Sonographic Gallstone Diagnosis

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Publisher

FALK FOUNDATION e.V.

Leinenweberstr. 5
79108 Freiburg
Germany

www.falkfoundation.org

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13th edition 2024

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1 Introduction

In the context of cholelithiasis, sonography is an examination method that is easy to perform, has a low burden on the patient and is available almost everywhere. Sonography is the primary method of examination and the primary strategy for further clarification after taking the medical history, performing a physical examination, and sometimes also performing blood chemistry tests. The aim of this brochure is therefore to give the reader a brief, up-to-date overview of sonographic diagnosis of the very common disease of cholelithiasis.

2 Fundamentals

2.1 Anatomy, examination technique, imaging sections

The gallbladder is located in the gallbladder fossa on the underside of the right lobe of the liver. There, it can typically be found between the anterior axillary line and the midclavicular line. When the patient is in a fasted state, the usually pear-shaped hollow organ exhibits a fundus, a corpus, and an infundibulum.
For the examination of the gallbladder, the patient should be in a fasted state. The sonographic examination starts with the patient in a supine position. The patient can aid in achieving a better examination result by breathing in and allowing the abdominal wall to protrude outwards as this causes the liver and the gallbladder to peek out from underneath the right costal arch, preventing rib shadows and air filled intestinal loops from getting in the way and spoiling the image. As a rule, the gallbladder should be examined in three planes (Fig. 1).

The longitudinal slice has been proven to be an effective way to locate the gallbladder (Fig. 2). The transducer is placed in the middle of the upper abdomen, parallel to the body's longitudinal axis. While in the longitudinal plane, the right lobe of the liver (between the medial line and the midclavicular line, up to the anterior axillary line as the maximum) is examined. In this liver

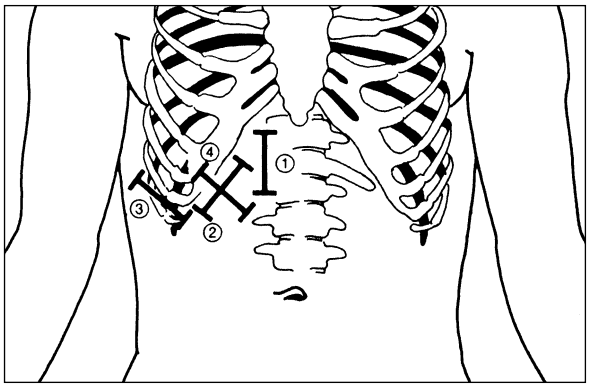

Fig. 1:
Diagram showing the three planes used for examination of the gallbladder.

section, the gallbladder can be seen dorsal to the right lobe of the liver in the sonographic image. Already at this stage, it is possible to make an initial diagnostic assessment using only the longitudinal slice. The next step in the examination is the subcostal oblique slice (Fig. 3). Starting from the longitudinal axis, the transducer is turned 90° counterclockwise until it is lying parallel to the right costal arch. By using tilting movements, it is possible to obtain a good image of the gallbladder.

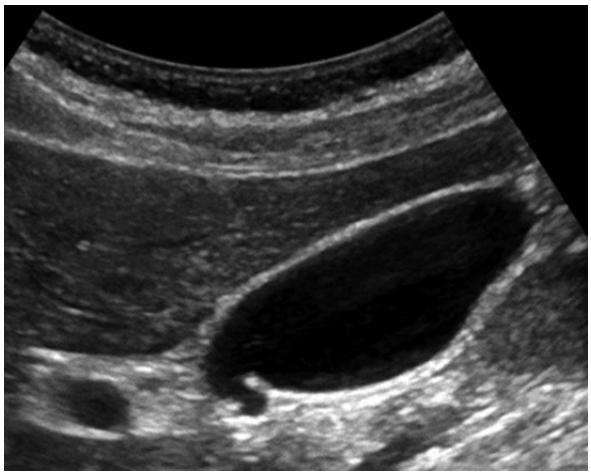

Fig. 2:
Longitudinal slice of the gallbladder.

This is the easiest way to assess small gallbladders that are difficult to demarcate. The right main branch of the portal vein is the guiding structure in this plane; the gallbladder can be found on the right end of it. The subcostal oblique slice is also a suitable way to assess the hepatic duct bifurcation and the right hepatic duct. The latter can be found ventral to the portal vein/the right main branch of the portal vein. In the case of cholestasis, the congested bile ducts can also be seen in this view. Using a clockwise rotational movement and sliding the transducer in the caudal direction causes the ductus hepatocholedochus to come into view in this plane. Otherwise, the easiest method for imaging of the bile ducts is using the line that passes through the common bile duct, the portal vein, and the vena cava (in other words a

shoulder-to-navel slice) with the patient breathing in deeply (Fig. 4). This can be done with the patient in a supine position, but an examination with the patient lying on their left side will be more accurate because this position will cause the transverse fissure of the liver to peek out further underneath the costal arch. Thus, the ductus hepatocholedochus, the portal vein, and the vena cava come into view, from ventral to dorsal. The junction of the hepatic duct and the cystic duct usually cannot be clearly identified, so the visible areas of the main biliary tract (common hepatic duct, common bile duct) are typically referred to as the ductus hepatocholedochus in the context of a sonography. The patient remains lying down on their left side for the flank slice/intercostal slice (Fig. 5). Lifting the right arm above the head causes a widening of the intercostal spaces and increases the distance between the iliac crest/costal arch, which improves the examination conditions. The transducer is placed parallel to the course of the ribs. This plane is particularly good for assessing the infundibulum and the cystic duct. Sonographic examination of the gallbladder is only complete once sonography-guided palpation has been performed in order to check the gallbladder for tenderness on palpation and plasticity.

Fig. 3:
Subcostal oblique slice of the gallbladder.

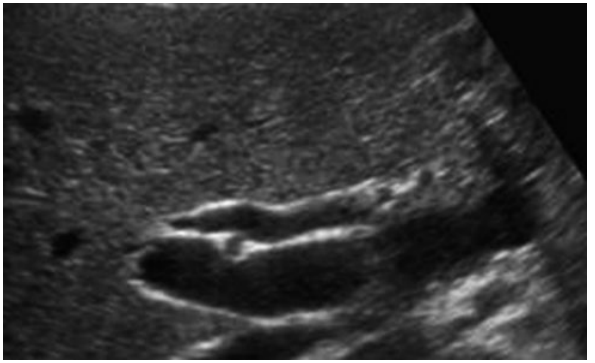

Fig. 4:
Depiction of the line that passes through the common bile duct, the portal vein, and the vena cava with the patient lying on their left side. The bile duct is 5 mm wide. A cross-section of the hepatic artery between the bile duct, which is in a ventral position, and the dorsally situated portal vein.

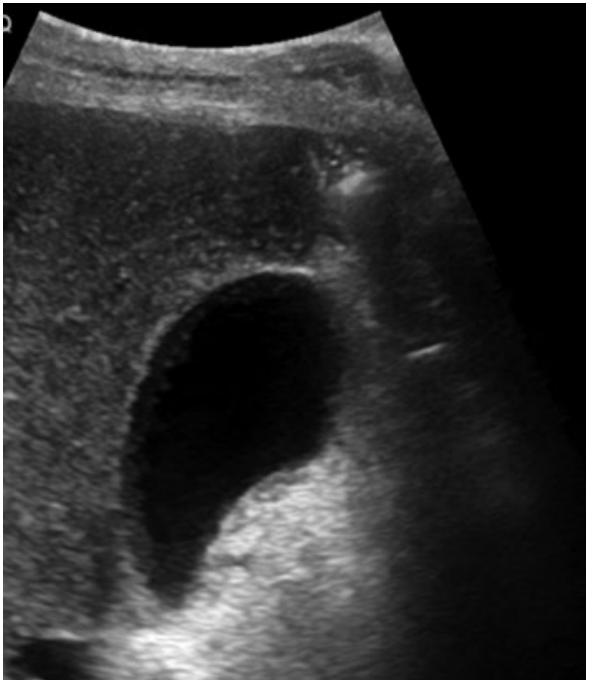

Fig. 5:
Right-side flank slice. Normal gallbladder.

2.2 Indications for sonography in the case of cholelithiasis

The most common indication for sonography of the abdomen is the need to diagnose pain in the right upper abdomen. One of the main clinical questions in such cases is whether the cause may be cholelithiasis (Tab. 1). Sonography can then be used to determine the number, size, and position of the concrements. In the case of acute or chronic cholecystitis, a correlate for the inflammatory process may be found in the sonogram. Gallbladder polyps (cholesterol polyps, adenomas, or malignomas) and masses in the bile ducts such as Klatskin tumors can often be detected either through their direct appearance in the sonogram or through the appearance of secondary focal cholestasis. Sonography plays a key role in differentiating between hepatocellular and obstructive jaundice, and in determining the location in the case of obstructive cholestasis. If regularly used to follow up on gallbladder polyps, sonography can ensure that the indica-

Indications for sonography of the gallbladder and the bile ducts:

Gallbladder:

– Cholelithiasis
– Acute and chronic cholecystitis
– Empyema/hydrops
– Gallbladder polyps (cholesterol polyps)
– Gallbladder tumor
– Pain/palpation findings in the right upper abdomen
– Litholysis
– Checking of gallbladder function

Bile ducts:

– Clarification of cholestasis (intra-/extrahepatic)
– Suspected choledocholithiasis
– Suspected bile duct tumor
– Pneumobilia/hemobilia
– Sclerosing cholangitis
– Autoimmune cholangitis

Tab. 1

tion for surgery is established quickly should the polyps increase in size. Sonography is also used to plan and monitor treatment in the case of drug-based litholysis. Today, this treatment is mainly used for preventing stone formation following gastric bypass surgery. Other conditions that may be associated with an increased risk of stone formation include very rapid, severe weight loss, treatment with somatostatin or somatostatin analogs, and estrogen therapy. In some very specific cases, a few small concrements (no larger than 4–5 mm) that likely have a high cholesterol content can be treated with drugs, provided that the patient has been informed about the risk of relapse (approx. 50%) and the curative alternative of cholecystectomy. A further requirement is a normal emptying of the gallbladder. In order to assess whether the gallbladder is functioning correctly, it is usually sufficient to measure its size sonographically before eating a meal for stimulation, and about 30 minutes thereafter (see Section 5).

2.3 Normal findings, normal variations, artifacts

In the sonogram, a normal gallbladder appears as an echo-free, pear-shaped organ in the right upper abdomen. Typically, there is acoustic enhancement dorsal to the organ. In addition, cyst lateral shadowing can be observed at both ends, and these should not be confused with concrement shadows. The gallbladder wall itself can be demarcated well since it is a hyperechoic border. In the fasted state, the wall thickness is 1–3 mm; in the postprandial state (caution: sometimes also after smoking), it is 4–5 mm maximum (Fig. 6).

Any larger wall diameter in the fasted state must be considered pathological. The size of the gallbladder varies greatly between individuals. The longitudinal diameter is usually between 6 and 9 cm, and the transverse diameter usually measures 3–4 cm (Tab. 2). In the case of many years of diabetes, hypothyroidism, primary sclerosing cholangitis, or parenteral nutrition, the gallbladder is

often conspicuously large. In the postprandial state, the gallbladder may no longer be sonographically detectable after complete emptying. After cholecystitis has run its course, the gallbladder may also be completely shrunken and may therefore not be detectable by sonography.

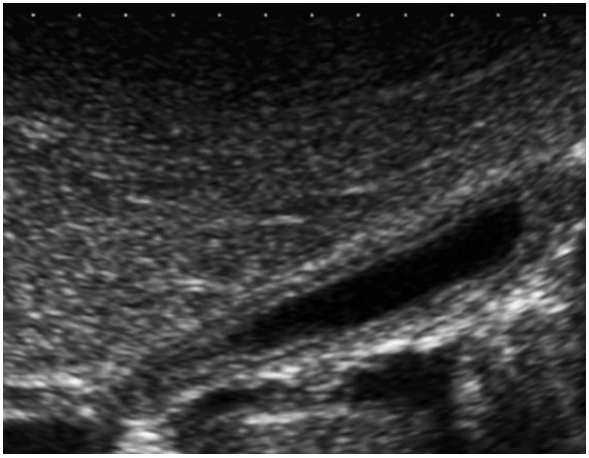

Fig. 6:
Longitudinal slice: Postprandial thickening of gallbladder wall.

The gallbladder frequently varies in shape. In addition to the typical pear shape, round, indented, kinked or septated gallbladder shapes may be seen (Fig. 7).
If the gallbladder has a rounded shape, it can sometimes be difficult to differentiate from liver

Normal dimensions of the gallbladder and the bile ducts:

– Length 6–9 cm
– Width 3–4 cm
– Wall thickness 2–3 mm
(up to 5 mm postprandially)
– Maximum width of the ductus hepatocholedochus: 5–7 mm, up to 8–9 mm
in the case of a history of cholecystectomy

Tab. 2

cysts; an examination in all three planes usually solves this problem. One or more kinks may appear to be a septated gallbladder (Fig. 8).
The formation of a kink in the fundus area leads to a Phrygian cap. In the case of true oblique or longitudinal septum formation, each individual septum can be seen in all planes. Small wall-adherent echoes in the neck of the gallbladder correspond to the spiral valves of Heister. These must not be confused with cystic duct concrements.
Normally, the gallbladder appears as an echo-free, fluid-filled organ. Bright internal echoes may occur due to oblique acoustic waves hitting the back wall of the gallbladder.
This phenomenon is known as a slice thickness artifact (Fig. 9), and may be confused with gallbladder sludge. However, by changing the position of the transducer, these internal echoes can be made to disappear again, since the sound waves once again strike the gallbladder wall perpendicularly. As a second frequent artifact, noise near the transducer can affect the exam-

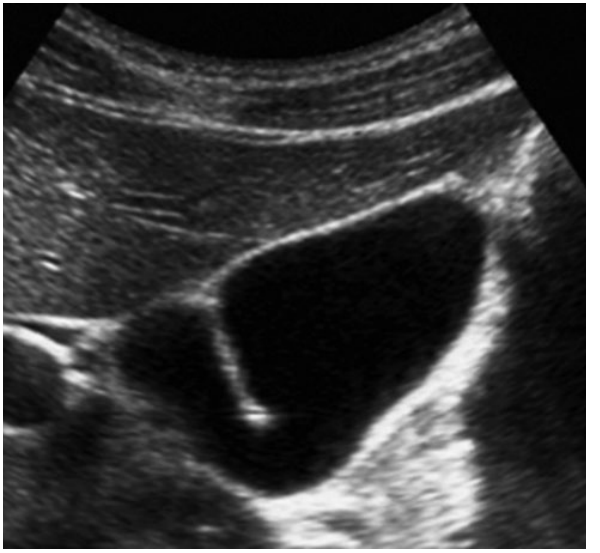

Fig. 7:
Longitudinal slice: Kinked gallbladder.

Fig. 8:
Longitudinal slice: Septated gallbladder.

ination result (Fig. 10). In the subcostal slice in particular, the gallbladder fundus is depicted close to the transducer.

As a result, noise near the transducer conceals a part of the gallbladder. In these cases, the gallbladder fundus must be assessed in the longitudinal or intercostal slice in order to achieve a sufficiently long advancing distance. Sometimes using a high-frequency transducer can also help. If the gallbladder cannot be visualized despite a thorough sonographic examination in a fasted state, chronic cholecystitis with an inflamed, shrunken gallbladder must initially be considered. In the case of a stone-filled gallbladder, the pronounced acoustic shadow can be misinterpreted as an air-filled intestinal loop. Malpositioning or agenesis are very rare (Tab. 3).

Fig. 9:
Subcostal oblique slice: Slice thickness artifact of the gallbladder.

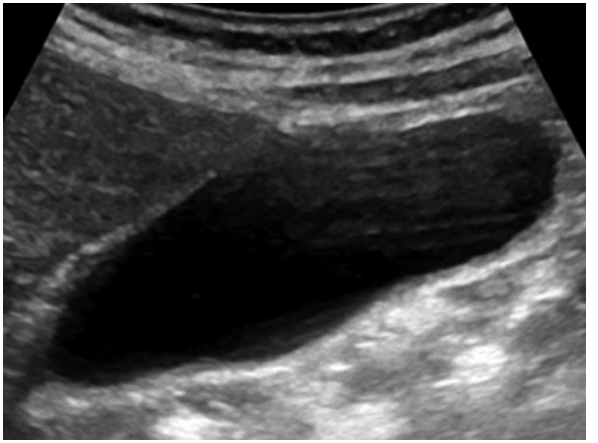

Fig. 10:
Longitudinal slice: Ventral noise near the transducer.

Reasons for an inability to obtain a sonographic image of the gallbladder:

– Postprandial gallbladder contraction
– History of gallbladder surgery (usually cholecystectomy)
– Shrinking in the case of chronic cholecystitis
– Stone-filled gallbladder
– Malpositioning, agenesis

Tab. 3

3 Echogenic structures

3.1 Stones

Sonography is superior to all other procedures when it comes to gallbladder stones, and endoscopic sonography is the superior procedure when it comes to bile duct stones. This is the gold standard in diagnostic imaging. Gallstones are detected by sonography as echogenic structures in the gallbladder lumen that typically exhibit a dorsal acoustic cancellation phenomenon (dorsal acoustic shadow). The extent of the acoustic shadow depends on the size of the stone and its composition. In differential diagnostics, the mobility of stones when changing the position of the body must be taken into account in order to distinguish between these and other echogenic structures, in particular polyps (see below). Only very rarely are there concrements bonded to the gallbladder wall that no longer exhibit any positional variability. Gallstones can be characterized sonographically in terms of their size (the maximum diameter is usually given), shape, position, and echo pattern (Fig. 11).

A stone can be detected by sonography at a size of approx. 1–2 mm. The stone diameter can be precisely defined within the range of 1–3 mm. An acoustic shadow usually only occurs at a size of 3 mm or more.

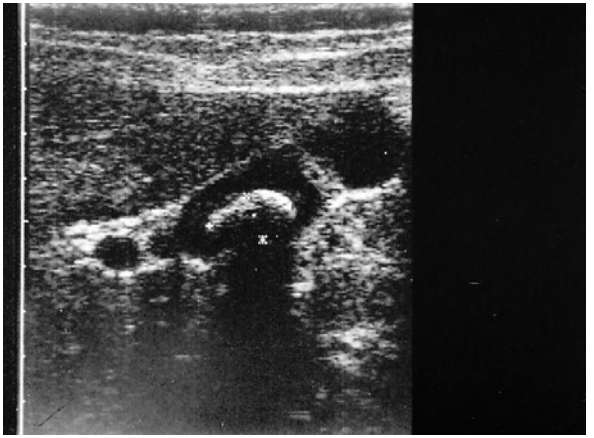

Fig. 11:
Longitudinal and transverse diameter of a gallbladder concrement.

The shape of the surface of a gallstone (e.g. crescent shaped or triangular) can only provide a limited indication of the composition of the stone. The subcategories of the recognizable sonographic echo pattern of gallstones can sometimes be very complex and have not yet been established in the clinical routine. Conclusions regarding the composition of the stones based on the hardness of the surface echo, on recognizable internal echoes, or on the size of the acoustic shadow compared to the diameter of the stones can only ever be approximate (Fig. 12). Small (< 5 mm) stones in which weak surface reflection still reveals many internal echoes in the stones during sonography-guided "shaking" of the gallbladder are presumably predominantly composed of cholesterol (Fig. 13). If such stones fill only a small part of the gallbladder lumen, they may respond to oral litholysis with ursodeoxycholic acid. Conversely, stones with only a slight acoustic shadow compared to the diameter are often low in cholesterol and rich in pigment (Fig. 14), meaning that such concrements are usually not suitable for conservative gallstone treatment.

Fig. 12:
Solitary gallbladder stone with a weak surface echo but many internal echoes and a clear dorsal acoustic shadow; likely a concrement with a high cholesterol content.

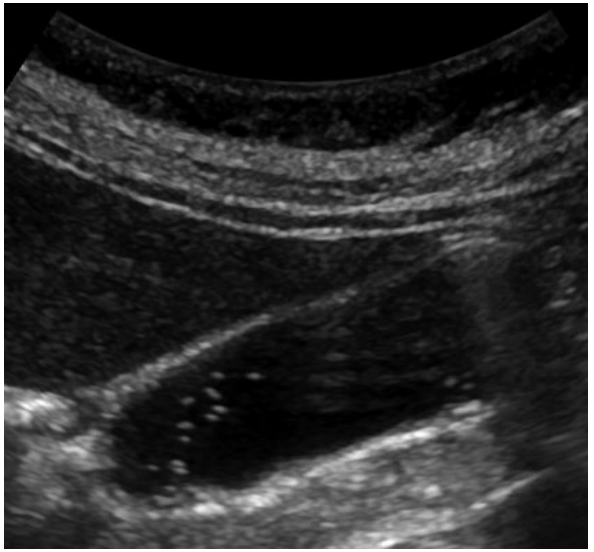

Fig. 13:
Small, floating stones, likely with a high cholesterol content.

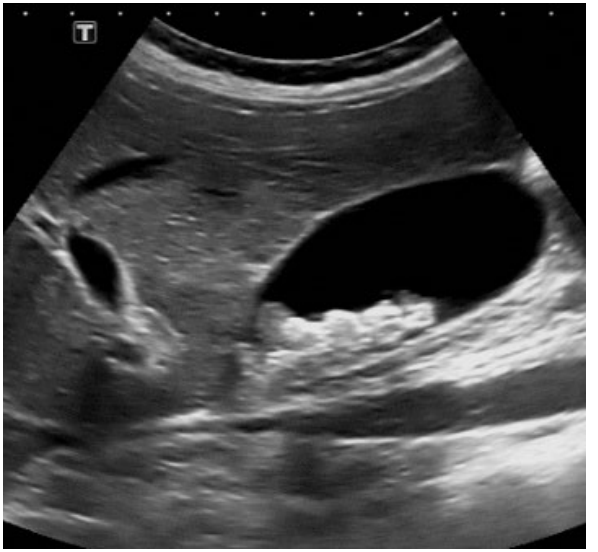

Fig. 14:
Gallbladder stones without any detectable dorsal acoustic shadow, likely with a high pigment content.

3.2 Sludge

Sludge in the gallbladder is characterized by tiny, grit-like reflections without acoustic shadows, which move when the body position changes (Fig. 15). Sometimes, caked sludge may stay in the same place and can then not be distinguished from a polypoid mass or tiny concrements in the sonography. In such cases, a prompt follow-up may help, as sludge in the gallbladder is often a transient phenomenon. Sludge reflections are often found during parenteral nutrition, but they can also be observed spontaneously. Increased incidence of sludge under the use of antibiotics (e.g. ceftriaxone) has also been reported.
There is often sludge in the gallbladder in the case of obstruction of the cystic duct (Fig. 16). In a gallbladder with this much internal echo, it can often be difficult to differentiate between empyema and cholecystitis (Fig. 25). Sometimes, sludge formation may be observed in the early-stages of the formation of compact concrements. Some theories suggest that cholesterol crystallization and gallstone formation take place embedded in a viscous gallbladder sludge. On the other hand, many other factors, especially genetically determined factors, are required for the formation of a stone. After shock-wave lithotripsy of single gallbladder stones was

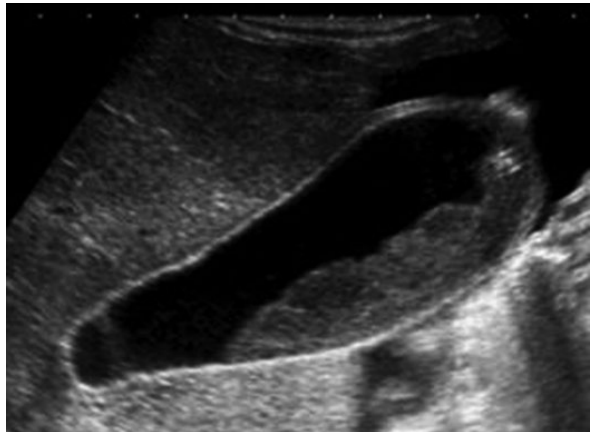

Fig. 15:
Longitudinal slice of the gallbladder with sludge that changes position when moved (e.g. when shaken).

Fig. 16:
Impacted gallbladder stone in the infundibulum near the cystic duct, sludge echoes in the gallbladder lumen; wall thickened to 6 mm.

performed as a treatment in the past, the gallbladder was often filled with sludge particles (Fig. 17), which for the most part were discharged from the gallbladder within a few hours or days.

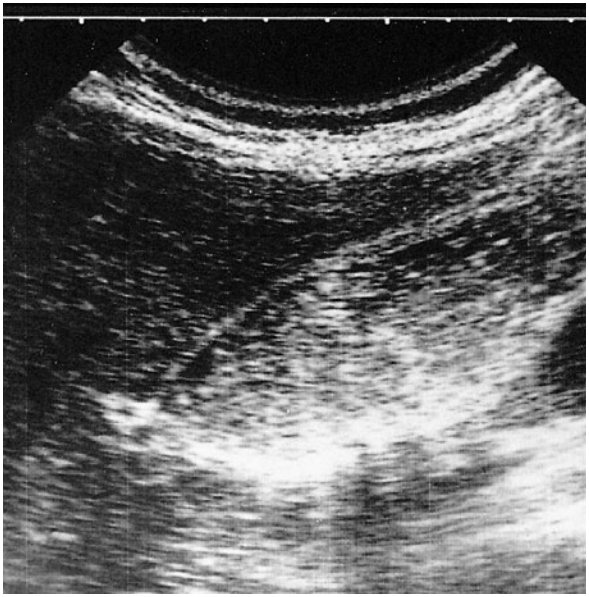

Fig. 17:
Immediately after shock-wave therapy, the gallbladder is filled with sludge-like echoes that do not produce an acoustic shadow.

3.3 Polyps, tumors

Sonography is superior to all other imaging procedures when it comes to detection of gallbladder carcinomas with exophytic growth. However, most gallbladder polyps detected by sonography are chance findings without any clinical relevance, and cholesterol polyps are by far the most common. Benign tumors are divided into epithelial and non-epithelial neoplasms, inflammatory polyps and cholesterol polyps, and hyperplastic changes (adenomyomatosis) (Fig. 18). Adenomas, which are rare, but also the most common epithelial tumors, grow exclusively exophytically and either sit across a wide area of the gallbladder wall (Fig. 19), or are connected to it by a pedicle. They have a predominantly hyperechoic internal structure without acoustic shadows, and do not shift position. In order to differentiate between these and sludge, an additional color Doppler sonography or contrast-enhanced sonography can be used to help to distinguish between the perfusion of polyps and sludge.

In the case of neoplastic polyps, if there is no surgical indication from the outset, regular sonographic size checks should be carried out, due to the risk of degeneration.
The question of whether there is an indication for surgical polyp removal must be answered on an individual basis. In the case of a rapid increase in size, an inhomogeneous internal structure, or an irregular surface, surgery is more likely to be indicated. In polyps of more than 10 mm in size, cholecystectomy is indicated due to the increased risk of malignancy. Deposits of cholesterol on and within the gallbladder wall lead to the finding of cholesteatosis. Their polypoid shape can be recognized in the sonogram by multiple, hyperechoic wall-adherent protrusions ("strawberry gallbladder") (Fig. 18b).
This finding is pathogenetic and comparable with adenomyomatosis (Fig. 18c), a hyperplasia of the gallbladder wall caused by the proliferation of the Rokitansky-Aschoff sinuses. In adenomyomatosis, the gallbladder wall appears thickened with small, cyst-like changes and

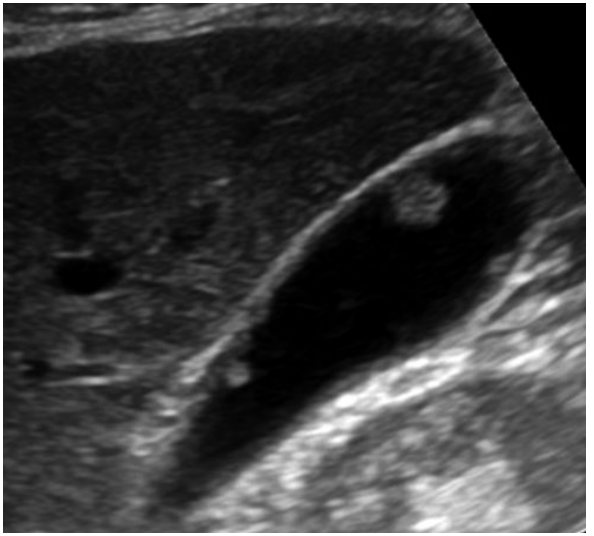

Fig. 18a:
Longitudinal slice through the gallbladder. Hyperechoic structures sitting on the gallbladder wall, suggesting three small gallbladder polyps.

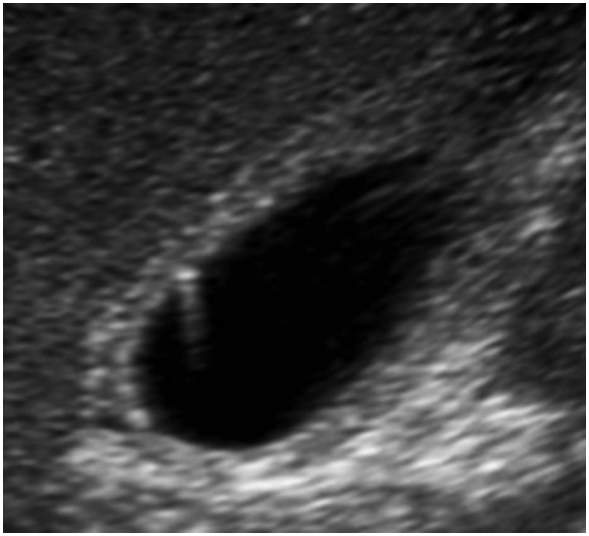

Fig. 18b:
Cholesteatosis: Small, wall-adherent bright reflection with reverberation artifact.

Fig. 18c:
Adenomyomatosis: Wall thickening in the corpus with small, cyst-like wall changes and crystalline cholesterol deposits (light/bright echogenic structures with reverberation artifacts).

build-up of cholesterol deposits. Adenomyomatosis can affect the entire gallbladder wall, or just parts of it.

Malignant gallbladder tumors are very rare and are usually diagnosed at an older age and in an advanced stage. In rare cases, gallbladder carcinomas can be detected by sonography while still in the asymptomatic stage.

In the sonogram, gallbladder carcinomas can be recognized by their uneven internal structure and their mostly uneven surface (Figs. 20 and 21). Depending on the stage, the tumor can fill the entire volume of the gallbladder, infiltrate the adjacent liver, or be only the size of a polyp. Primary wall-infiltrating tumors may be suspected due to a thickening of the gallbladder wall. When cholelithiasis and gallbladder carcinoma coincide, which is frequently the case, concrements are often found in the tumor. Indirect indications of a malignant gallbladder tumor include liver metastases, local liver infiltration, and cholestasis.

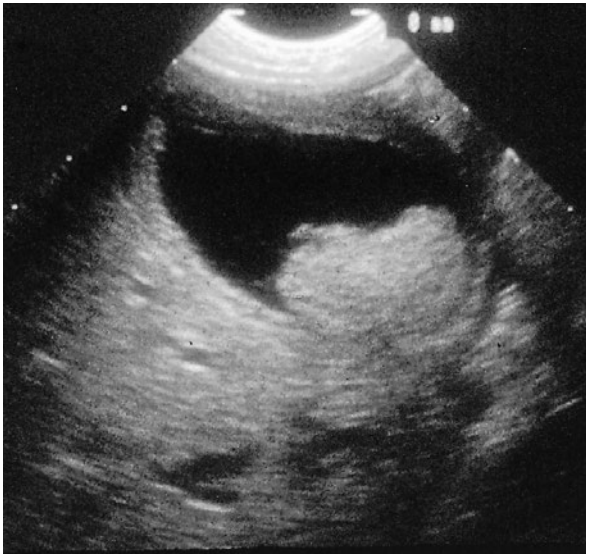

Fig. 19:
Subcostal slice through the gallbladder (7.5 MHz).
Broad-based polyp-like change on the gallbladder neck; suspected adenoma.

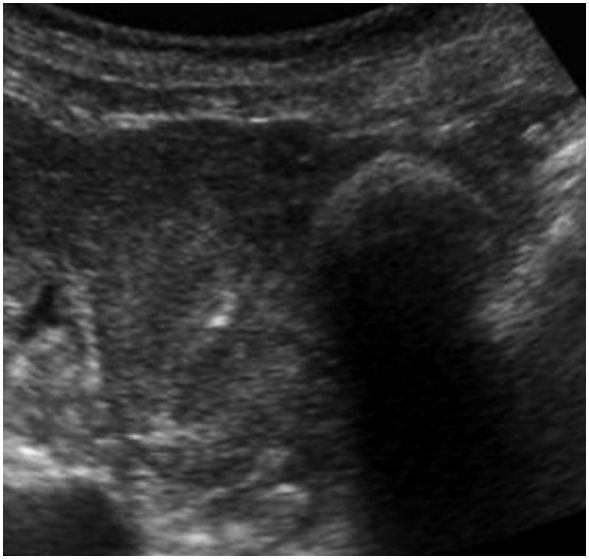

Fig. 20:
Longitudinal slice through the gallbladder. Inhomogeneous, hyperechoic, partially hypoechoic structure on the base of gallbladder. Infiltration into the liver (poor definition). A large concrement embedded in the tumor. Histology of the tumor: Gallbladder carcinoma.

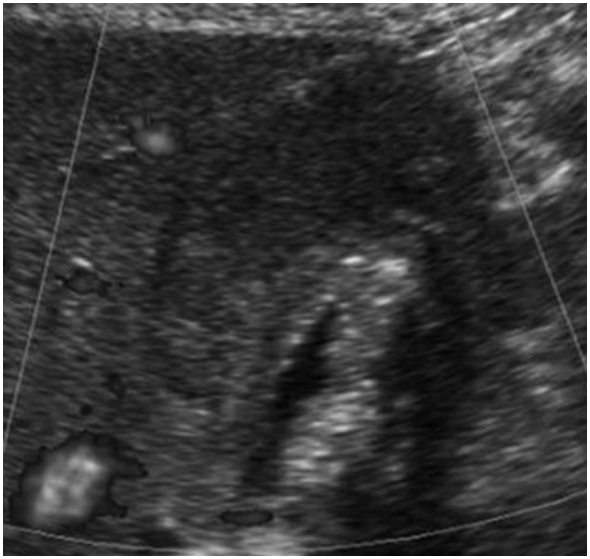

Fig. 21:
Advanced gallbladder carcinoma infiltrating into the liver. The gallbladder wall can still be demarcated focally. Narrow residual lumen of the gallbladder.

3.4 Aerobilia, hemobilia

Pneumobilia or aerobilia is caused by pathological or surgically created connections between the intestines and the bile ducts. The most common cause is a history of papillotomy. In rare cases, severe cholangitis with gas-producing bacteria is the cause of air in the bile ducts. Sonography shows many hyperechoic striped or dotted areas in the intrahepatic region, which may exhibit a dorsal acoustic shadow (Fig. 22). The pattern of distribution corresponds to that of the bile ducts. Aerobilia can be distinguished from liver calcifications (which have a similar appearance) through position-dependent localization.

Hemobilia is very rare. It is mainly caused by connections between blood vessels and the biliary system brought about by trauma. Fresh hemorrhaging causes an echo-free dilation of the bile ducts.

Older hematomas that are partially organized or in the process of being absorbed can become hyperechoic as healing proceeds.

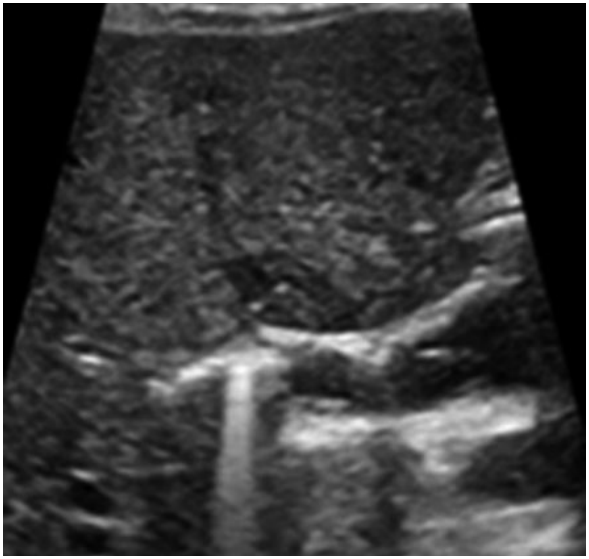

Fig. 22a:
Extrahepatic bile duct with aerobilia. Bright/light reflection with comet-tail dorsal acoustic shadow artifact; reflection is mobile in the live image.

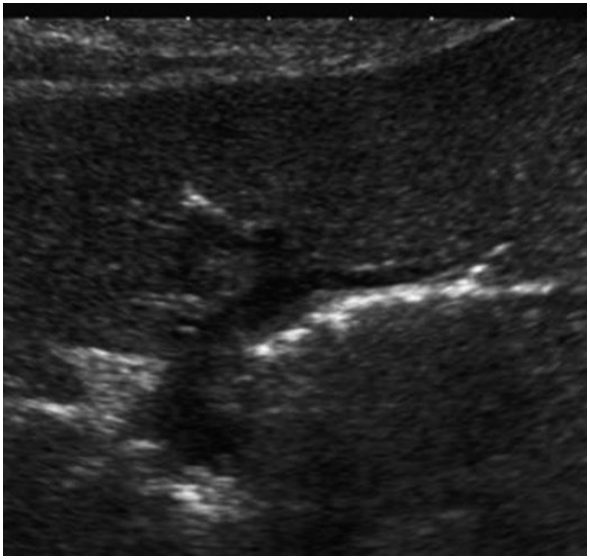

Fig. 22b:
Aerobilia in the intrahepatic bile duct. Tiny, bright air reflections. Ventral to this, segmental portal vein branch.

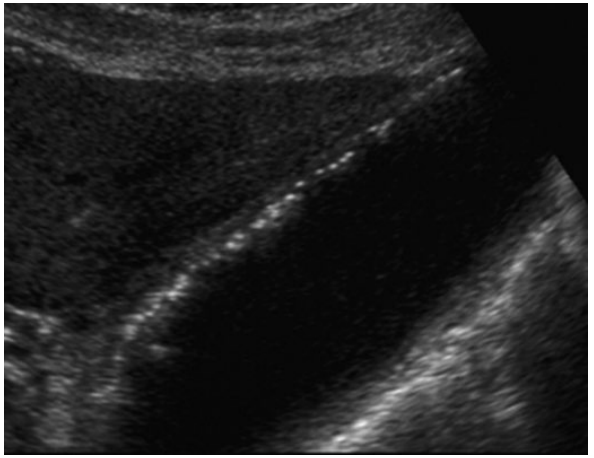

Fig. 22c:
Aerobilia in the gallbladder. Small, pearl-like air reflections, as opposed to concrements floating along the ventral wall.

Fig. 22d:
Aerobilia in the gallbladder. Two sickle-shaped air reflections in the gallbladder. Unlike concrements (acoustic shadows), these air reflections exhibit comet-tail artifacts dorsally, and are ventrally positioned.

4 Complications of gallstones

4.1 Cystic duct obstruction, cholecystitis

Stones can temporarily or permanently block the gallbladder outlet if they are impacted in the infundibulum or in the cystic duct. The gallbladder can react asymptomatically with nearly complete, persistent contraction and nearly absent residual lumen (Fig. 23), and with sludge formation (Fig. 16); it can also react symptomatically with incipient hydrops (Fig. 24), empyema (Fig. 25), or cholecystitis (Figs. 26 and 27). Occasional asymptomatic cystic duct obstructions (occurring in 2–5% of cases) are observed both spontaneously in stone carriers and during oral drug-based litholysis (previously also after shock-wave therapy), and they subside in more than half of these patients after a few weeks or months. During these phases in which an outlet is blocked, the gallbladder does not function at all. Because such cystic duct obstructions can lead to cholecystitis, these patients must be monitored especially carefully and closely.

Fig. 23:
Small shrunken gallbladder without residual lumen with multiple tiny concrements inside. Asymptomatic patient who has been under observation for over five years.

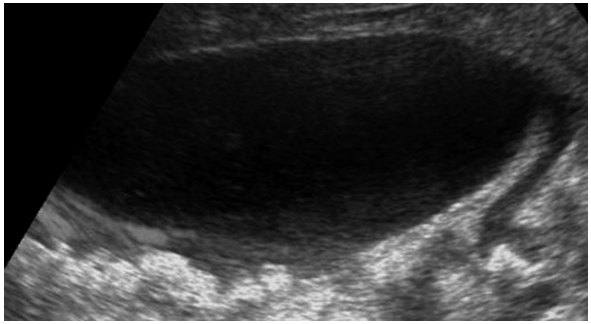

Fig. 24:
Longitudinal slice through the gallbladder. Incipient hydrops with some sludge echoes in the lumen. Obstructive triangular concrement in the cystic duct (lower right).

Fig. 25:
Longitudinal slice through the gallbladder. Cholecystitis in the presence of cholecystolithiasis. Echogenic bile in the gallbladder lumen, strong suspicion of gallbladder empyema.

Fig. 26:
Small gallbladder stones (lower right in the gallbladder lumen), slightly thickened gallbladder wall, incipient cholecystitis.

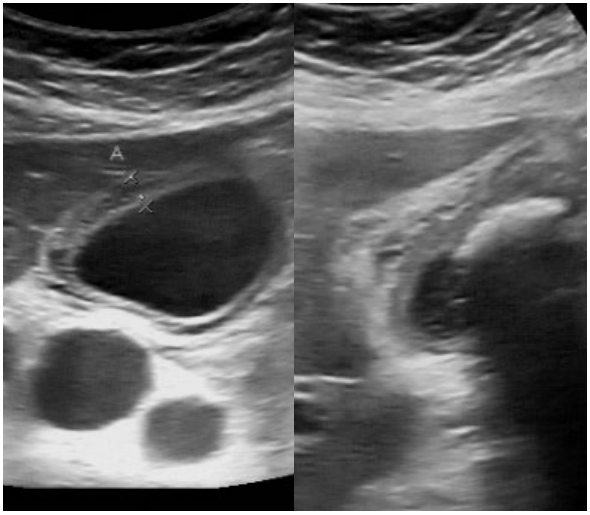

Fig. 27:
Split image: On the left, the transverse slice of the gallbladder with the three-layer phenomenon in the presence of a markedly thickened wall (6–7 mm). On the right, the transverse slice of the gallbladder with massive wall thickening and a reaction in the surrounding tissue in the presence of cholecystitis with pericholecystitis.

In the case of a clinical suspicion of acute cholecystitis, sonography should be performed as the first imaging procedure after taking the medical history and performing a physical examination. Even in the early stage, without a corresponding image, a circumscribed tenderness on palpation in the gallbladder bed can be a diagnostically relevant finding in the case of sonography-guided palpation.

In the further course, a thickening of the gallbladder wall is detected as a result of an inflammatory wall edema (Fig. 26). The wall thickness in a fasted patient is then 3–4 mm. The "three-layer phenomenon" is characteristic of this. The thickened wall is depicted as a hypoechoic zone, delimited by a hyperechoic surrounding band on both sides (Fig. 27). The most common cause of cholecystitis is cholelithiasis (Tab. 4).

It has been established that there is a higher incidence of inflammatory gallbladder diseases not only in HIV-infected and immunosuppressed patients, but also in the context of viral infections, even without the detection of stones (Fig. 28). In the case of ascites and acute hepatitis (Tab. 6), the gallbladder may appear the same in the sonogram as it does in the case of acute cholecystitis. In the case of advancing cholecystitis, an inflammatory pericholecystic edema may initially be depicted in the form of a hypoechoic surrounding band (Fig. 27). It is then difficult to differentiate between this and gangrene with

Sonographic findings in the case of acute cholecystitis:

– Stone(s) usually detected
– Tenderness upon sonography-guided palpation
– Gallbladder wall thickening (over 3–4 mm)
– Three-layer phenomenon
– Sludge often detected
– Pericholecystitis common

Tab. 4

abscess formation. If inflammatory swelling or concrements cause shifting of the cystic duct, a gallbladder hydrops forms (Fig. 24). This causes the gallbladder to increase in size both longitudinally and especially in the transverse direction. The gallbladder will appear rounded and it becomes difficult to make an impression in it. The accumulation of detritus often causes inflammatory sludge in the gallbladder (Fig. 24). If the inflammatory sediment mixes with pus, this corresponds to a finding of empyema (Fig. 25). In the sonogram, this finding appears similar to "echogenic bile". The finding is, however, nonspecific, and it is also found in many other gallbladder diseases (Tab. 5).

The complications of cholecystitis (perforation, formation of abscesses, liver infiltration) can be detected by sonography at an early stage (Fig. 29). In the case of acute perforation, there may be a short time-window, during which sonography-guided palpation is painless. In the case of chronic cholecystitis, the typical sonographic finding is a thickened, hyperechoic gall-

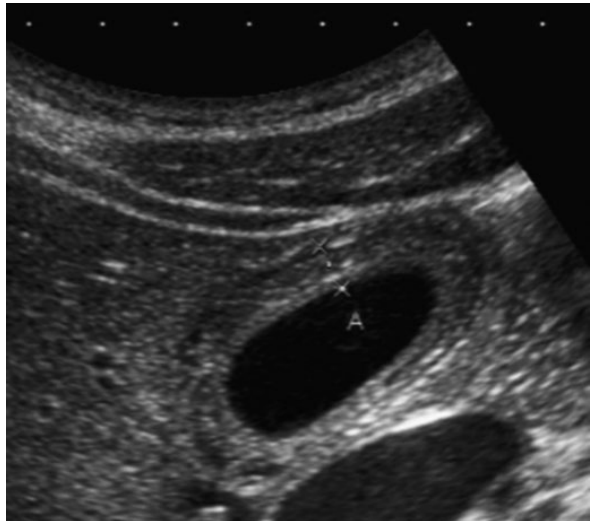

Fig. 28:
Longitudinal slice through the gallbladder. Patient with Epstein-Barr virus infection. Edematous and multilayered thickening of the gallbladder wall. No signs of cholecystitis in the clinical examination and the laboratory chemistry.

Causes of echogenic bile:

– Sludge, empyema
– Gallbladder is unable to adequately contract
– No contraction stimulus (fasting, parenteral nutrition)
– Biliary sludge

Tab. 5

Causes of thickened gallbladder wall:

– Acute or chronic cholecystitis
– Ascites in the presence of hypoalbuminemia, cirrhosis of the liver
– Acute infection, viral hepatitis
– HIV infection
– Cholesteatosis
– Adenomyomatosis
– Intramural venous collateral pathways in portal hypertension
– Porcelain gallbladder
– Malignant tumors with diffuse growth

Tab. 6

bladder wall. Usually, the entire gallbladder is reduced in size due to the recurrent inflammation, and it is difficult to locate. In the rare condition of porcelain gallbladder, calcareous deposits are found in the gallbladder wall (Fig. 30). A thickened gallbladder wall alone is not specific to acute or chronic cholecystitis (Tab. 6).

Fig. 29:
Gallbladder perforation (in the ventral direction) in the presence of cholecystitis and cholecystolithiasis.

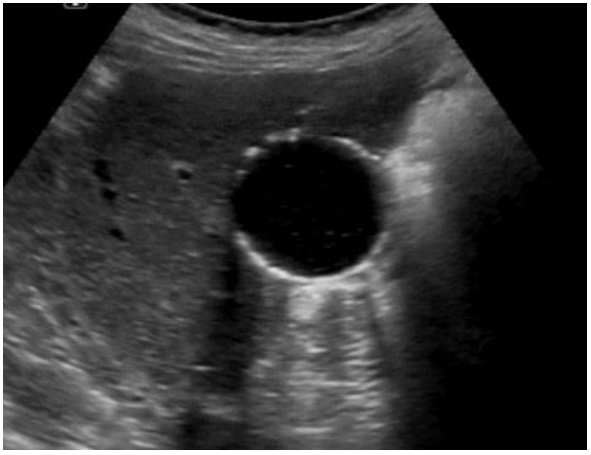

Fig. 30:
Transverse slice of a porcelain gallbladder.

4.2 Bile duct stones, common bile duct obstruction

The ductus hepatocholedochus can normally be visualized in the sonogram with a maximum width of 5–7 mm; only in the case of a history of cholecystectomy are "normal" bile duct measurements of up to 7–9 mm possible. The intrahepatic bile ducts usually appear delicate with a maximum width of 1–3 mm. Obstruction of the bile ducts by stones is a clinically relevant condition. In addition to medical history, examination, and laboratory testing, the sonographic examination of the bile ducts serves not only as a way to directly detect stones, but also above all as a way of searching for extrahepatic and/or intrahepatic bile duct dilation as an indirect sign of obstruction (Figs. 31 and 32). Depending on the location of the obstruction, different parts of the biliary system can be dilated: An obstruction located within the liver will lead to a build-up in one or more liver segments.

When the obstruction is located in the hilar region, all intrahepatic bile ducts will be dilated. When the obstruction is located in the extra-

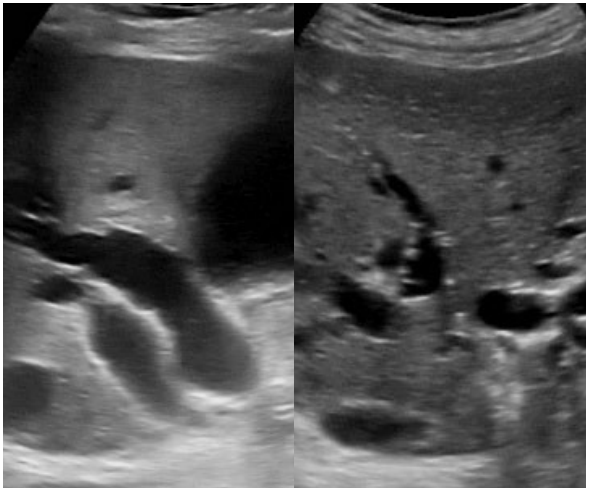

Fig. 31:
Left: Dilated bile ducts in the region of the hepatic hilum and in the area of the ductus hepatocholedochus.
Right: Dilated intrahepatic bile ducts.

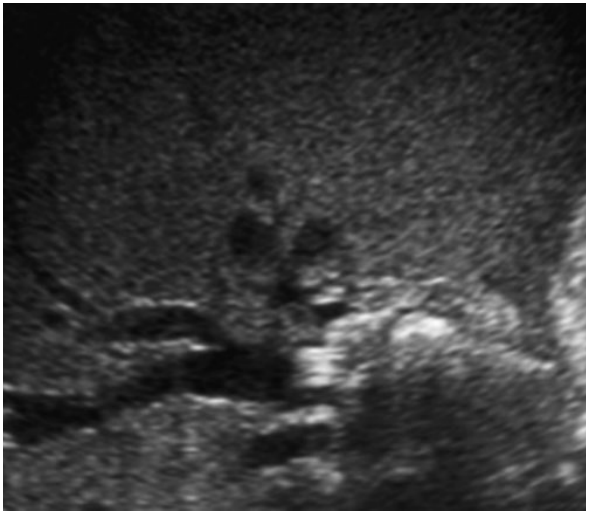

Fig. 32a:
Intrahepatic bile duct stones near the hilum with dilation of the bile duct in the affected segment.

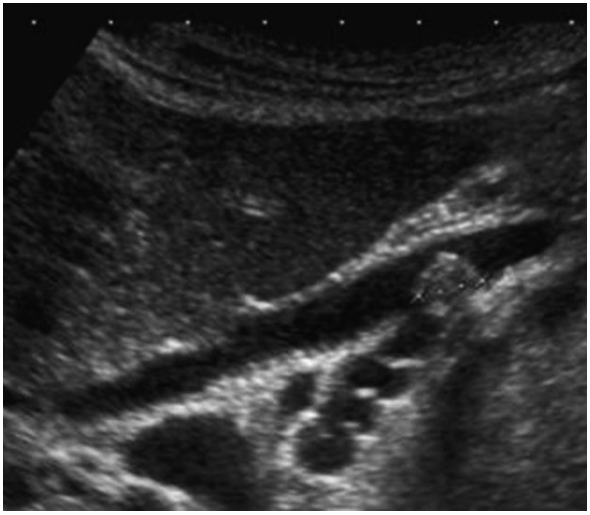

Fig. 32b:
Choledocholithiasis with mobile concrement.
No dilation of the bile duct. Very clear valves of Heister of the adjoining dilated cystic duct.

hepatic bile duct above the junction with the cystic duct, the gallbladder will be small, whereas an obstruction at the level of the papilla is associated with dilation of the entire efferent biliary system, including the gallbladder.
A dilated, obstructed ductus hepatocholedochus is suspected when the width is over 5–7 mm.
The direct sonographic detection of bile duct stones (Fig. 32) can only be achieved in half of patients due to the stone being located in an area where it is overlapped with intestinal gas. In addition, concrements in the bile duct often have only a slight dorsal acoustic shadow.
The usefulness of sonography as a method for the direct visualization of bile duct stones (Fig. 32) should therefore not be overestimated; predominantly indirect signs provide more certainty regarding the clinical suspicion of an obstruction of the common bile duct. Dilation of intrahepatic bile ducts typically appears sonographically as a "fox's den-like" duct system, with the region of the hepatic hilum being the easiest to visualize (Fig. 31).

Intrahepatically positioned concrements on the other hand can usually be visualized more easily. Isolated dilations of the intrahepatic or extrahepatic bile ducts may be observed in the context of congenital bile duct cysts, or in the context of Caroli disease. Sometimes there are concrements in these ectatic regions (Fig. 33).

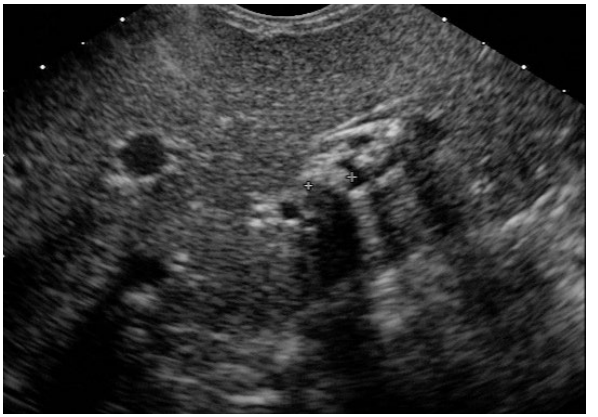

Fig. 33:
Caroli disease with acoustic shadow-producing concrements in dilated intrahepatic bile ducts.

The very rare LPAC (low phospholipid-associated cholelithiasis) syndrome is typically associated with intrahepatic concrements.
The most important complications of bile duct stones are biliary pancreatitis and cholangitis.

4.3 Biliary pancreatitis

In the case of biliary pancreatitis, arguably the most serious complication of gallstones, sonography can provide important supplementary information. If the pancreas can be well visualized sonographically, naturally, a very differentiated diagnosis of the parenchyma (e.g. normal echo pattern or hypoechoic-edematous pattern, normal or coarse, clumped calcifications or concretions appropriate echoes, echo-free pseudocysts, sharp or blurred parenchymal demarcation), the pancreatic ducts (dilation over 2–3 mm, intraductal concrements) and the surrounding structures (e.g. necrosis) can take place. When visualizing the pancreas in this situation, it is important to take one's time and examine carefully.
With this approach, it is often possible to overcome the problem of overlapping air, which is not uncommon in the case of pancreatitis in particular, through controlled compression with the transducer and through exercising sufficient patience during the examination. By visualizing dilated bile ducts (due to obstruction by a stone near the papilla, but also due to edematous obstruction of the common bile duct in the intrapancreatic course) when pancreatitis is present, sonography can indirectly provide more certainty regarding a suspicion that the pancreatitis has a biliary cause in the case of known cholecystolithiasis, and can have a decisive influence on the further therapeutic procedure.

5 Sonography for assessing gallbladder function

The emptying function of the gallbladder can be easily assessed using sonography. These days, this is only required as part of studies or prior to oral litholysis, which is only used in exceptional cases. Usually, a standardized, fat-rich "stimulus" meal is administered, and the surface of the gallbladder lumen is measured before and after the emptying of the gallbladder has been stimulated. The gallbladder volume can be determined almost exactly using the formula: length × width × depth × 0.5.

For a basic examination of the emptying function, the gallbladder can be measured in its largest longitudinal and transverse diameter before and 30–45 minutes after a fat-rich standard meal (alternatively: chocolate). A reduction of the measured parameters of at least 30% indicates a sufficient emptying function and a secondary finding of probable patency of the cystic duct.

6 Use of sonography in differentiated treatment of gallstones

Sonography can almost always directly detect gallbladder stones. In the case of suspected bile duct stones, indirect indications are often helpful, direct detection is less commonly achieved. Sonography is therefore a non-invasive, rapidly available imaging method and the first diagnostic step in patients with suspected gallstones, or suspected complications of gallstones such as cholecystitis, bile duct obstruction, or biliary pancreatitis. The resolution and image quality available today, when combined with appropriate training, makes it possible to use this method, which is often decisive for the therapeutic procedure, in a targeted, logical, and above all cost-effective manner.

Since the introduction of laparoscopic cholecystectomy, mainly due to repeated stone formation, oral drug-based litholysis has only been indicated in certain cases.

Oral litholysis with ursodeoxycholic acid can be used in individual cases (small, non-calcareous concrements, ideally with sonography-targeted shaking of floating stones, good gallbladder contraction; the patient must be informed about the success rates and risk of relapse).

Extracorporeal shock-wave lithotripsy (ESWL) is no longer used for gallbladder stones (due to risk of relapse), but it still has its place in the case of large, impacted, or intrahepatic bile duct stones.

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