen in the reticulum because of the gas content of the reticulum. Radiography is the method of choice for identifying radiodense foreign bodies and magnets (Braun et al., 1993a). On the left side of the animal, the wall of the craniodorsal blind sac of the rumen, the ruminoreticular groove and the wall of the ventral sac of the rumen are seen as echogenic lines caudal to the reticulum (Fig. 3). From the right ventral thorax, part of the omasum, abomasum, and sometimes the liver are imaged. The abomasum is frequently seen between the craniodorsal blind sac of the rumen or rumen and ventral abdominal wall, immediately caudal to the reticulum.

For an assessment of reticular motility, the transducer is placed over the left ventral thoracic region. The reticulum is located and observed for 3 min without moving the transducer. The number, amplitude, duration and speed of reticular contractions and the duration of the interval of relaxation between two biphasic reticular contractions are assessed. The reticulum normally contracts once per minute. Thus, in the 3-min-observation period, the reticulum has three biphasic contractions, the first of which is incomplete. Contraction of the craniodorsal blind sac of the rumen is frequently seen immediately after the second reticular contraction. Rumination is associated with an additional ruminal contraction, which occurs immediately prior to the biphasic contraction. The duration of the first reticular contraction ranges from 2.0 to 3.5 s and the second reticular contraction lasts from 3.0 to 5.5 s (Götz, 1992). The velocity of the first reticular contraction varies from 3.3 to 10.0 cm/s. The interval of relaxation between two biphasic contractions ranges from 25 to 75 s.

The abdominal wall, spleen and wall of the rumen or reticulum can usually be imaged from the sixth and seventh intercostal spaces of the left ventral thorax (Fig. 4). Ultrasonographically, the spleen appears in cross-section as a 2–3 cm thick structure situated between the abdominal wall and the rumen or the reticulum. It tapers off ventrally, where the lateral and the medial surface merge. The capsule of the spleen appears as an echogenic line, and the splenic pulp appears as many small, evenly distributed echoes. The vasculature of the spleen is seen in cross-section as oval hypoechogenic structures in the pulp.

The reticulum, omasum and liver can be imaged from the intercostal spaces of the right thorax. The omasal wall is seen as a circular, distinctly echogenic line, immediately adjacent to the right thoracic wall. The wall of

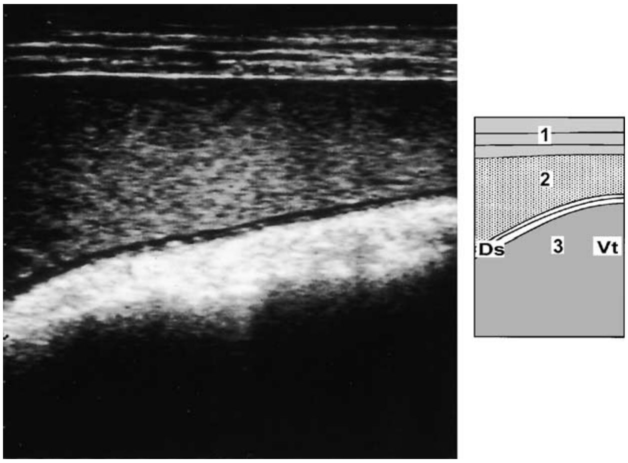

Fig. 4. Ultrasonogram of the normal spleen and reticulum viewed on the left side from the distal portion of the sixth intercostal space. (1) Lateral thoracic wall, (2) spleen, (3) reticulum, Ds: dorsal and Vt: ventral.

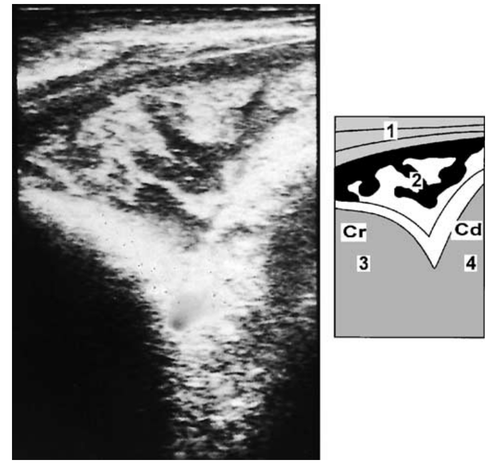

Fig. 5. Ultrasonogram of the reticulum and craniodorsal blind sac of the rumen of a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. There are echogenic deposits cavitated by hypoechogenic fluid ventral to the reticulum and craniodorsal blind sac of the rumen. (1) Ventral abdominal wall, (2) fibrinous deposits, (3) reticulum, (4) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

the omasum is thicker than that of the reticulum. The contents of the omasum cannot usually be imaged.

The left wall of the rumen and the longitudinal groove, which divides the rumen into the dorsal and ventral sacs of the rumen, can be seen from the left thoracic and abdominal walls.

2.2. Traumatic reticuloperitonitis

In cattle with traumatic reticuloperitonitis, ultrasonography can be used to identify morphological changes in the region of the cranial, ventral, or caudal reticular wall (Braun et al., 1993b). The caudoventral reticular wall is the most frequently affected, often in association with the craniodorsal blind sac of the rumen. The changes in the contour of the reticulum depend on the severity of the inflammatory changes. Deposits of fibrinous tissue interspersed with fluid pockets are frequently seen on the reticular serosa. Ultrasonographically, these appear as echogenic areas cavitated by hypoechogenic areas (Fig. 5). Deposits that consist solely of fibrinous tissue are homogeneously echogenic (Fig. 6).

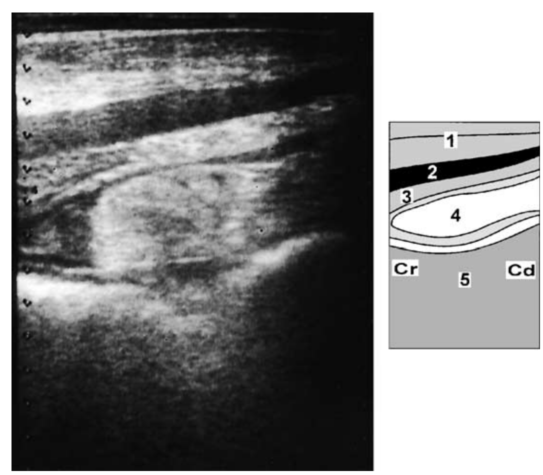

Fig. 6. Ultrasonogram of echogenic deposits on the reticulum of a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) musculophrenic vein, (3) diaphragm, (4) echogenic deposits, (5) reticulum: Cr: cranial and Cd: caudal.

Reticular abscesses have an echogenic capsule of varying thickness, which surrounds a homogeneous hypoechogenic to moderately echogenic centre (Fig. 7). The contents of an abscess are frequently partitioned by echogenic septa (Fig. 8). Abscesses are usually caudoventral to the reticulum, but may be cranial or lateral to the reticulum. Abscesses are often seen between the reticulum and spleen, reticulum and liver or reticulum and omasum or abomasum. Reticular abscesses vary in diameter from a few centimetres to more than 15 cm. Occasionally, the thick capsule of an abscess produces an acoustic shadow. It is possible to drain abscesses through an ultrasound-guided transcutaneous incision (Braun et al., 1998a). However, the abscess must be immediately adjacent to and attached to the abdominal wall, and the intercostal space over the abscess must be large enough.

Reticular activity is almost always affected in cattle with traumatic reticuloperitonitis. The frequency, amplitude or velocity of contractions, singly or combined, may be abnormal. The frequency can be reduced from three to two, one or no contractions per 3 min. The reduction in the amplitude of contractions varies; when formation of adhesions is extensive, reticular contractions appear indistinct via ultrasonography. Although the pattern of biphasic contraction often is maintained,

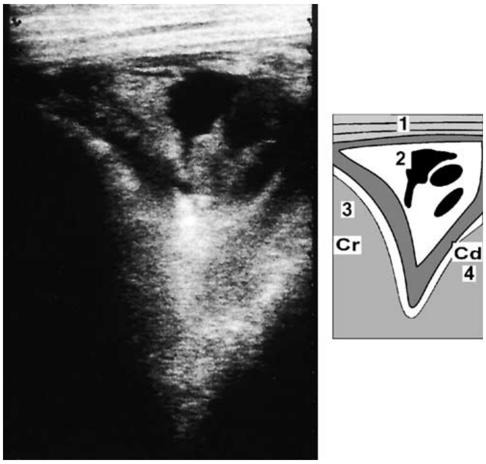

Fig. 7. Ultrasonogram of an abscess caudoventral to the reticulum and ventral to the craniodorsal blind sac of the rumen of a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) abscess, (3) reticulum, (4) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

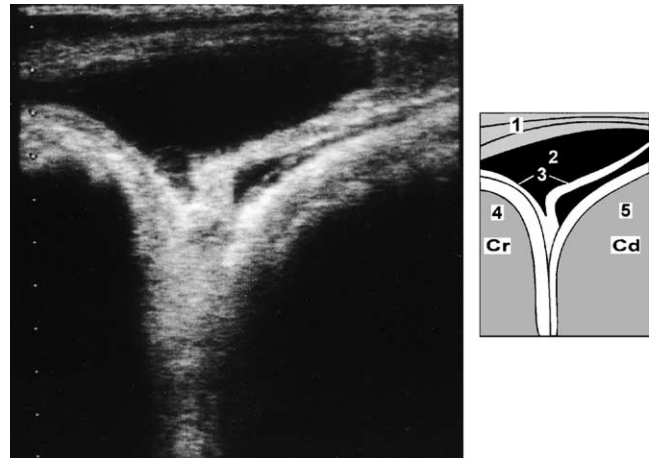

Fig. 9. Ultrasonogram showing echogenic deposits on the reticulum and craniodorsal blind sac of the rumen and accumulation of fluid in a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) accumulation of anechoic fluid, (3) echogenic deposits, (4) reticulum, (5) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

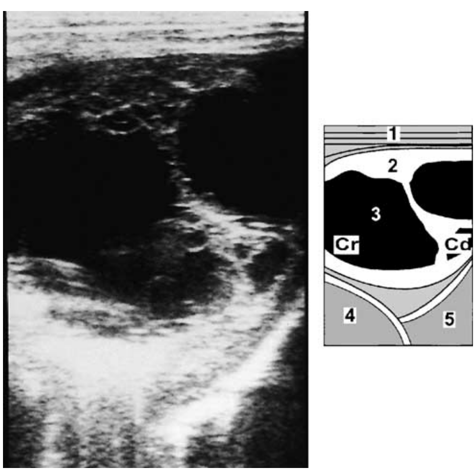

Fig. 8. Ultrasonogram of an abscess caudoventral to the reticulum and ventral to the craniodorsal blind sac of the rumen of a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) abscess capsule, (3) abscess lumen, (4) reticulum, (5) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

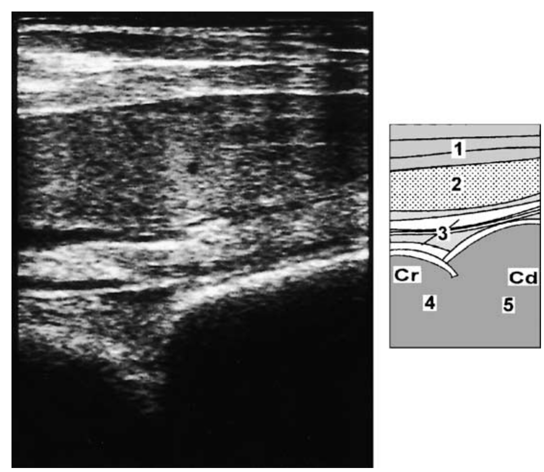

Fig. 10. Ultrasonogram showing fibrinous adhesions between the reticulum, craniodorsal blind sac of the rumen and spleen of a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) spleen, (3) echogenic deposits on spleen and reticulum, (4) reticulum, (5) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

the reticulum contracts by only 1–3 cm. The velocity of reticular contractions may be normal but can be markedly reduced. In cattle with reticulo-omasal obstruction due to a foreign body, the frequency of reticular contractions may be increased (Braun et al., 2002b).

Peritoneal effusion is visible ultrasonographically as an accumulation of fluid without an echogenic margin and restricted to the reticular area (Fig. 9). Depending on the fibrin and cell content, the fluid may be anechoic or hypoechogenic. Fibrinous deposits are easily identified in the fluid, and sometimes, bands of fibrin are seen within the effusion. Occasionally, the peritoneal effusion is considerable and extends to the caudal abdomen.

The spleen, particularly its distal portion, is often affected in cattle with traumatic reticuloperitonitis. Fibrinous changes are frequently seen as echogenic deposits of varying thickness (Fig. 10), often surrounded by fluid, between the spleen and reticulum or rumen. The spleen may be covered with fibrinous deposits (Fig. 11). Occasionally, one or more splenic abscesses are visible, and the vasculature may be dilated indicating splenitis.

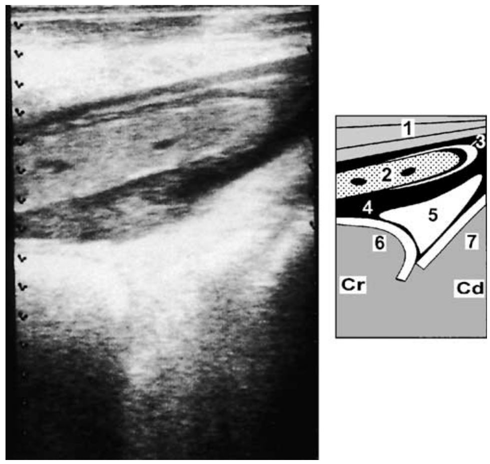

Fig. 11. Ultrasonogram showing fibrin on the distal aspect of spleen, fibrinous changes and inflammatory fluid in a cow with traumatic reticuloperitonitis viewed from the left ventral thorax. (1) Ventral abdominal wall, (2) spleen, (3) fibrin on spleen, (4) fluid, (5) fibrinous changes, (6) reticulum, (7) craniodorsal blind sac of the rumen. Cr: cranial and Cd: caudal.

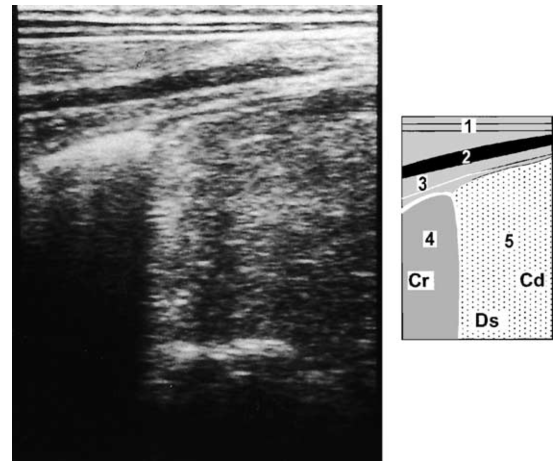

Fig. 12. Ultrasonogram of the abomasum situated caudal to the reticulum and viewed from the ventral midline caudal to the sternum. (1) Ventral abdominal wall, (2) musculophrenic vein, (3) diaphragm, (4) reticulum, (5) abomasum. Cr: cranial and Cd: caudal.

2.3. Comparison of ultrasonographic and radiographic findings in cows with traumatic reticuloperitonitis

Radiography is a reliable method of identifying metallic foreign bodies, whereas ultrasonography rarely identifies metallic objects, including magnets (Braun et al., 1994). Radiography is best suited for the detection of metallic foreign bodies in and outside the reticulum, and the position of the foreign body is the most reliable indicator for diagnosing traumatic reticuloperitonitis by radiography. In contrast, ultrasonography is the method of choice for detecting fibrinous deposits and abscesses, which cannot be determined using radiography.

Although neither radiography nor ultrasonography alone allow a complete diagnosis of traumatic reticuloperitonitis, the two techniques complement one another well.

3. Abomasum

3.1. Ultrasonographic examination of the normal abomasum

Ultrasonography is a valuable technique for the assessment of the size, position and contents of the abomasum. The abomasum can be visualised approximately 10 cm caudal to the xyphoid process from the left and right paramedian regions and from the ventral midline (Braun et al., 1997a). The bulk of the abomasum is situated to the right of the ventral midline. The abomasum is frequently seen immediately caudal to the reticulum between the craniodorsal blind sac of the rumen, or the rumen, and the ventral abdominal wall (Fig. 12). The wall of the abomasum appears at the most as a thin echogenic line. However, the abomasum is easily differentiated from neighbouring organs by the ultrasonographic appearance of its contents, which are seen as a heterogeneous moderately echogenic mass with echogenic stippling. Parts of the abomasal folds can occasionally be seen as echogenic structures within the content of the abomasum. Passive and slow movement of the abomasal contents is frequently seen.

3.2. Abomasocentesis

Percutaneous ultrasound-guided abomasocentesis can be performed to evaluate the nature and chemical composition of abomasal contents (Braun et al., 1997b). The procedure is performed at a site where the abomasum appears large and where no other organs are in the way. The site is cleaned with a disinfectant solution and the animal restrained by a tail grip flank-fold grip. A spinal needle (0.12×9.0 cm) with a stylet is guided by ultrasonography through the skin and abdominal wall and into the abomasum (Fig. 13). In one study, spontaneous flow of abomasal fluid occurred in only a third of cattle, whereas in most cows it was necessary to aspirate a sample using a syringe (Braun et al., 1997b). The risk of side effects is low provided that the technique is performed carefully. In a study of 50 cows, which were slaughtered within two hours of abomasocentesis, the only changes seen were localised haemorrhages on the serosal and mucosal surfaces of the abomasum at the site of penetration (Braun et al., 1997b). There was no evidence of peritonitis or other severe changes. Moreover, in cows slaughtered 10 days after abomasocentesis, lesions associated with the procedure were minimal.

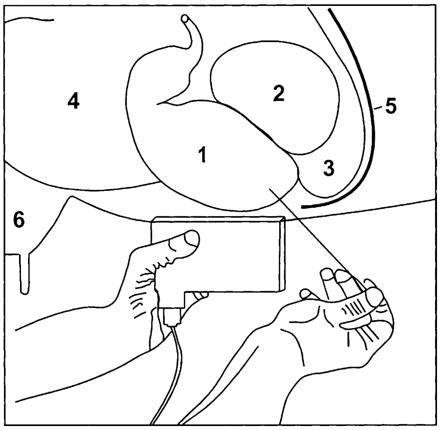

Fig. 13. Schematic representation of ultrasound-guided abomasocentesis as viewed from the right side. (1) Abomasum, (2) omasum, (3) reticulum, (4) rumen, (5) diaphragm, (6) udder (reproduced from Braun et al., 1997b).

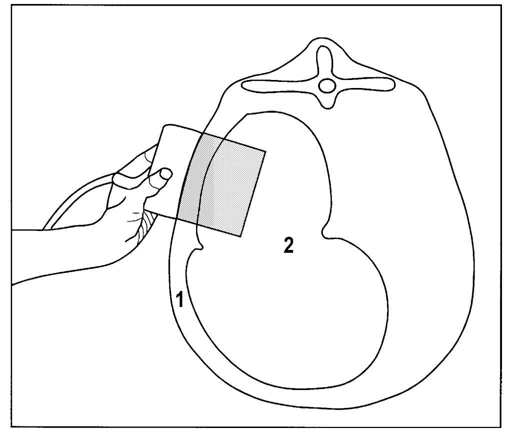

Fig. 14. Ultrasonographic examination of the abdominal cavity of a cow from the last intercostal space of the left abdominal wall. In an animal with a normal abomasum, the rumen is situated immediately adjacent to the abdominal wall. (1) Abdominal wall, (2) rumen (reproduced from Braun et al., 1997c).

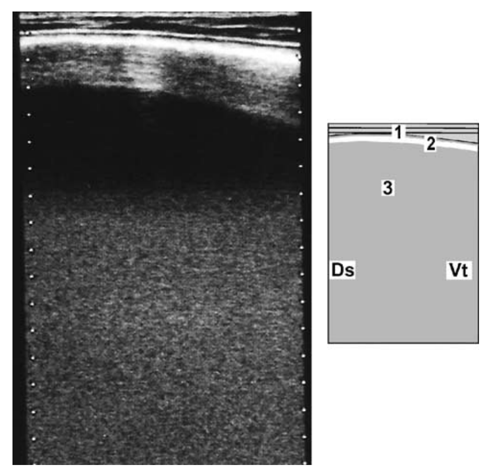

Fig. 15. Ultrasonogram showing the rumen adjacent to the abdominal wall in a healthy cow; viewed from the 12th intercostal space on the left side. (1) Abdominal wall, (2) wall of rumen, (3) rumen. Ds: dorsal and Vt: ventral. (reproduced from Braun et al., 1997c).

Abomasal fluid is assessed for colour, smell and the presence of blood, and the pH is determined. Additional analyses include determination of the concentrations of sodium, potassium, volatile fatty acids, bile acids and pepsin. Normally, the colour ranges from olive green to grey, and the fluid has a sour smell. The pH of abomasal fluid varies from 1.38 to 4.50 (2.5 ± 0.87) (Braun et al., 1997a). Higher values occur with abomasal haemorrhage, addition of bile or chronic abomasitis due to ostertagiosis. Blood or haemoglobin, which is determined using a commercial test kit, such as hemoFEC (Boehringer), does not normally occur in abomasal fluid and its presence indicates disease. In the majority of cases, blood originates from an abomasal ulcer (Braun et al., 1997b) and rarely from the rumen or small intestine.

3.3. Left displacement of the abomasum

An ultrasonographic examination is useful to confirm the diagnosis of left displacement of the abomasum in unclear cases (Braun et al., 1997c). The last three intercostal spaces on the left side are examined ventrally to dorsally with the transducer held parallel to the ribs (Fig. 14). Normally, the rumen is immediately adjacent to the left abdominal wall (Fig. 15). Thus, on ultrasonograms, the ruminal wall is medial to the abdominal wall and ventrodorsally appears as a smooth, thick, echogenic line, which is indented at the left longitudinal sulcus. The ruminal contents cannot be visualised because of their gaseous nature. With left displacement of the abomasum, the wall of the rumen often remains immediately adjacent to the abdominal wall in the ventral region (Fig. 16). When the transducer is moved dorsally, it becomes apparent that the wall of the rumen is pushed medially and can no longer be imaged ultrasonographically. Instead the abomasum is seen, located between the abdominal wall and rumen. Moving the transducer further dorsally, the abomasum disappears and the rumen reappears on the screen. The abomasal contents do not appear uniform because, ventrally, there are fluid ingesta, and dorsally, there is a gas cap that varies in extent. The ingesta visible ventrally in the abomasum appear hypoechogenic (Fig. 17). Occasionally, the abomasal folds are visible among the ingesta and appear as elongated, echogenic, sickle-shaped structures (Fig. 18). The ruminal wall can often be seen medial to the ingesta. The abomasal gas cap, seen further dorsally, is characterised by reverberation artifacts (Fig. 19) similar to those observed during the ultrasonographic examination of lung. The artifacts are caused by the reflection of the ultrasound waves by abomasal gas and

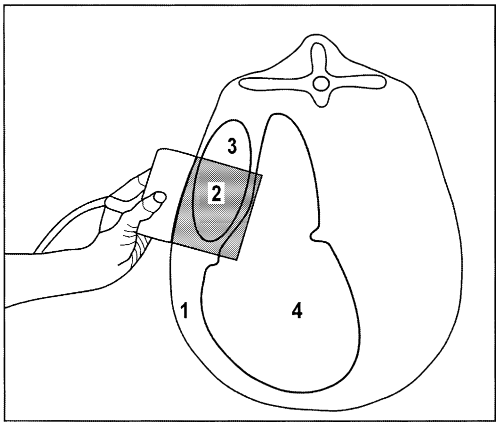

Fig. 16. Ultrasonographic examination of left displacement of the abomasum imaged from the 12th intercostal space. The abomasum is situated between the left abdominal wall and the rumen. (1) Abdominal wall, (2) ventral part of abomasum containing ingesta, (3) dorsal portion of abomasum with gas cap, (4) rumen. (reproduced from Braun et al., 1997c).

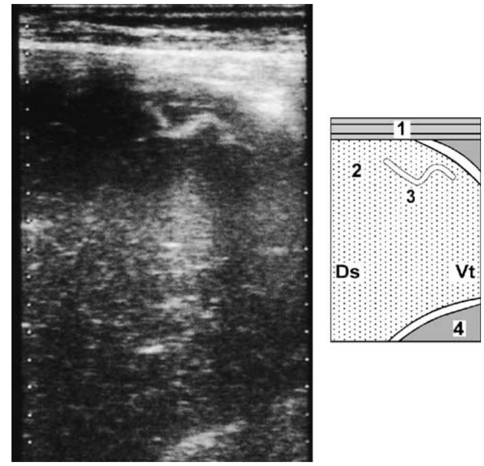

Fig. 18. Ultrasonogram of left displacement of the abomasum viewed from the ventral region of the 12th intercostal space. (1) Abdominal wall, (2) abomasum with hypoechogenic ingesta, (3) abomasal fold, (4) rumen. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1997c).

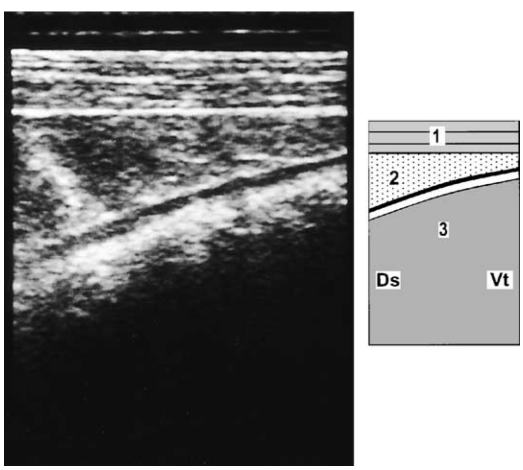

Fig. 17. Ultrasonogram of left displacement of the abomasum viewed from the ventral region of the 12th intercostal space. (1) Abdominal wall, (2) abomasum with hypoechogenic ingesta, (3) rumen displaced medially. Ds: dorsal and Vt: ventral. (reproduced from Braun et al., 1997c).

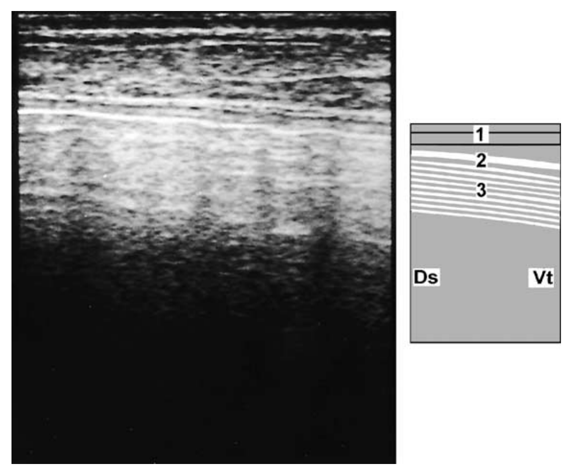

Fig. 19. Ultrasonogram of left displacement of the abomasum imaged from the dorsal region of the 12th intercostal space. The abomasal gas cap is not visible because of reverberation artifacts at the abomasal surface. (1) Abdominal wall, (2) abomasal wall, (3) reverberation artifacts. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1997c).

reverberation between the transducer and the abomasal surface. They appear as lines of varying echogenicity running parallel to the abomasal surface and become weaker as the distance from the transducer increases. At a depth of 7–8 cm, they are no longer visible (Braun et al., 1997c). Reverberation artifacts prevent the visualisation of the ruminal wall medial to the abomasal gas cap.

3.4. Right displacement of the abomasum

Ultrasonography is a useful diagnostic tool in doubtful cases of right displacement of the abomasum. The area immediately caudal to the last rib and the caudal two to three intercostal spaces on the right side are examined ventrodorsally with the transducer held parallel to the ribs (Braun, 1997). Normally, loops of small intestine are imaged in cross-section and, less commonly, longitudinally in the ventral abdomen; further dorsally, the liver is seen immediately adjacent to the right abdominal wall. In animals with right displacement of the abomasum, the liver is displaced from the abdominal wall and cannot be imaged. The abomasum is seen where the liver would normally be, immediately adjacent to the right abdominal wall.

Its ultrasonographic appearance is the same as that described previously for left displacement.

3.5. Defects in abomasal emptying

Defects in abomasal emptying occur with functional or mechanical pyloric stenosis. Abomasal emptying can also be impaired secondary to intestinal ileus. With all these disorders, the abomasum is dilated but not displaced dorsally or torsed. Depending on its degree of fill, the dilated abomasum can be imaged on the right side from the ventral region of intercostal spaces 8 to 12, or even from the ventral abdomen caudal to the ribs. In contrast to left or right displacement, there is no accumulation of gas in the non-displaced, dilated abomasum. The abomasal contents appear predominantly hypoechogenic and homogeneous, and because of sequestration of hydrochloric acid (HCl), are frequently fluid in nature. This often allows for good visualisation of the abomasal folds, which appear as thin, echogenic, wavy structures (Fig. 20). In animals with ileus, the loops of intestine are dilated and clearly visible. With pyloric stenosis, the small intestine is empty.

Discrete lesions of the abomasal mucosa such as chronic abomasitis, parasitic nodules, erosions and type-I ulcers cannot be imaged ultrasonographically using a 3.5 MHz linear transducer. In a study involving 50 cows, chronic abomasitis identified on postmortem examination in 48 cows could not be visualised by ultrasonography before slaughter (Wild, 1995; Braun et al., 1997a). The same was true for mucosal erosions or type-I ulcers found in the fundic and pyloric regions, respectively, in 16 cows.

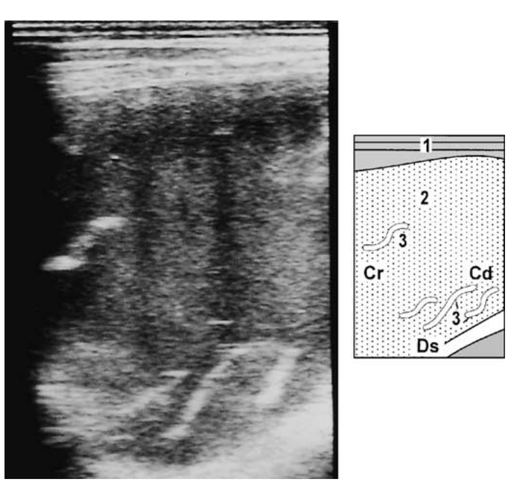

Fig. 20. Ultrasonogram showing dilatation of the abomasum secondary to intussusception of the jejunum of a cow, viewed from the right paramedian region. (1) Abdominal wall, (2) abomasum, (3) abomasal fold. Cr: cranial, Cd: caudal, and Ds: dorsal (reproduced from Braun, 1997).

4. Intestine

4.1. Normal small intestine

For ultrasonography of the small intestine in cattle (Fig. 21), the area from the tuber coxae to the eighth intercostal space and from the transverse processes of the vertebrae to the linea alba on the right side is examined (Braun and Marmier, 1995; Marmier, 1993). The appearance of loops of small intestine and their diameter, contents and motility are assessed. The wall of the normal small intestine is 2–3 mm thick and its luminal diameter is 2–4 cm (Braun and Marmier, 1995). Evaluation of the contents of the small intestine in cattle is usually straightforward because there is generally no gas. As, unlike in small animals and humans, ruminants digest carbohydrates principally in the forestomachs, from which the gas is eructated (Gürtler, 1980).

The ultrasonographic appearance of the contents of the small intestine varies. Most commonly, the intestine contains mucus or feed, which appears hyperechogenic. In these cases, not only the intestinal wall closest to the transducer, but also the intestinal contents and the wall furthest from the transducer can be visualised. This is also true for intestine filled with fluid, which is hypoechogenic. In rare cases with gaseous intestinal contents, the intestinal wall closest to the transducer appears as a hyperechogenic line adjacent to an acoustic shadow. Because of reflection of the ultrasound waves at the soft tissue–air interface, the intestinal contents and the intestinal wall furthest from the transducer cannot be

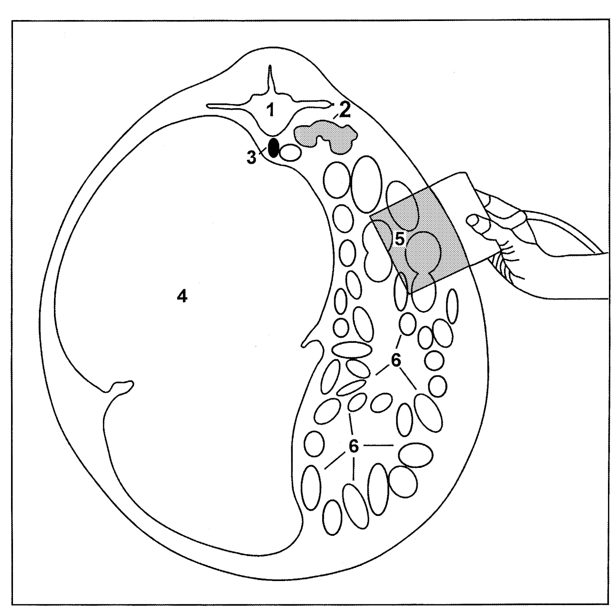

Fig. 21. Ultrasonographic examination of the intestine viewed from the level of the first lumbar vertebra on the right side. (1) First lumbar vertebra, (2) right kidney, (3) aorta, (4) rumen, (5) large intestine, (6) small intestine (reproduced from Braun, 1997).

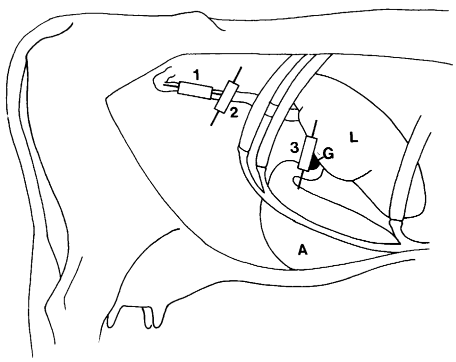

Fig. 22. Schematic representation of ultrasonographic examination of the duodenum in cows. L: liver, G: gallbladder, A: abomasum. (1) Position of the transducer for the longitudinal examination of the descending part of the duodenum. (2) Position of the transducer for the examination of the descending duodenum in cross-section. (3) Position of the transducer for examination of the cranial part of the duodenum (reproduced from Braun and Marmier, 1995).

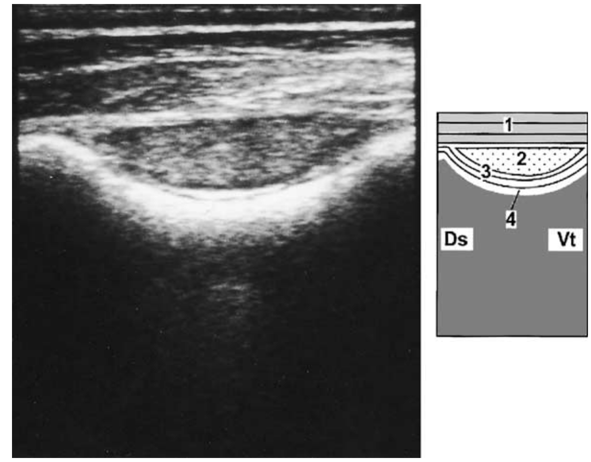

Fig. 24. Ultrasonogram of a cross-section through the descending part of the duodenum, viewed from the flank. The descending part of the duodenum is between the abdominal wall and the large intestine and is surrounded by the greater omentum. (1) Abdominal wall, (2) descending duodenum, (3) greater omentum, (4) colon. Ds: dorsal and Vt: ventral (reproduced from Braun and Marmier, 1995).

visualised. In contrast with results in dogs (Penninck et al., 1989), there is no difference between the diameter of most of the small intestine before and after feeding in cattle. This uniformity is probably because the forestomachs constitute a feed reservoir and ingesta passes along the intestine continuously, independent of feed intake, and without changes in the diameter of the intestinal lumen, which would be measurable by ultrasonography.

The cranial part of the duodenum is relatively easy to identify because it originates from the abomasum and is in close proximity with the liver and gallbladder (Fig. 22). It is seen in cross section or longitudinally, medial or ventral to the gallbladder and almost always from the

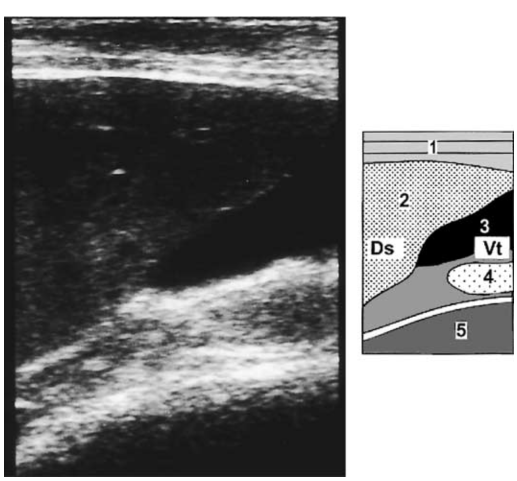

Fig. 23. Ultrasonogram of a cross-section through the cranial part of the duodenum, viewed from the 10th intercostal space. The cranial part of the duodenum lies medially to the gallbladder, which serves as an acoustic window. (1) Abdominal wall, (2) liver, (3) gallbladder, (4) cranial part of the duodenum, (5) omasum. Ds: dorsal and Vt: ventral (reproduced from Braun and Marmier, 1995).

10th or 11th intercostal space (Fig. 23). The diameter of the cranial part of the duodenum ranges from 0.9 to 5.5 cm (Braun and Marmier, 1995). The descending duodenum is also quite easily imaged in most cattle. From the 10th, 11th or 12th intercostal space and from the dorsal region of the right flank, it is observed in cross-section or longitudinally (Fig. 24). The following characteristics allow accurate identification of the descending duodenum: it is situated immediately adjacent to the abdominal wall and runs horizontally and caudally between the serosal lamellae of the omentum, which appears as an echogenic envelope around the descending duodenum. It then courses caudally to form the caudal duodenal flexure at the level of the tuber coxae. After this, it runs medially and cranially to form the ascending duodenum. The diameter of the descending duodenum varies from 1.5 to 3.5 cm. The ascending duodenum is situated more than 20.0 cm from the right abdominal wall and as a result cannot be imaged using ultrasonography.

The jejunum and ileum form the longest part of the small intestine and cannot be differentiated from one another ultrasonographically. It is typical to see more than ten loops of jejunum and ileum immediately adjacent to one another from the flank and lateral abdominal wall and from intercostal spaces 9 to 12 (Braun and Marmier, 1995). The loops of small intestine are usually seen in cross-section and occasionally longitudinally. They can be differentiated from the descending duodenum because they are not surrounded by omentum and because they are constantly in motion (Fig. 25). Loops of jejunum and ileum are seen from the 10th intercostal space in approximately 70% of cows and from the 9th intercostal space in approximately 10% cows. They are

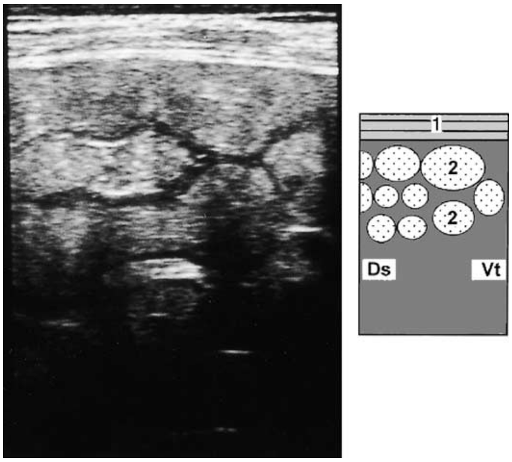

Fig. 25. Ultrasonogram of cross-sections through loops of the jejunum viewed from the flank. Several loops of jejunum, seen in cross-section, are situated immediately adjacent to one another. (1) Abdominal wall, (2) loops of jejunum. Ds: dorsal and Vt: ventral (reproduced from Braun and Marmier, 1995).

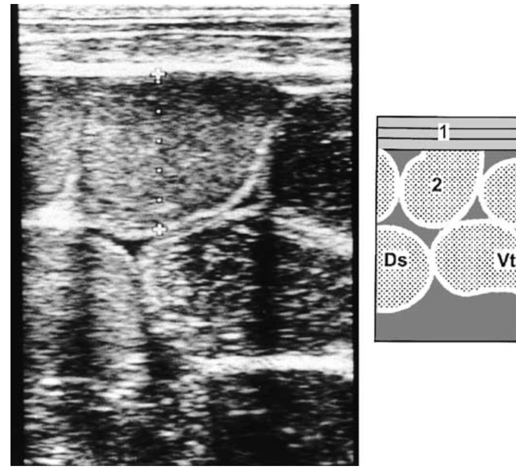

Fig. 26. Ultrasonogram of cross-sections through dilated loops of jejunum in a cow with an intussusception of the distal jejunum. The transducer was placed in the 12th intercostal space. The contents of the intestine appear echogenic. (1) Abdominal wall, (2) cross-section through loops of jejunum. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1995).

not usually seen from the 8th intercostal space. The diameter of the jejunum and ileum ranges from 2 to 4 cm. The number of loops of jejunum and ileum visible longitudinally and in cross-section are approximately the same when viewed from the flank and the 12th intercostal space, but decreases when viewed from successive intercostal spaces.

4.2. Ileus of the small intestine

When ileus of the small intestine is suspected, an ultrasonographic examination should evaluate the diameter, motility and anatomical arrangement of the small intestine, evidence of peritonitis and the possible cause of the ileus (Braun, 1997; Braun et al., 1995). The most important parameters are diameter and motility of the small intestine; identification of the cause of ileus using ultrasonography is however rarely possible. In cattle with ileus, the small intestine is dilated in at least one area and has a diameter of more than 3.5 cm (Braun et al., 1995). Moreover, the motility of the small intestine is usually reduced or absent. Sometimes, hypoechogenic fluid, attributable to transudation, is visible between the dilated loops of intestine.

Independent of the localisation of ileus and its cause, the loops of small intestine are most commonly imaged in cross-section (Fig. 26), often in both cross-section and longitudinally (Fig. 27) but rarely only longitudinally.

The site of ileus markedly affects the number of dilated loops of intestine seen in cross-section and longitudinally from either the flank or each intercostal space. When only one or a few, usually markedly dilated, loops of small intestine are seen (Fig. 28), ileus of the duodenum is most likely. More than five loops of small intestine seen in one area usually indicates ileus of the

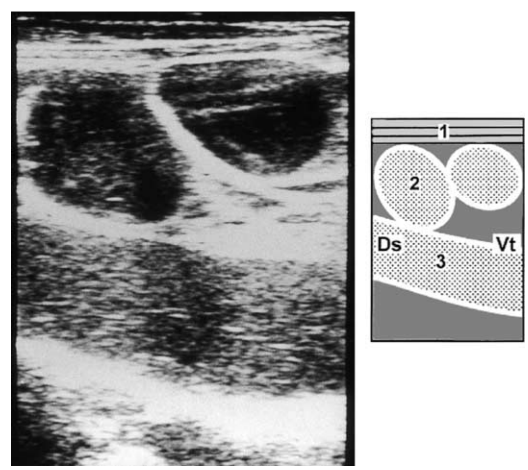

Fig. 27. Ultrasonogram of cross-sections and longitudinal views of dilated loops of jejunum in a cow with an intussusception of the distal jejunum. The transducer was placed in the 12th intercostal space. The contents of the loops viewed in cross-section appear hypoechogenic and those of the loops viewed longitudinally have an echogenic appearance. (1) Abdominal wall, (2) loop of jejunum in cross-section, (3) loop of jejunum viewed longitudinally. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1995).

jejunum or ileum. Rarely, when the ileus is localised in the proximal jejunum, only one or two dilated loops of small intestine are imaged. The number of dilated loops of small intestine increases if the localisation of the ileus is more distal. Conversely, in the 8th and 9th intercostal spaces, the number of dilated loops of small intestine generally decreases.

The loops become more dilated with ileus of the proximal small intestine. The largest diameter of intestine measured from the 12th intercostal space varied

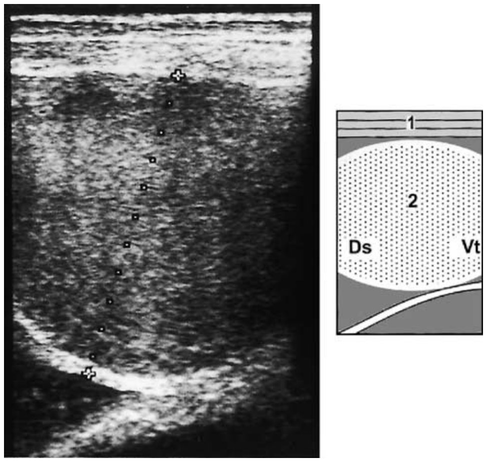

Fig. 28. Ultrasonogram of a cross-section through the dilated duodenum of a cow in which the descending duodenum was obstructed by a bezoar. The transducer was placed in the 11th intercostal space. The contents of the duodenum have an echogenic appearance and the diameter of the intestinal lumen is 8.5 cm. (1) Abdominal wall, (2) dilated duodenum in cross-section. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1995).

from 6.5 to 9.9 cm (7.7 ± 1.9) in animals with ileus of the duodenum, from 3.5 to 9.8 cm (5.5 ± 1.7) in animals with ileus of the jejunum and from 4.4 to 5.5 cm (5.0 ± 0.4 cm) in animals with ileus of the ileum (Braun et al., 1995). When interpreting the diameter of the intestine, it is important to remember that in healthy cows, in which the intestine is full of ingesta, all parts of the intestine will have a similar diameter. By contrast, in animals with ileus, in addition to the extremely dilated loops of intestine proximal to the ileus, there are usually empty loops of intestine distal to the ileus (Fig. 29). Furthermore, the intestinal lumen of a healthy cow is constantly changing, whereas the increased intestinal diameter of a cow with ileus remains unchanged because the intestinal motility is markedly reduced or absent.

The contents of the small intestine appear predominantly echogenic and rarely anechoic. Different parts of the intestine of the same animal may be echogenic or anechogenic. Intraluminal gas, which is associated with reverberation artifacts, is rarely observed.

In the majority of cows with ileus of the small intestine, intestinal motility is markedly reduced or absent. However, movement of intestinal contents often is apparent although no intestinal contractions are visible. This flowing movement is presumably due to the passive movement of the intestine by respiratory activity and possibly by the movement of adjacent organs such as the rumen or abomasum.

The cause of ileus can seldom be determined ultrasonographically. Often, this is because the cause of ileus is further from the abdominal wall than the penetration capacity of the transducer. A common cause of ileus is intussusception, the ultrasonographic appearance of which in cross-section has been described as bowel within bowel, bull's eye lesion, target pattern or as multiple layered, onion ring-type mass with varing echogenicities (Fig. 30). Typically, the invaginated intestinal wall is swollen. Depending on the severity of oedema and the imaging plane, the affected area of intestine may appear hyperechogenic or hypoechogenic. Viewed longitudinally, the typical lumen-

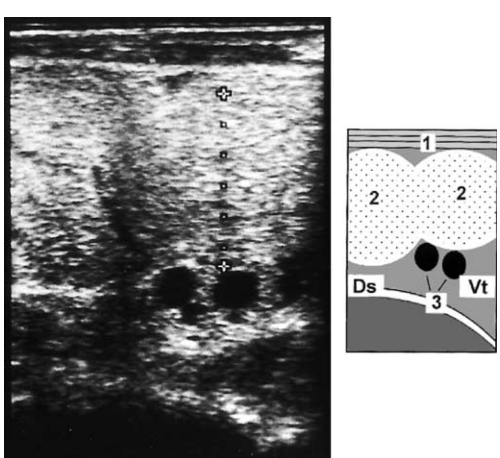

Fig. 29. Ultrasonogram of dilated prestenotic and empty poststenotic loops of jejunum of a cow with incarceration of the mid-jejunum in a hernia involving the left lateral abdominal wall. (1) Left lateral abdominal wall, (2) dilated prestenotic loops of intestine, (3) empty poststenotic loops of intestine containing a small amount of hypoechogenic fluid. Ds: dorsal and Vt: ventral.

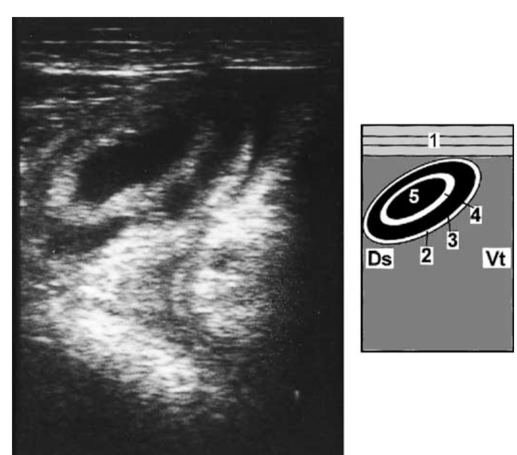

Fig. 30. Ultrasonogram of an intussusception of the distal jejunum. The transducer was placed on the right lateral abdominal wall. The intussusception has the appearance of multiple concentric rings. A hyperechogenic outer ring surrounds an echo-poor area and an inner highly reflective ring with an anechogenic centre. (1) Abdominal wall, (2) hyperechogenic outer ring (wall of intussuscipiens), (3) Echo-poor area, (4) highly reflective inner ring (wall of intussusceptum), (5) anechogenic centre. Ds: dorsal and Vt: ventral (reproduced from Braun et al., 1995).

within-a-lumen can be clearly identified and has been described as a "sandwich" configuration. In rare cases, compression of the small intestine by abscesses in the region of the liver or compression of the duodenum between the liver and gallbladder can be identified. Ileus can also be caused by generalised peritonitis with fibrinous adhesions involving the small intestine. In such cases, thickening of the intestinal wall, fibrinous deposits and accumulation of intraabdominal fluid are usually seen.

Failure of ingesta to pass through the small intestine results in delayed passage of ingesta through the abomasum, omasum and rumen, which consequently become dilated (see Section 3.5).

Uncomplete perforation of the intestine usually leads to chronic peritonitis. Ultrasonographically, this is seen as intraabdominal fluid with bands of fibrin, which may have a spiderweb-type of appearance among the loops of intestine and organs. Free intra-abdominal gas with its associated reverberation artifacts may be seen if intestinal gas has leaked through the perforation.

4.3. Normal large intestine

Carbohydrates remaining in the ingesta after their passage through the forestomachs are fermented in the large intestine, and the gas produced makes it more difficult to image this section of the bowel (Marmier, 1993). The large intestine is always visible from the flank and is situated medial to the descending duodenum, whereby the colon is more dorsal and the proximal loop of the colon and caecum are more ventral. The large intestine is usually easy to differentiate from the small intestine based on its marked gas content (Amrein, 1999; Braun and Amrein, 2001; Marmier, 1993). Because of the gas, only the wall of the large intestine closest to the transducer can usually be imaged and appears as a thick echogenic line. However, reverberation artifacts originating from the tissue-gas interphase may become superimposed on the image of the wall and obscure it. The wall of the large intestine furthest from the transducer cannot be imaged. Usually, the proximal loop of the large colon, the caecum and the colon can be visualised. The proximal loop of the large colon and the caecum appear as thick, echogenic, continuous and slightly curved lines (Fig. 31). The spiral loop of the colon has the appearance of a garland with a number of echogenic arched lines next to each other (Fig. 32). In contrast to the small intestine, which has vigorous peristaltic activity and segmental contractions, very few contractions are observed in the large intestine.

4.4. Caecal dilatation

Diagnosis of caecal dilatation usually is straightforward but may be difficult when the dilatation is complicated by retroflexion of the caecum. In that case, either no abnormal findings can be palpated, or a distended viscus can be palpated only with the tips of the fingers. The differential diagnoses must include ileus of the small intestine and right displacement of the abomasum, respectively. A diagnosis by clinical examination alone may not be possible, but ultrasonography allows the differentiation between right displacement of the abomasum, ileus of the small intestine and caecal dilatation. A dilated caecum can always be imaged from the lateral abdominal wall (Amrein, 1999; Braun et al.,

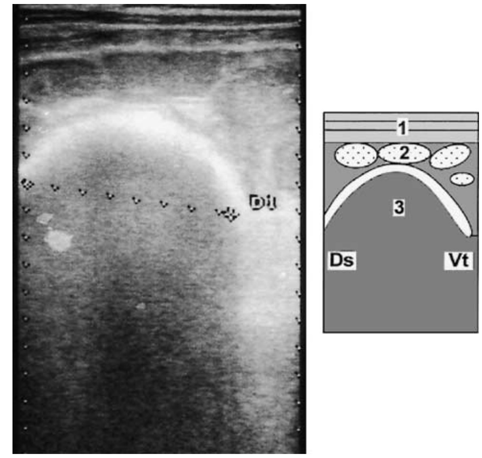

Fig. 31. Ultrasonogram of a cross-section of the caecum viewed from the flank. The caecal wall closest to the transducer is echogenic and the wall furthest from the transducer cannot be visualised because of the gas content of the caecum. Several loops of small intestine, viewed in cross-section, are seen between the abdominal wall and caecum. (1) Abdominal wall of right flank, (2) cross-sections of loops of small intestine, (3) caecum. Ds: dorsal and Vt: ventral (reproduced from Braun, 1997).

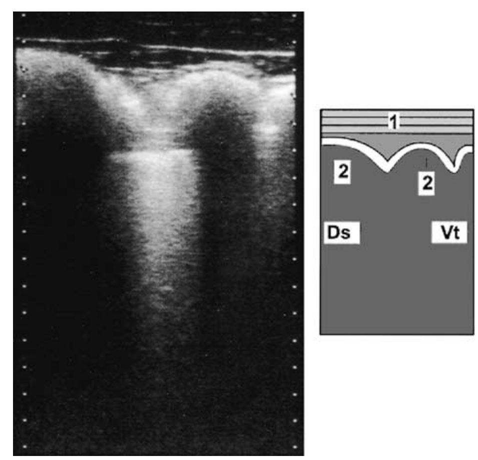

Fig. 32. Ultrasonogram of a cross-section of the spiral colon viewed from the flank. The portion of colon has a garland-like appearance. The wall of the colon closest to the transducer appears echogenic. (1) Abdominal wall of right flank, (2) Colon. Ds: dorsal and Vt: ventral (reproduced from Braun, 1997).

2002a) and in some cases, may be seen from the 12th, 11th and 10th intercostal spaces. The dilated caecum and the proximal loop of the colon are almost always immediately adjacent to the abdominal wall. Because of the gaseous contents, only the wall of the dilated caecum (Fig. 33) and proximal loop of the colon closest to the transducer are seen ultrasonographically and appear as thick, echogenic, semi-circular lines (Fig. 34). In cases with fluid ingesta instead of gaseous contents in the caecum and proximal loop of the colon, the lumen appears moderately echogenic. Differentiation of caecum and proximal loop of the colon may be difficult ultrasonographically unless the ileocaecal fold of the peritoneum between the two can be identified.

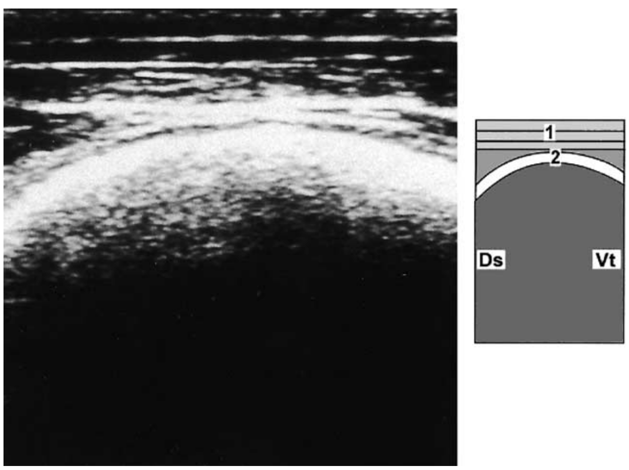

Fig. 33. Ultrasonogram of a dilated caecum of a cow with caecal dilatation and torsion viewed from the right flank. The caecal wall closest to the transducer appears as a curved echogenic line. The caecal contents and wall furthest from the transducer are not visible. (1) Lateral abdominal wall, (2) caecal wall. Ds: dorsal and Vt: ventral (reproduced from Braun, 1997).

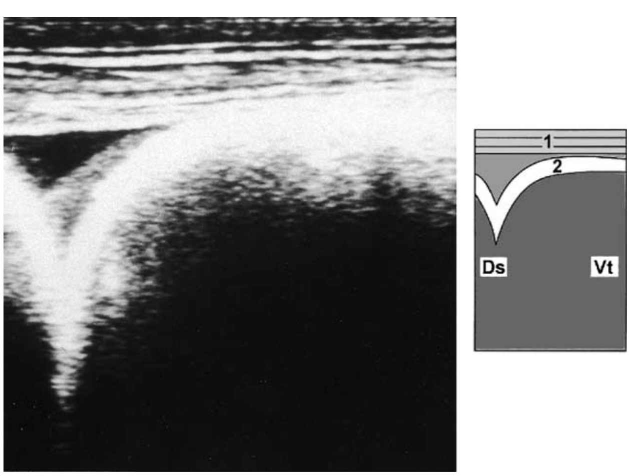

Fig. 34. Ultrasonogram of part of the spiral colon of a cow with caecal dilatation and torsion viewed from the right flank. The intestinal wall closest to the transducer appears echogenic. (1) Lateral abdominal wall, (2) part of the colon. Ds: dorsal and Vt: ventral (reproduced from Braun, 1997).

References

Amrein, E.M., 1999. Ultraschalluntersuchungen bei Kühen mit Blinddarmdilatation. DrMedVet Thesis, Faculty of Veterinary Medicine, University of Zurich.

Braun, U., 1997. Atlas und Lehrbuch der Ultraschalldiagnostik beim Rind. Parey Buchverlag, Berlin.

Braun, U., Amrein, E., 2001. Ultrasonographic examination of the caecum and proximal and spiral loop of the colon of cattle. The Veterinary Record 149, 45–48.

Braun, U., Amrein, E., Koller, U., Lischer, C., 2002a. Ultrasonographic findings in cows with dilatation, torsion, and retroflexion of the caecum. The Veterinary Record 150, 75–79.

Braun, U., Flückiger, M., Götz, M., 1994. Comparison of ultrasonographic and radiographic findings in cows with traumatic reticuloperitonitis. The Veterinary Record 135, 470–478.

Braun, U., Flückiger, M., Nägeli, F., 1993a. Radiography as an aid in the diagnosis of traumatic reticuloperitonitis in cattle. The Veterinary Record 132, 103–109.

Braun, U., Götz, M., 1994. Ultrasonography of the reticulum in cows. American Journal of Veterinary Research 55, 325–332.

Braun, U., Götz, M., Marmier, O., 1993b. Ultrasonographic findings in cows with traumatic reticuloperitonitis. The Veterinary Record 133, 416–422.

Braun, U., Iselin, U., Lischer, C., Fluri, E., 1998a. Ultrasonographic findings in five cows before and after treatment of reticular abscesses. The Veterinary Record. 142, 184–189.

Braun, U., Marmier, O., 1995. Ultrasonographic examination of the small intestine of cows. The Veterinary Record 136, 239–244.

Braun, U., Marmier, O., Pusterla, N., 1995. Ultrasonographic examination of the small intestine of cows with ileus of the duodenum, jejunum, or ileum. The Veterinary Record 137, 209–215.

Braun, U., Pusterla, N., Schönmann, M., 1997c. Ultrasonographic findings in cows with left displacement of the abomasum. The Veterinary Record 141, 331–335.

Braun, U., Schweizer, G., Flückiger, M., 2002b. Radiographic and ultrasonographic findings in three cows with reticulo-omasal obstruction due to a foreign body. The Veterinary Record 150, 580–581.

Braun, U., Wild, K., Guscetti, F., 1997a. Ultrasonographic examination of the abomasum of 50 cows. The Veterinary Record 140, 93–98.

Braun, U., Wild, K., Merz, M., Hertzberg, H., 1997b. Percutaneous ultrasound-guided abomasocentesis in cows. The Veterinary Record 140, 599–602.

Götz, M., 1992. Sonographische Untersuchungen an der Haube des Rindes. DrMedVet Thesis, Faculty of Veterinary Medicine, University of Zurich.

Gürtler, H., 1980. Die Physiologie der Verdauung und Absorption. In: Kolb, E. (Ed.), Lehrbuch der Physiologie der Haustiere. Veb Gustav Fischer, Stuttgart, pp. 177–339.

Kaske, M., Midasch, A., Rehage, J., 1994. Sonographic investigation of reticular contractions in healthy sheep, cows, and goats and in cows with traumatic reticulo-peritonitis. Journal of Veterinary Medicine, Series A 41, 748–756.

Marmier, O., 1993. Sonographische Untersuchungen am Darm des Rindes. DrMedVet Thesis, Faculty of Veterinary Medicine, University of Zurich.

Penninck, D.G., Nyland, T.G., Fisher, P.E., Kerr, L.Y., 1989. Ultrasonography of the normal canine gastrointestinal tract. Veterinary Radiology 30, 272–276.

Wild, K., 1995. Sonographische Untersuchungen am Labmagen des Rindes. DrMedVet Thesis, Faculty of Veterinary Medicine, University of Zurich.