Ultrasonography of the liver in cattle

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Abstract

Hepatic diseases are of great importance in cattle. Fascioliasis, hepatic abscesses, hepatic neoplasia, metabolic disturbances (eg, fatty liver disease) and diseases of major vessels (eg, thrombosis of the caudal vena cava) caused by hepatic abscesses that have broken into the vein are some examples. Until recently, diagnosis of many hepatic diseases was difficult because signs may be nonspecific. In many cases, diagnostic methods such as hepatospecific enzyme tests are insufficient. A complete ultrasonographic examination of the liver should give detailed information about the size, position, and ultrasonographic parenchymal pattern of the liver, the size and position of the gallbladder and the intra- and extrahepatic bile ducts, and the topography of the major vessels. Ultrasound-guided collection of hepatic biopsy samples, centesis and aspiration of abscesses, and cholecystocentesis and aspiration of bile samples (for examination for fluke eggs and determination of bile acids concentration) can be performed safely. In the first part of this article, the methods of ultrasonographic examination of the liver and the ultrasonographic appearance of the normal liver are discussed, followed in the second part by a description of specific liver diseases.
Ultrasonography of the liver in cattle

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Abstract

The ultrasonographic examination of the liver is performed on the right side of the standing animal using a real-time 3.5 to 5.0 MHz linear or convex transducer. Depending on the patient, cholecystocentesis and aspiration of a bile sample for microscopic examination, collection of a liver biopsy sample or aspiration of an abscess may be performed. The parenchymal pattern of the normal liver consists of numerous weak echoes homogeneously distributed over the entire liver. The portal and hepatic veins can be seen within the liver, and their diameter increases toward the portal vein and the caudal vena cava. The intrahepatic bile ducts are only visible when they are calcified or when there is bile stasis. The caudal vena cava has a characteristic triangular shape on cross section. The portal vein is circular on cross section and has stellate ramifications into the hepatic parenchyma. The normal gallbladder is a pear-shaped cystic structure of variable size and is easy to recognize. Cholecystocentesis and examination of the bile should always be performed in cows with suspected hepatic disease. Hepatic abscesses result in circumscribed structural changes in the hepatic parenchyma. The content of the abscess appears anechogenic to hyperechogenic. Hepatic tumors may appear homogeneous or heterogeneous. Tumors situated on the surface of the liver result in a circumscribed bulge in the hepatic contour. In cases with rupture of a tumor into a vessel, echogenic thrombi may be seen. In cases with diffuse fatty liver disease, the number and intensity of the internal echoes increases as the severity of the disease increases. In advanced stages of the disease, the liver appears white on ultrasonograms and is difficult to differentiate from surrounding tissue. Calcified bile ducts, caused by chronic fascioliasis, result in discrete sonographic changes in the liver parenchyma. They are intensely hyperechogenic and accompanied by an acoustic shadow distally. In cross section, calcified bile ducts appear as ring-like and in longitudinal section, tube-like hyperechogenic structures. Obstructive cholestasis can almost always be diagnosed on the basis of the observation of dilated bile ducts. A proximal obstruction, which occurs in the area of the hepatic hilus, can...
be differentiated from a distal obstruction, which occurs in the region of the duodenal papilla. With a proximal obstruction, only the intrahepatic bile ducts are dilated. With a distal obstruction, there is dilatation of the common bile duct and the gallbladder, which may be associated with dilatation of the intrahepatic bile ducts. In cows with congestion of the caudal vena cava, the caudal vena cava loses its normal triangular shape and becomes round to oval on ultrasonograms. At the same time, the diameter of the vein increases. Ultrasonography is a valuable tool for the diagnosis of liver disease. Discrete or diffuse lesions can be imaged, aspirated and biopsied under visual guidance. However, ultrasonography cannot be used to evaluate liver regions obscured by the lungs.

**Introduction**

Hepatic diseases are of great importance in cattle. Fascioliasis, hepatic abscesses, hepatic neoplasia, metabolic disturbances such as fatty liver disease and diseases of major vessels such as thrombosis of the caudal vena cava caused by hepatic abscesses that have broken into the vein are some examples. Until recently, diagnosis of many hepatic diseases was difficult because signs may be nonspecific. In addition, in many cases, diagnostic methods such as hepatospecific enzyme tests are insufficient. A complete ultrasonographic examination of the liver should give detailed information about the size, position and ultrasonographic parenchymal pattern of the liver, the size and position of the gallbladder and the intra- and extra hepatic bile ducts as well as the topography of the major vessels. Furthermore, ultrasound-guided collection of hepatic biopsy samples, centesis and aspiration of abscesses and cholecystocentesis and aspiration of bile samples (for examination for fluke eggs and determination of bile acids concentration) can be performed safely. In the first part of this review the methods of ultrasonographic examination of the liver and the ultrasonographic appearance of the normal liver are discussed, followed in the second part by a description of specific liver diseases.
Ultrasonographic examination of the liver and normal findings

The bovine liver is situated immediately adjacent and medial to the right body wall; its cranial aspect is hidden by lung. The ultrasonographic examination is performed on the right side of the standing animal. The liver is examined ultrasonographically from caudal to cranial, beginning caudal to the last rib and ending at the 5th intercostal space and from dorsal to ventral in every intercostal space using a real-time 3.5 to 5.0 MHz linear or convex transducer [1-4]. First, the various hepatic structures are assessed subjectively, and then the exact size of some of them is determined. Depending on the patient, cholecystocentesis and aspiration of a bile sample for microscopic examination, collection of a liver biopsy sample or aspiration of an abscess may be performed.

Subjective assessment of hepatic structure

Subjective assessment of hepatic structure includes assessment of the hepatic parenchyma, the position of the liver, the diaphragmatic and visceral surfaces, the angle of the liver, the caudal vena cava, the hepatic veins, the portal vein and its branches in the hepatic parenchyma, the gallbladder and the biliary system. Dorsally, the liver can be imaged to the ventral acute margin of the lung. Parts of the liver beneath the lungs cannot be visualized via ultrasonography. The reticulum is seen adjacent to the liver in the 6th and 7th intercostal spaces; it appears as a half moon-shaped structure and is characterized by regular biphasic contractions [5, 6]. In the 8th to the 10th intercostal spaces, the liver is adjacent to the omasum, the wall of which is clearly recognizable as a thick echogenic line [7, 8]. Loops of intestine are situated adjacent to the liver in the 11th and 12th intercostal spaces [9, 10]. In most cases, the right kidney can be imaged high dorsally in the 12th intercostal space where the so called hepatic window is created at the site of the impressio renalis of the liver [11].
The measurable size of the liver is largest in the intercostal spaces 10 to 12 and becomes progressively smaller cranially because of superimposition of the lungs. The parenchymal pattern of the normal liver consists of numerous weak echoes homogeneously distributed over the entire liver. The portal and hepatic veins can be seen within the liver, and their diameter increases toward the portal vein and the caudal vena cava. The lumen of these vessels appears anechoic. In contrast to the hepatic veins, the wall of the portal veins is characterized by an echogenic border that facilitates its identification. The portal veins can be clearly differentiated from the hepatic vein only in the area of the stellate ramifications of the portal vein. The intrahepatic bile ducts are only visible when they are calcified or when there is bile stasis.

The caudal vena cava is always situated more dorsally and medially than the portal vein and usually can be visualized in the 12th and 11th intercostal spaces (Fig. 1). It is rarely visualized in the 10th intercostal space and never in the more cranial intercostal spaces, because it is hidden by the lungs. The caudal vena cava has a characteristic triangular shape on cross section, because it is embedded in the sulcus of the vena cava in the liver. The diameter of the caudal vena cava does not change from the 12th intercostal space to the 10th intercostal space and measures from 1.8 to 5 cm (Table 1) [1]. Toward the liver, hepatic veins are seen joining the caudal vena cava. The common trunk of the left gastric vein and the splenic vein or individual splenic and gastric veins are observed in cross section before they unite, medial to the caudal vena cava and outside of the hepatic parenchyma. These veins are usually circular on cross section.

The portal vein is always situated ventrally and laterally to the caudal vena cava and is usually visible in the 12th to 8th intercostal spaces (Fig. 2). The portal vein is circular on cross section and has stellate ramifications into the hepatic parenchyma. The diameter of the portal vein in the 12th and 11th intercostal spaces is between 2.9 and 5.3 cm and decreases cranially. In contrast to the hepatic veins, the walls of the portal veins are easier to identify
because they are characterised by an echogenic border. Differentiation of hepatic and portal veins is only possible in the area of the stellate branching of the portal vein.

The gallbladder is situated between the 9th and 11th intercostal spaces. It is usually visible in one, sometimes in two and rarely in three intercostal spaces. The normal gallbladder is a pear-shaped cystic structure of variable size and is easy to recognize (Fig. 3). Ultrasonographically, the gallbladder has an image typical of a fluid-filled vesicle and thus on ultrasonograms appears almost anechoic surrounded by a thin white rim. The gallbladder is situated on the visceral surface of the liver. Depending on the degree of fullness, the gallbladder extends beyond the ventral liver margin such that it becomes situated directly adjacent to the abdominal wall. The size of the gallbladder varies greatly. By following the neck of the gallbladder and the cystic duct, one usually can identify the common hepatic duct. The common bile duct cannot always be visualized. It originates from the cystic duct several centimeters away from the neck of the gallbladder. It sometimes can be seen at this point where in cross section it appears as a circular structure, with a diameter of approximately 0.3 cm. Normally, the course of the common bile duct to the duodenal papilla cannot be imaged.

Assessment of position and size of the liver and its vessels

To quantitate findings that were obtained by subjective assessment, the position and size of the liver and its vessels can be determined by measuring various structures in individual intercostal spaces. Examples are the determination of the dorsal and ventral margins of the liver and the size of the liver in different intercostal spaces and the diameters of the caudal vena cava and the portal vein and the thickness of the liver over these vessels. The method of measurement has been described in detail [1-4]. The dorsal and ventral margins of the liver are measured in relation to the midline of the back. For example, the dorsal margin is determined by measuring the distance between the dorsal margin of the liver and the midline of the back using a tape measure. Determination of the ventral margin of the liver is analogous. The
visible size of the liver in a given intercostal space is determined by subtracting the distance between the dorsal liver margin and midline of the back from the distance between ventral liver margin and midline of the back [1,2,4]. For determination of the diameter of the caudal vena cava and the portal vein and the thickness of the liver over these vessels, the ultrasonographic image is electronically stored at maximal inspiration of the cow. The appropriate measurements are then made electronically on the ultrasonogram by means of the two cursors. The means and ranges determined from a study involving 186 cows were reported [2-4]. The results indicate that breed and age do not influence the different variables. However, there are significant correlations between body size, height at the withers, milk production and several of the variables determined by ultrasonography. There is also a correlation between the stage of pregnancy and variables determined by ultrasonography. The diameter of the caudal vena cava increases with advancing pregnancy; in contrast, the diameter of the portal vein decreases.

**Ultrasound-guided cholecystocentesis**

Cholecystocentesis should always be performed in cows with suspected hepatic disease, especially if fascioliasis is a possibility. Microscopic examination of bile for liver fluke eggs is the most reliable method of diagnosing fascioliasis [12-14]. In cows with chronic fascioliasis and negative fecal findings, cholecystocentesis and microscopic examination of bile is the best diagnostic method. Bacteriological and cytological examination of bile is important in cows with suspected cholecystitis or pyocholecystitis. Inflammatory changes and, or bacteria such as *Fusobacterium necrophorum* have been detected in the bile of cows with cholestasis [15]. The risk of bile peritonitis is low when percutaneous ultrasound-guided cholecystocentesis is performed carefully. Complications related to cholecystocentesis did not occur in short and long term studies in cows [3]. In cows, the gallbladder is readily accessible for ultrasonographic examination and centesis. The dorsal area of the gallbladder is accessible
only transhepatically, because it is situated on the visceral surface of the liver. Depending on the amount of bile, the gallbladder may extend beyond the ventral margin of the liver so that it lies adjacent to the abdominal wall where it can be reached transperitoneally. Thus, the gallbladder can be reached transhepatically or transperitoneally. In humans, the transhepatic approach to the gallbladder is considered the safest, because the liver acts to seal off the site of centesis, thus reducing the risk of bile peritonitis caused by leakage of bile into the abdomen [16]. In our experience involving over 1000 cows, transperitoneal cholecystocentesis appears to be as safe as transhepatic cholecystocentesis. Percutaneous cholecystocentesis is performed at the location where the gallbladder is best visualized via ultrasonography. This is usually in the 10th or 11th intercostal space. A spinal needle (20 gauge x 3.5 inches) with stylet is introduced and guided by ultrasonography through the skin and abdominal wall toward the gallbladder (Fig. 4). Depending on the position of the gallbladder, the needle is advanced transhepatically or transperitoneally to the wall of the gallbladder, and with a slight thrust, is pushed through. The end of the needle within the gallbladder is usually visible in ultrasonograms. The stylet is removed and, using a syringe, 10 ml of bile is aspirated. The bile sample can be used for the bacteriological and cytological examination or for the determination of bile acids; however, it is not suitable for the microscopic detection of liver fluke eggs, because the latter are not evenly distributed within the bile but rather sediment to the lowest point in the gallbladder. To stir up liver fluke eggs, 10 ml of isotonic NaCl solution is infused in the gallbladder. Immediately after, 10 ml of diluted bile is aspirated for examination for liver fluke eggs. Bile is poured into a centrifuge tube and placed in a refrigerator overnight. Then the sediment is aspirated by use of a Pasteur pipette, placed on a glass slide, and examined microscopically.

Hepatic abscess
The ultrasonographic examination is of substantial importance in the diagnosis of hepatic abscesses in cows. The ultrasonographic appearance of hepatic abscesses has been described in feedlot cattle [17-21], in cows [22, 23] and in a breeding bull [24]. In cattle with experimentally induced hepatic abscesses, the portal vein was inoculated with *Fusobacterium necrophorum* under ultrasonographic guidance [17, 19]. The development and ultrasonographic appearance of the hepatic abscesses were then recorded via regular ultrasonographic examinations, and it was shown that the ultrasonographic appearance changed during the course of disease.

Abscesses result in circumscribed structural changes in the hepatic parenchyma (Fig. 5). The ultrasonographic appearance of hepatic abscesses in cattle is variable. The content of the abscess appears anechogenic to hyperechogenic. Abscesses may appear homogeneous or heterogeneous. A heterogeneous ultrasonogram with single or multiple hyperechogenic foci and no evidence of a capsule indicates an early stage in the development of the abscess. Homogeneous content, capsule formation and substantial size (Fig. 6) indicate that the abscess is long-standing. The abscess may be divided into several chambers by septa which indicates partial destruction of the liver. The individual compartments may become confluent during the course of the disease. The diameter of an abscess ranges from 3 to 20 cm, and the abscess may extend across one to five intercostal spaces [22].

*Aspiration of hepatic abscesses*

A diagnosis of hepatic abscess often cannot be made based solely on its ultrasonographic appearance, because the appearance of hepatic abscesses varies greatly and may change with time. The differential diagnosis of circumscribed changes in the liver must include neoplasia and cysts. Thus, ultrasound-guided centesis of such changes should be performed to confirm the diagnosis [22]. It is important that the needle (20 G x 3 ½”, 0.90 x 90 mm) used for centesis is closed with a stylet during introduction into and withdrawal from the lesion. A
definitive diagnosis of hepatic abscess can be made in nearly all cases based on the macroscopic nature of the aspirated material. When in doubt, the latter can be examined bacteriologically and cytologically.

*Treatment of liver abscesses*

In the author’s experience, multiple small abscesses with a diameter of less than 3 cm can often be effectively treated with a broad-spectrum antibiotic, such as amoxicillin, over 14 days. Percutaneous ultrasound-guided lancing and draining can be attempted to treat larger solitary abscesses provided that they are situated immediately adjacent to the abdominal wall. It may be possible to drain abscesses located further away from the abdominal wall via laparotomy [25] or through the reticulum [26]. However, cattle often have multiple abscesses, for example in the caudal vena cava or lungs, and treatment is not indicated in these patients. Therefore, it is critical that other organs be examined.

**Hepatic tumors**

Hepatic tumors are rare in cattle. Most are metastatic tumors that reach the liver from the gastrointestinal tract via the portal vein or from the lungs via the hepatic artery. In rare cases the tumor may originate in the liver. Hepatic tumors are divided into hepatocellular and cholangiocellular adenoma and carcinoma [27]. Hepatocellular carcinoma is usually solitary and may be surrounded by intrahepatic metastases. Occasionally, the tumor may penetrate through the capsule and attach itself to the peritoneum. It is characteristic for a hepatocellular carcinoma to rupture into the large hepatic veins and caudal vena cava [27]. The tumors also may extend to the portal vein, spleen and stomach, which may result in portal hypertension. Cholangiocellular carcinomas are usually multifocal or diffuse; rarely are they solitary tumors. The liver of animals with this type of tumor is otherwise usually normal.
Ultrasonographically, hepatic tumors are characteristically single or multiple circumscribed structures [28]. The ultrasonographic appearance of bile duct carcinoma, adenocarcinoma and hepatocellular adenoma have been described in cattle [28]. The ultrasonographic features of hepatic tumors essentially reflect changes in the shape and texture of the liver and displacement of vessels and bile ducts [29]. The neoplastic changes may appear homogeneous or heterogeneous [28]. Tumors situated on the surface of the liver result in a circumscribed bulge in the hepatic contour. In addition, the ultrasonographic appearance of most metastases is different from that of the liver (Fig. 7). There are also metastases that have the same echogenicity as the liver; they are recognized as bulges in the contour of the liver. The echogenic pattern of metastases varies greatly and depends upon its vascularity and rate of growth. Rapidly growing metastases that are composed of predominantly tumor cells are hypoechochogenic, because they have few acoustic surfaces. In contrast, slowly growing metastases usually contain vascular and connective tissue and thus appear more echogenic. In cases with rupture of a tumor into a vessel, echogenic thrombi may be seen. Occasionally the portal vein becomes congested when there is a decrease in liver perfusion [28]. Percutaneous ultrasound-guided liver biopsy is recommended to confirm a tentative diagnosis of neoplasia and in most cases can be used to determine the type of tumor.

**Diffuse hepatic disease**

Many diseases result in diffuse hepatic damage with non specific ultrasonographic features; the echogenicity may be increased or decreased, and in contrast to circumscribed structural changes, the liver is uniformly affected. Fatty liver degeneration is the most common hepatic disease with a diffuse distribution of lesions. Hepatic cirrhosis and congestion are seen less often.

Diffuse hepatic damage is often observed on ultrasonograms, but its ultrasonographic features are not very specific [29]. Thus, a liver biopsy sample is usually obtained to aid in the
diagnosis. Diffuse hepatic disease is often accompanied by enlargement of and an increase in the weight of the liver. Therefore, estimating the weight of the liver using ultrasonographic measurements may aid in diagnosing diffuse hepatic disease. The most reliable criterion is the thickness of the liver as measured over the caudal vena cava and over the portal vein [2]. The weight of the liver \( y \) (kg) can be estimated using the formula \( y = -3.97 + 1.036 \times \text{thickness of liver (cm)} \) measured in the eleventh intercostal space (\( r = 0.76, p < 0.01 \)). Other indications of enlargement of the liver are rounding and blunting of the margins of the liver and an increase in the ventral angle of the liver.

**Fatty liver disease**

In cases with diffuse fatty liver disease, the number and intensity of the internal echoes increases as the severity of the disease increases [30-32]. In advanced stages of the disease, the liver appears white on ultrasonograms and is difficult to differentiate from surrounding tissue. In severe fatty liver disease, weakening of the echoes occurs as the distance from the abdominal wall increases, because the fat-containing hepatocytes enhance the acoustic impedance. The result is that the region near the abdominal wall is hyperechogenic, whereas areas more distant are hypoechoegenic or cannot be imaged at all (Fig. 8). The contrast between the liver and vessels is also decreased. Often only large vessels are seen; small vessels may be poorly imaged or not be seen at all. This is because the small vessels are compressed by swollen hepatic tissue [29]. In addition, in the hyperechogenic areas of the diseased liver there is an increase in scattered echoes. These project onto the vessels resulting in deterioration of the contrast between the hepatic parenchyma and hepatic vessels. A number of authors have tried with moderate success to determine the fat content of the liver using its ultrasonographic echogenicity [30-33]. A more promising method appears to be calibrated computer-aided B-mode ultrasonography [34]. The mean transcutaneous liver tissue echo level correlates well with liver fat score (\( r = 0.80 \)). The most reliable method of determining
the fat content of the liver is histological evaluation of a liver biopsy sample. In rare cases, multifocal areas of fat deposition can be recognized in the liver (Fig. 9) [35]. These fatty areas are intensely echogenic and contrast the rest of the hepatic parenchyma.

**Congestion of the liver**

As a result of an increased fluid content with systemic congestion, the liver becomes enlarged and has noticeably fewer parenchymal echoes. Chronic liver congestion eventually leads to an increase in the amount of connective tissue in the liver. The ultrasonographic appearance then changes from that of acute liver congestion to one similar to that seen with liver cirrhosis, in which the parenchyma appears heterogeneous and hyperechogenic with strong individual echoes.

**Seneciosis**

Diseases caused by the ingestion of poisonous plants of the *Senecio* species are common and have the greatest economic impact of all plant poisonings. Plants of the *Senecio* spp. contain toxic substances termed pyrrolizidine alkaloids [27, 36], which constitute cumulative hepatotoxins after transformation in the liver to pyrrole metabolites. They inhibit mitosis of hepatocytes and cause megalocytosis. Proliferation of the endothelium of the centrilobular and hepatic veins results in the occlusion of these vessels and in veno-occlusive fibrosis. Other hepatic changes are generalised fibrosis and hyperplasia of bile ducts. This leads to impaired hepatic perfusion and to portal hypertension with ascites. Ultrasonographic evaluation of patients with seneciosis reveals an enlarged and heterogeneous liver with echogenic nodular lesions (Fig. 10) [37]. Endothelial proliferation in the centrolobular veins and veno-occlusive fibrosis result in decreased blood flow from the hepatic veins into the caudal vena cava. The lumina of the hepatic veins and caudal vena cava are therefore distinctly smaller than normal on ultrasonograms. There is concurrent congestion in the portal
vein, which leads to intrahepatic portal hypertension and an increase in the diameter of the portal vein. The results can be imaged via ultrasonography and include ascites and edema of the omentum, mesentery, gastrointestinal tract and gallbladder wall [37]. In advanced stages of the disease, histological evaluation of a liver biopsy sample reveals severe liver fibrosis, which alerts the clinician to the possibility of seneciosis.

**Bile ducts and gallbladder**

*Calcification of the bile ducts*

The most common cause of bile duct calcification is chronic fascioliasis. Calcified bile ducts result in discrete sonographic changes in the liver parenchyma. They are intensely hyperechogenic and accompanied by an acoustic shadow distally. In cross section, calcified bile ducts appear as ring-like (Fig. 11) and in longitudinal section, tube-like hyperechogenic structures.

*Cholestasis*

In obstructive cholestasis, the flow of bile is *mechanically* impaired. The most common causes of biliary obstruction in cattle are fascioliasis, fibrinous or purulent products and solid deposits; other less common causes include gall stones and tissue proliferation [38]. Inflammatory products that result from cholangitis may also impair the flow of bile. In rare cases, the flow of bile may be obstructed by compression of the major bile ducts by tumours, abscesses or peritoneal changes. In cows with suspected cholestasis, the diagnostic examination should include the determination of the activities of hepatic enzymes, ultrasonographic examination of the liver, histological examination of a liver biopsy specimen and ultrasound-guided cholecystocentesis with examination of a bile sample [39]. Obstructive cholestasis can almost always be diagnosed on the basis of the observation of dilated bile ducts. Ultrasonographic assessment of the dilatory pattern of the intra- and extrahepatic bile
ducts and of the gallbladder may reveal the location of the obstruction and other abnormalities, such as a hepatic abscess. A proximal obstruction, which occurs in the area of the hepatic hilus, can be differentiated from a distal obstruction, which occurs in the region of the duodenal papilla. With a proximal obstruction, only the intrahepatic bile ducts are dilated. With a distal obstruction, there is dilatation of the common bile duct and the gallbladder, which may be associated with dilatation of the intrahepatic bile ducts. Normally, the intrahepatic bile ducts, which run parallel to the branches of the portal vein, are not visible ultrasonographically, however, when they are dilated they become visible (Fig 12). Severe congestion results in lacunar dilatation of the bile ducts (Fig 13).

Dilatation of the gallbladder alone is not an indication of cholestasis. In many anorexic cows, there is no reflex stimulus for emptying of the gallbladder, and its volume increases without any impairment of the flow of bile. However, thickening of the wall of the gallbladder due to inflammation suggest disease. An abnormal gallbladder content, such as sediment or concretion, without thickening of the wall of the gallbladder, can also be observed in anorexic cows with various problems not specific to the liver. The content of the gallbladder can appear homogeneous or heterogeneous. A homogeneous content usually appears echogenic and a heterogeneous content consists of an echogenic sediment and a hypoechogenic supernatant (Fig. 14). Thickening of the wall of the gallbladder without other signs of cholestasis suggests oedematous rather than inflammatory changes. Edema of the wall of the gallbladder occurs in patients with right-sided cardiac insufficiency, thrombosis of the caudal vena cava and hypoproteinemia. In cattle suspected of having cholestasis, ultrasound-guided cholecystocentesis is indicated (see Cholecystocentesis). A sample of bile is then examined microscopically, bacteriologically and for liver fluke eggs.

Without resolution of obstructive cholestasis, rupture of the gallbladder may ensue with subsequent generalized peritonitis or intraabdominal haemorrhage. In three cows with rupture of the gallbladder, the lead ultrasonographic findings were generalized peritonitis with ascites.
and fibrin deposition [40]. In only one cow with characteristic signs of cholestasis, which
included icterus, bilirubinuria and elevated liver enzyme activity, a rupture of the gallbladder
could be tentatively diagnosed intra vitam [38, 40]. The ultrasonographic findings included
thickening of the gallbladder wall, which was poorly-demarcated, and dilatation of
intrahepatic and extrahepatic bile ducts. Abdominocentesis yielded bile-containing fluid.

Pneumobilia

Pneumobilia or aerobilia refers to air or gas accumulation in the bile ducts and may be
due to a variety of causes [41]. Pneumobilia may be the result of gas-producing bacteria in
suppurative cholangitis. Pneumobilia of individual bile ducts attributable to suppurative
cholangitis has been described in cattle [39]. On ultrasonograms, pneumobilia appears as
hyperechogenic structures which reflect the branching of the bile ducts from central to
peripheral. Depending on the position of the transducer, these echoes may be band-shaped or
miliary structures that are accompanied by reverberations or a distal acoustic shadow.

Caudal vena cava

The lumen of the caudal vena cava may be dilated or narrowed. Congestion in the
systemic circulatory system results in dilatation of the caudal vena cava. Causes include right-
sided cardiac insufficiency, thrombosis of the caudal vena cava and compression of the caudal
vena cava in the thorax or in the subphrenic region by space occupying lesions. The ul-
trasonographic appearance of the caudal vena cava is a substantial aid in diagnosing
congestion in the systemic circulation. In cases with congestion of the caudal vena cava, a
change in the cross-sectional shape of the vein is important for making a reliable diagnosis
[42-46]. The caudal vena cava loses its normal triangular shape when congested and becomes
round to oval (Fig. 15) on ultrasonograms. At the same time, the diameter of the vein in-
creases. In addition, congestion of the caudal vena cava results in marked dilatation of the
hepatic veins that empty into it (Fig. 16) and other signs of liver congestion (see liver congestion) including an edematous gallbladder wall. Occasionally ascites can be seen. In animals with congestion of the caudal vena cava, dilatation of the jugular veins indicates right-sided cardiac insufficiency, whereas normal jugular veins indicate obstruction or compression of the caudal vena cava between the liver and the heart. In cattle with thrombosis of the caudal vena cava, the thrombus is rarely seen; ultrasonographic identification of a thrombus has been reported in only one cow [44] and one heifer [47]; in the latter a thrombus was also seen in the right hepatic vein. Imaging a thrombus is difficult because it is situated cranially in the caudal vena cava where it is obscured from view by the lungs. However, it may be possible to see a liver abscess in cattle with thrombosis of the caudal vena cava. A further report describes the antemortem diagnosis of caudal vena cava thrombosis by intraoperative ultrasonography in two cows [48].

The caudal vena cava also can have a very narrow lumen. The most common cause of this is compression by an enlarged rumen. Impairment of the venous circulation of the liver due to severe hepatic cirrhosis for example, also may result in narrowing of the lumen of the caudal vena cava when the venous blood flow is severely decreased [37]. In such cases, the portal vein is dilated because of congestion.

**Portal vein**

In portal hypertension, there is dilatation of the portal vein with an increase in its diameter. Causes include prehepatic portal hypertension due to thrombosis of the portal vein, intrahepatic portal hypertension due to hepatic cirrhosis, tumors and abscesses and posthepatic portal hypertension attributable to right-sided cardiac insufficiency or thrombosis or compression of the caudal vena cava. In such cases, the lumen of the portal vein is abnormally large and has a diameter exceeding 5.5 cm in the twelfth intercostal space. There often is dilatation of the stellate ramifications of the portal vein and the intrahepatic portal
veins. The portal vein was not visible via ultrasonography in the region of the hepatic portal in a 10-week-old Holstein-Friesian calf with an elevated concentration of serum ammonia caused by a portosystemic shunt [49]. Instead, the cranial mesenteric vein was very prominent, and the portocaval shunt was identified using color Doppler sonography.

**Centesis and catheterization of the portal vein**

Percutaneous ultrasound-guided centesis and catheterization of the portal vein is a procedure that can be carried out for various experimental reasons [19, 50-54].

**Summary**

Ultrasonography is a valuable tool for the diagnosis of liver disease. Discrete or diffuse lesions can be imaged, aspirated and biopsied under visual guidance. This imaging modality can also be used to aspirate bile from the gallbladder for the diagnosis of liver flukes. However, ultrasonography cannot be used to evaluate liver regions obscured by the lungs.

**References**


Legend to figures

Fig. 1 : Ultrasonogram of normal liver and caudal vena cava imaged from the 11th intercostal space. 1 Abdominal wall, 2 Liver, 3 Caudal vena cava, 4 Common trunk of the splenic vein and the left gastric vein before the entry into the portal vein, Ds Dorsal, Vt Ventral.

Fig. 2 : Ultrasonogram of liver and portal vein imaged from the 10th intercostal space. 1 Abdominal wall, 2 Liver, 3 Portal vein, Ds Dorsal, Vt Ventral.

Fig. 3 : Ultrasonogram of liver and gallbladder imaged from the 9th intercostal space. 1 Abdominal wall, 2 Liver, 3 Gallbladder, Ds Dorsal, Vt Ventral.

Fig. 4 : Ultrasonogram of transhepatic cholecystocentesis of the gallbladder under ultrasonographic control imaged from the 10th intercostal space. 1 Abdominal wall, 2 Liver, 3 Gallbladder, 4 Spinal needle penetrating the abdominal wall, the liver and the gallbladder, Ds Dorsal, Vt Ventral

Fig. 5 : Ultrasonogram from a cow with multiple abscesses in the liver imaged from the 11th intercostal space. 1 Abdominal wall, 2 Liver, 3 Hepatic abscesses, Ds Dorsal, Vt Ventral.

Fig. 6 : Ultrasonogram and post-mortem specimen from a cow with a hepatic abscess in the right lobe of the liver. The liver was frozen before cutting. 1 Abdominal wall, 2 Liver, 3 Liver abscess, Ds Dorsal, Vt Ventral.

Fig. 7 : Ultrasonogram and postmortem specimen of the liver in a cow with lymphosarcoma imaged from the 11th intercostal space. 1 Abdominal wall, 2 Liver, 3 Tumour nodules, 4 Tumour invaded into a hepatic vein, 5 Portal vein, Ds Dorsal, Vt Ventral.
Fig. 8: Ultrasonogram and postmortem specimen of the liver of a cow with severe fatty liver degeneration. The liver is hyperechoic near the abdominal wall and cannot be visualized very far from the abdominal wall. 1 Abdominal wall, 2 Liver, Ds Dorsal, Vt Ventral.

Fig. 9: Ultrasonogram and postmortem specimen of focal fatty liver disease imaged from the 10th intercostal space. 1 Abdominal wall, 2 Liver, 3 Focal fatty liver degeneration, 4 Portal vein, Ds Dorsal, Vt Ventral.

Fig. 10: Ultrasonogram and postmortem specimen of the liver of a cow with seneciosis imaged from the 11th intercostal space. There are multiple hyperechogenic nodules and the portal vein is dilated due to intrahepatic portal hypertension. 1 Abdominal wall, 2 Liver, 3 Hyperechoic nodular alterations, 4 Dilated portal vein. Ds Dorsal, Vt Ventral. The postmortem specimen shows a cross section through the enlarged liver. The liver parenchyma consists of small (1 to 2 cm) and large nodules (2 to 4 cm). Histopathologically there were multifocal nodules of regenerative hyperplasia with varying numbers of megalocytic hepatocytes throughout the parenchyma. Approximately two thirds of portal triads and bile ducts had distinct fibroplasia and proliferation, respectively.

Fig. 11: Ultrasonogram of a calcified bile duct (in cross section) in a cow with fascioliasis. The calcified bile duct appears as a ring-shaped echogenic structure and is accompanied by an acoustic shadow. 1 Abdominal wall, 2 Liver, 3 Calcified bile duct, 4 Acoustic shadow, Ds Dorsal, Vt Ventral.
Fig. 12: Ultrasonogram of dilated bile ducts in the liver of a cow with cholestasis imaged from the 10th intercostal space. 1 Abdominal wall, 2 Liver, 3 Dilated bile ducts, Ds Dorsal, Vt Ventral.

Fig. 13: Ultrasonogram of dilated bile ducts in the liver of a cow with cholestasis imaged from the 10th intercostal space. 1 Abdominal wall, 2 Liver, 3 Dilated bile ducts, Ds Dorsal, Vt Ventral.

Fig. 14: Ultrasonogram of the gallbladder in a cow with cholestasis imaged from the 9th intercostal space. The gallbladder contains an echogenic sediment and an anechoic supernatant. 1 Abdominal wall, 2 Anechoic supernatant in the gallbladder, 3 Sediment in the gallbladder, Ds Dorsal, Vt Ventral.

Fig. 15: Ultrasonogram of the caudal vena cava in a cow with thrombosis of the caudal vena cava imaged from the 12th intercostal space. The caudal vena cava has an oval shape and an enlarged diameter because of congestion. 1 Abdominal wall, 2 Liver, 3 Caudal vena cava, Ds Dorsal, Vt Ventral.

Fig. 16: Ultrasonogram of the right hepatic vein in a cow with thrombosis of the caudal vena cava imaged from the 11th intercostal space. The right hepatic vein is markedly dilated because of congestion. 1 Abdominal wall, 2 Liver, 3 Right hepatic vein, Ds Dorsal, Vt Ventral.