Ultrasound of the gall bladder and biliary tree: part 2

Ultrasound is the modality of choice for the initial assessment of the gall bladder and the biliary tree. This article details normal ultrasound appearances of the biliary tree, as well as appearances of biliary obstruction, biliary cirrhosis, biliary gall-stones, developmental disorders, cholangiopathies and cholangiocarcinoma.

Ultrasound is the modality of choice in the initial investigation of suspected gall bladder and biliary tree pathology. Ultrasound is accurate, highly sensitive, non-invasive, readily available and inexpensive. Some of the common indications for sonography of the liver and biliary tree include the investigation of jaundice, upper abdominal pain and abnormal liver function tests (Bennett and Balthazar, 2003; Hayes, 2004; Smith, 2011). This article is the second of two looking at the role of ultrasound in the investigation of gall bladder and biliary pathology. This article covers normal ultrasound appearances of the biliary tree, as well as appearances of biliary obstruction, biliary cirrhosis, biliary gall-stones, developmental disorders, choledochal cysts, cholangiopathies, cholangiocarcinoma and ultrasound-guided interventional procedures. The previous article (p. 312) covers normal ultrasound appearances of the gall bladder, as well as appearances of cholecystitis, sludge, adenomyomatosis, polyps, carcinoma and parasites.

Technique and normal appearances

Since the gall bladder needs to be assessed along with the biliary tree, patients should fast for 4 hours before ultrasound examination. Patients are scanned supine, with a curvilinear probe of as high a frequency as will allow sufficient penetration. The intra- and the extrahepatic biliary tree can be visualized by scanning at the right costal margin or intercostally. Turning the patient halfway to his/her left (left posterior oblique position) and scanning subcostally in full inspiration is a good way to visualize the common bile duct at the porta hepatis.

The probe is held at 90° to the right costal margin to image the common bile duct anteromedial to the portal vein together with the right hepatic artery, which usually lies between them (*Figure 1*). The distal common bile duct is usually obscured by duodenal gas but can be picked up again within the pancreatic head. The internal diameter of the common bile duct should be measured at the level of the right hepatic artery.

The calibre of the normal common bile duct is commonly quoted as being less than 5 mm. However, the normal calibre increases 1 mm for each decade after 50 years of age. Post cholecystectomy the common bile duct may be as large as 8–10 mm.

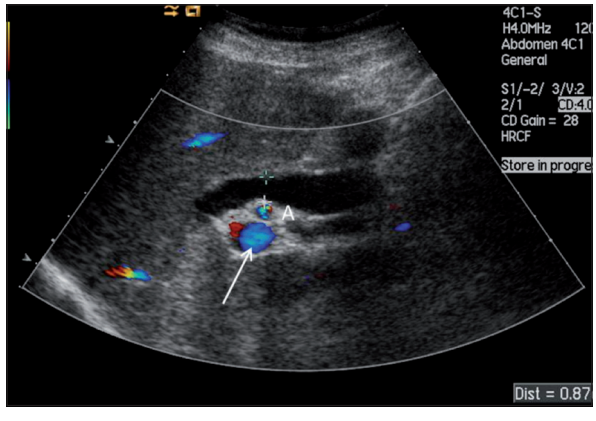
Intrahepatic bile ducts are seen as fine tubular structures measuring 1–2 mm running parallel to the portal vein branches.

Additional techniques that may be useful include contrast-enhanced ultrasonography, using blood-pool microbubbles, and elastography to assess liver stiffness.

Jaundice and biliary obstruction

The main role of ultrasound in the icteric patient is to ascertain whether jaundice is the result of obstruction of the biliary tree – if there is dilation, ultrasound is used to establish the level and cause where possible. Biliary obstruction is manifest by dilatation of the common bile duct and/or intrahepatic bile ducts, depending on the level of the obstruction (*Figure 2a*). The 'parallel-channel' sign is demonstrated when a dilated intrahepatic duct is imaged running alongside a portal vein branch within a peripheral portal triad (*Figure 2b*).

Figure 1. Common bile duct. Longitudinal section at the liver hilum showing a dilated common bile duct (callipers), right hepatic artery (A) and portal vein (arrow).



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When seen in cross section, paired dark circles are demonstrated ('double-barrelled shotgun' sign). Views of a dilated proximal and distal common bile duct are shown in *Figure 3*.

Causes of biliary duct dilatation include gall-stones and tumours at the porta hepatis and head of pancreas, and are listed in *Table 1*.

Duct dilatation without jaundice is uncommon but may result from persistent dilatation after relief of an obstruction (e.g. a passed bile duct stone) or from ball-valve calculi, which obstruct when the subject is upright and move away in the supine position, so that bile drains intermittently.

Duodenal gas may obscure the distal common bile duct on ultrasound so that further imaging with magnetic resonance cholangiopancreatography may be needed to identify the cause. However, secondary clues as to the site of obstruction can be seen on ultrasound. For example, pathologies in the pancreatic head such as a tumour commonly produce the 'double duct' sign – dilatation of both the common bile and main pancreatic ducts. Ultrasound can also be used to guide biliary drainage procedures. A liver abscess may also present with jaundice and sepsis (*Figure 4*), and ultrasound can guide aspiration or drainage according to size and number. Contrast-enhanced ultrasonography is particularly helpful here because the abscess is often much more extensive than is appreciated on the B-mode scan and is usually septated, both features better visualized with contrast-enhanced ultrasonography.

Biliary cirrhosis

Any cause of prolonged cholestatic jaundice may cause diffuse liver damage with attendant liver fibrosis, eventually leading to cirrhosis and its complications (portal hypertension and regenerating nodules that may transform into hepatocellular carcinomas).

Table 1. Causes of biliary dilatation in order of decreasing frequency

Choledocholithiasis
Biliary and pancreatic neoplasm
Biliary stricture
Post cholecystectomy
Cholangitis
Pancreatitis
Pharmacological (opiates)

Figure 2. Intrahepatic biliary duct dilatation. a. The dilatation of the intrahepatic biliary tree is seen as branching tubular structures. b. In the 'parallel channel' sign, a dilated intrahepatic bile duct runs alongside an intrahepatic branch of the portal vein. This is often best visualized in the left lobe of the liver.

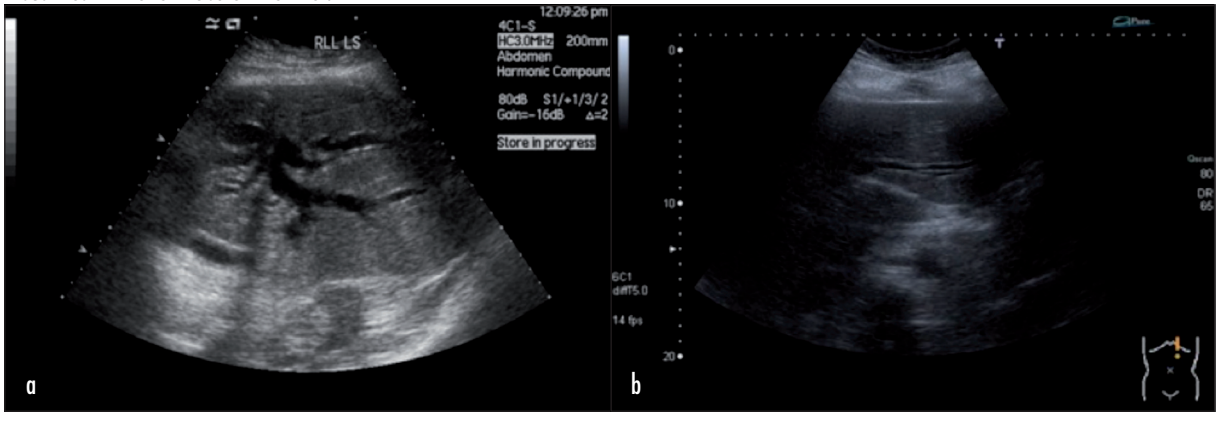
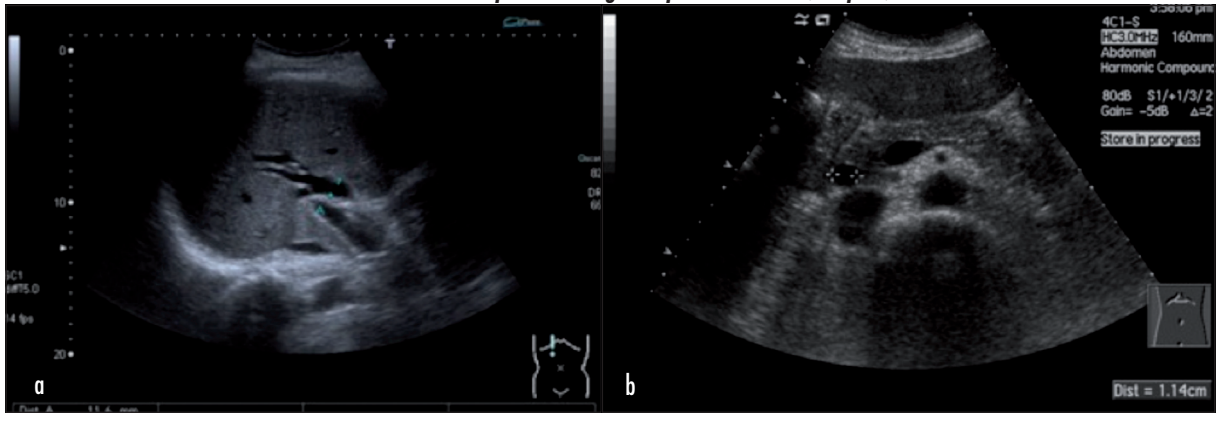


Figure 3. Common bile duct dilatation. a. Dilatation of the proximal common bile duct is demonstrated at the porta hepatis (callipers). b. The dilated distal common bile duct is visualized as it passes through the pancreatic head (callipers).



If the underlying aetiology is prolonged obstruction of the large ducts, ultrasonography readily demonstrates the dilated biliary tree, and there may have been time for calculi to form within the ducts.

Primary biliary cirrhosis is an autoimmune disease, possibly triggered by an altered response to Gram-negative bacteria. It is characterized by serum antimitochondrial antibodies. The ultrasonic features are non-specific with no macroscopic duct dilatation. In the late stages, features of cirrhosis may be detected. Shear wave ultrasound elastography can be used to quantify the degree of fibrosis in all these conditions (Bamber et al, 2013; Cosgrove et al, 2013).

Biliary calculi

Gall-stones can pass from the gall bladder via the cystic duct into the common bile duct and result in biliary obstruction with or without associated infection (cholangitis). They may also form in a chronically dilated biliary system and are typical findings in sclerosing cholangitis. Ultrasound is the initial investigation of choice in suspected common bile duct calculi but intraductal stones are only seen in approximately 50%, sometimes because they are little more than inspissated bile, sometimes seemingly because they are in direct contact with the walls of the duct (*Figure 5*).

Developmental disorders

The commonest biliary malformations are simple cysts, which are rarely symptomatic unless they become very large or undergo haemorrhage. Simple cysts have the typical appearance on ultrasound of cysts anywhere: echo-free, smooth-walled spaces with distal through transmission ('enhancement'). They may be single or multiple and in dominant polycystic disease may be numerous, although the liver is not always affected. They do not enhance on contrast-enhanced ultrasonography, even when they have undergone haemorrhage. Contrast-enhanced ultrasonography may reveal cysts not detected on unenhanced scans.

Biliary atresia is a rare condition in which the bile ducts either fail to form (fetal-embryonic type, often with associated developmental defects) or undergo involution with inflammation in the neonatal period. A practical classification separates them into operable cases (approximately 10%), where sufficient extrahepatic biliary tree survives to permit anastomosis to the duodenum (Kasai procedure) and those where correction is

Figure 4. Liver abscess. a. Ill-defined focal liver lesion on baseline B mode (callipers). The patient also has gall-stones. b. Dual display contrast-enhanced ultrasound showed enhancement of thickened septi in the abscess (not detected on B mode) as well as increasing the conspicuity of two subcapsular collections (arrows). (Contrast Pulse Sequencing CPS mode; Siemens, USA.)

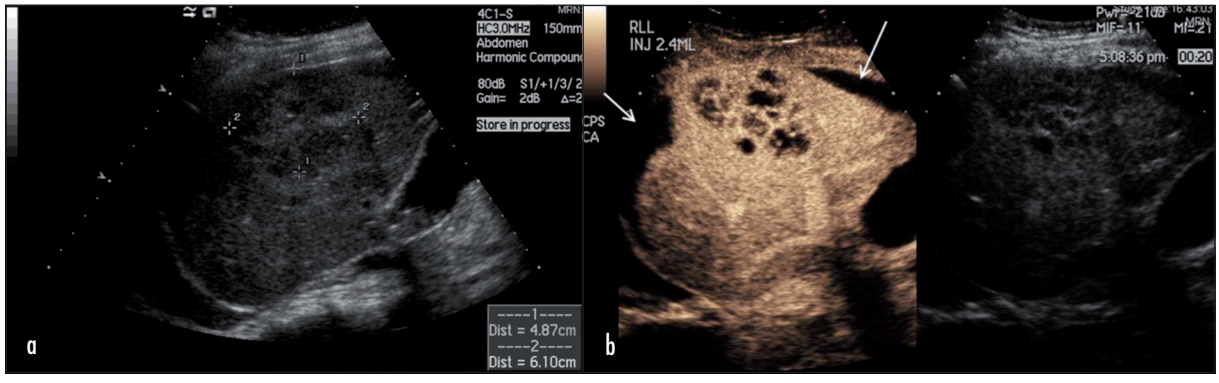
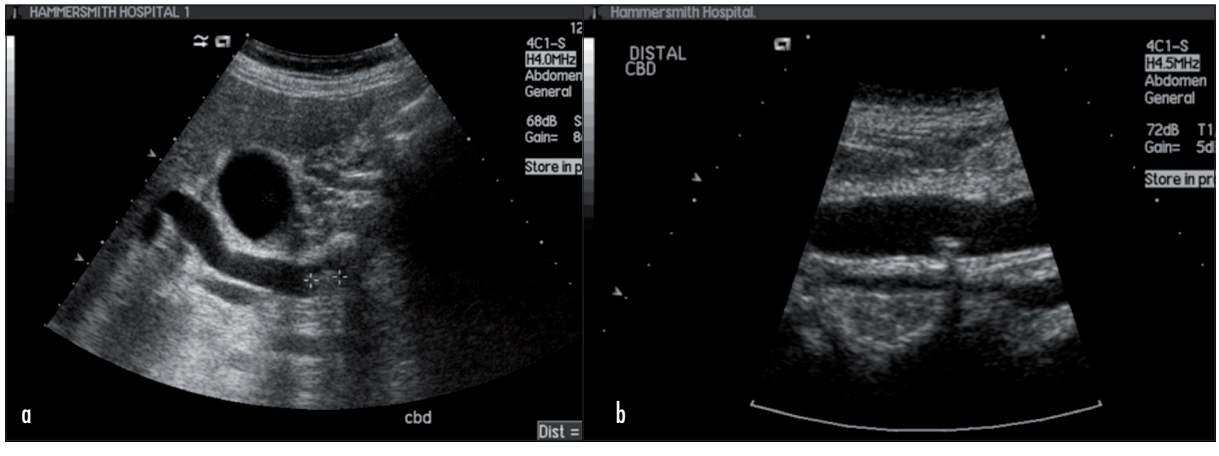


Figure 5. Intraductal gall-stones. B-mode ultrasound scanned longitudinally along the common bile duct. An 11 mm echogenic intraductal non-shadowing gall-stone was identified within the distal common bile duct (callipers in a) and (b) mid common bile duct, this one showing marked shadowing.

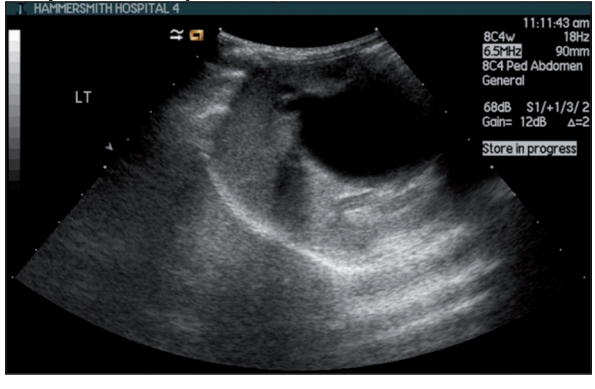


impossible, in which case liver transplantation is the only option. On ultrasound, the gall bladder may be atrophic and a characteristic triangular echogenic focus may be detected anterior to the porta hepatis. Because of the associated fibrosis, intrahepatic duct dilation is uncommon, although ectasia at the porta sometimes produces a pattern reminiscent of a choledochal cyst. The fibrosis lends a coarse texture to the liver. Hydroxy iminodiacetic acid (cholescintigraphy) scanning to demonstrate lack of bile excretion is usually required and magnetic resonance cholangiopancreatography may also be useful. Ultimately biopsy is often needed.

Choledochal cysts

This is a segmental cystic dilatation of the common bile duct (*Figure 6*), without involvement of the gall bladder or cystic duct. Although most commonly detected in childhood, choledochal cysts may present in adults with intermittent obstructive jaundice, recurrent right upper quadrant colicky pain and a right upper quadrant palpable mass. They are classified into five types. Type I (80–90%) is dilatation of the extrahepatic ducts, type II is a true diverticulum from the extrahepatic duct, type III is a dilatation of the extrahepatic bile duct within the duodenal wall (choledochocele), type IV is cysts or dilatations of the intra- and extrahepatic ducts and type V demonstrates multiple dilatations or cysts affecting the intrahepatic ducts only (known as Caroli's disease) (*Figure 7*). Complications include cholelithiasis, cholangitis, acute pancreatitis, biliary cirrhosis and cholangiocarcinoma. Management is by surgical resection.

Figure 6. Type 1 choledochal cyst. Ultrasound demonstrates cystic dilatation of the common bile duct of a choledochal cyst in this child who presented with jaundice.



Cholangiopathies

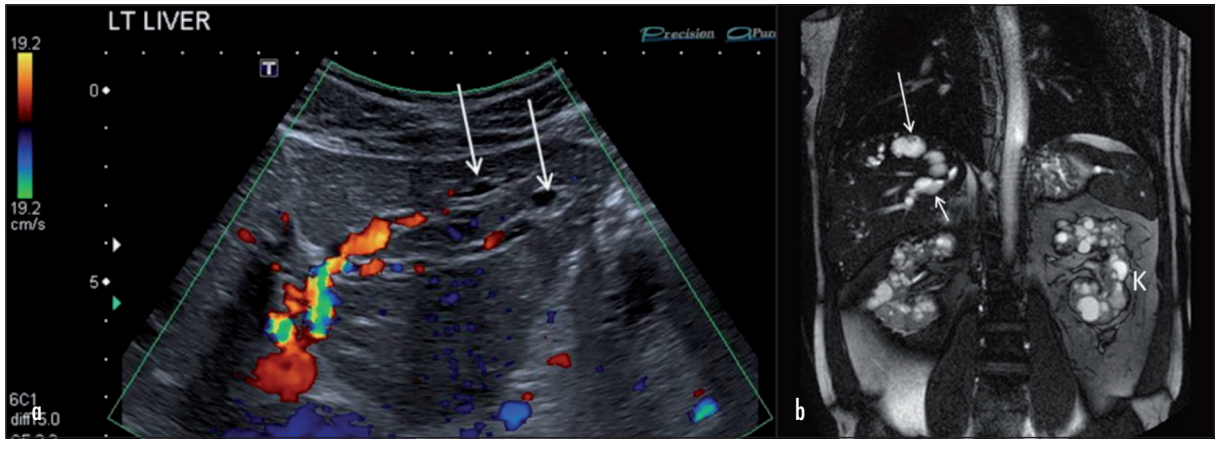
Several inflammatory bile duct pathologies are included in the group of cholangiopathies. They may be infective (usually bacterial), infestation by parasites, ischaemic (especially after liver transplantation), or immune (e.g. primary biliary cirrhosis and primary sclerosing cholangitis). Some forms of biliary atresia, especially the neonatal type, may also be considered as cholangiopathies.

Acute cholangitis occurs when obstructed ducts are infected with organisms such as *Escherichia coli* and *Klebsiella* spp. The sonographic features include dilated intrahepatic ducts (*Figure 8*), and often dilatation of the common bile duct, whose walls may be thickened. Stones or sludge may be seen within the intrahepatic ducts or there may be biliary strictures, which are difficult to recognize with ultrasound. It may be recurrent ('oriental cholangitis') in which intrahepatic calculi are typically found.

Infestations by flukes can affect the biliary tree, notably *Clonorchis sinensis*, in which increased periductal echogenicity has been reported, as well as intraductal calculi. Ascaris worms are larger and can be demonstrated as curved echogenic lines within the common duct (as well as in the gall bladder) (*Figure 9*); when viable, their writhing movements are striking and pathognomonic.

Primary sclerosing cholangitis is a progressive fibrosing inflammatory disorder of the biliary tree, with multifocal strictures, bead-like duct dilatation, bile duct obliteration and eventual biliary cirrhosis. It may be idiopathic or associated with inflammatory bowel disease (70% have ulcerative colitis). It affects males and females in a 2:1 ratio. Patients present with jaundice, itching, immune

Figure 7. Caroli's disease. a. Ultrasound showing intrahepatic biliary dilation (arrows). b. Coronal T2-weighted magnetic resonance scan showing cystic intrahepatic biliary dilatation (arrows) and adult polycystic kidneys (K) (a known association).



pancreatitis and non-specific systemic features. The condition progresses to liver failure following bile duct obliteration that causes biliary cirrhosis.

There are several variants in the pattern of involvement, but the common bile duct is almost always involved (*Figure 10a*). The focal biliary dilatation may be seen on ultrasound, as may the mural thickening (seen as echogenic portal triads). However, the biliary tree may appear normal on ultrasound. Endoscopic retrograde cholangiopancreatography (*Figure 10b*) and magnetic resonance cholangiopancreatography are more sensitive at demonstrating the intrahepatic biliary strictures than ultrasound. Ultrasound may demonstrate a coarse heterogeneous echotexture of the liver from cirrhosis as well as features of portal hypertension. On elastography, the liver stiffness is increased.

Management consists of endoscopic stenting of main duct strictures, stone removal (as these form in segments of stricturing) and liver transplantation when appropriate. There is also an increased incidence of cholangiocarcinoma.

Figure 8. Cholangitis. a. Ultrasound showing periportal echogenic changes (arrow) indicative of cholangitis. b. Computed tomography showing cholangitis confined to the left lobe resulting from a central stricture of the left hepatic duct.

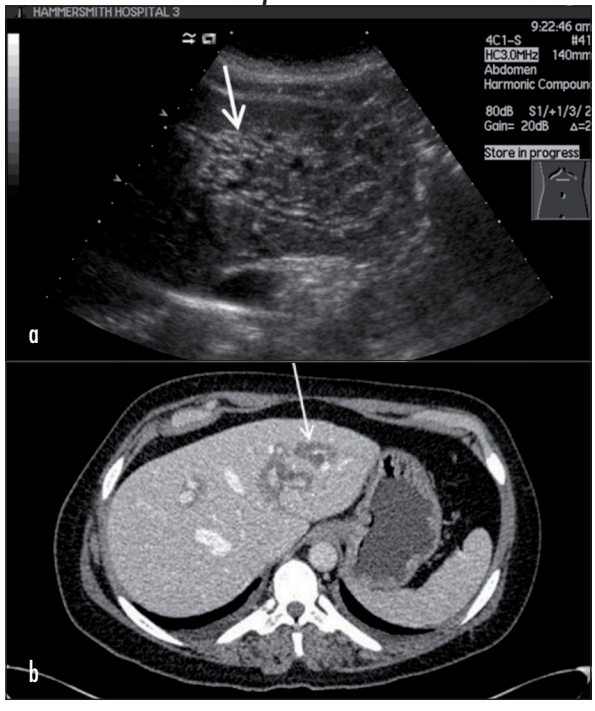


Figure 9. Ascaris. The typical parallel line appearance (arrow) of an ascaris worm is seen in the common bile duct (CBD). PV = portal vein.

Tumours and tumour-like conditions

Biliary hamartomas are found in up to 5% of livers at autopsy but most lesions are too small to be apparent on imaging. Larger and multiple biliary hamartomas may be visualized as submillimetre cysts that are distinguished by having posterior flares or 'comet tail' artefacts (*Figure 11*). They may also produce a coarse echotexture

Figure 10. Primary sclerosing cholangitis. a. Ultrasound demonstrates a dilated thick-walled common bile duct (CBD) (callipers). b. Endoscopic retrograde cholangiopancreatography shows beading and stricturing of the intrahepatic ducts and a strictured irregular common bile duct.

that can be confused with confluent malignancy, but they show no enhancement on contrast-enhanced ultrasonography. Often known as von Meyenburg complexes, they are of no clinical significance but may produce confusing imaging.

Cholangiocarcinoma

Ductal cholangiocarcinomas frequently present with obstructive jaundice manifested by intrahepatic bile duct dilatation on ultrasound – with or without extrahepatic bile duct dilatation, depending of the precise location of the tumour. Cholangiocarcinomas are most commonly extrahepatic (90%) and may be multifocal. The commonest type, hilar cholangiocarcinoma (the Klatskin tumour), develops at the confluence of the right and left hepatic ducts and typically demonstrates lobar dilatation and non-confluence of the right and left ducts at the porta hepatis (*Figure 12*). Although some cholangiocarcinomas are seen as a solid, vascular mass, most are very difficult to detect on ultrasound or computed tomography, having the same properties as liver parenchyma. Ultrasound contrast agents have been shown to increase the conspicuity of these tumours significantly by demonstrating early washout. The secondary signs of duct dilatation – particularly with focal irregularity, mass effect and subtle differences in liver echogenicity – may be helpful in diagnosis.

Predisposing conditions include ulcerative colitis, sclerosing cholangitis, Caroli's disease, choledochal cyst, *Clonorchis sinensis* infestation (prevalent in the far East and the commonest cause worldwide) and stones.

The prognosis is generally poor at presentation (median survival 5 months) because typically the tumour has already spread to the liver or nodes or invaded the portal vein and may be multifocal. The histological diagnosis is usually obtained by endoscopic retrograde cholangiopancreatography or biopsy on endoscopic ultrasound and the tumour is staged with computed tomography or magnetic resonance imaging. Surgery may be possible for localized disease. Chemotherapy has had limited success. Management is palliative with a stent to bypass the stricture and relieve the obstructive jaundice (*Figure 13*).

Figure 11. Biliary hamartomas. When large enough to be visualized, biliary hamartomas can be delineated as small cystic structures with a distal comet tail artefact (arrow). In other cases they produce a heterogeneous liver texture which is easily mistaken for confluent metastases.

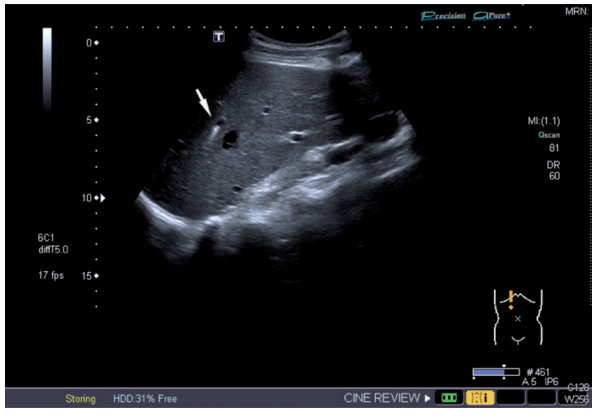


Figure 12. Cholangiocarcinoma. Dual display contrast-enhanced ultrasound showing a defect in the contrast mode (callipers on right screen) from a Klatskin tumour, which is not seen on the coregistered B mode (left screen).

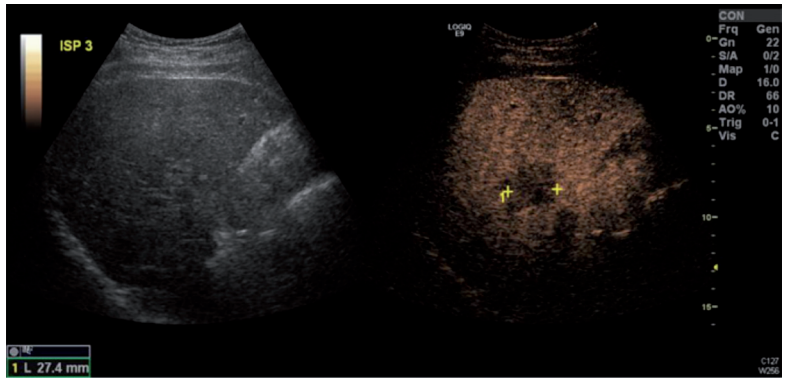
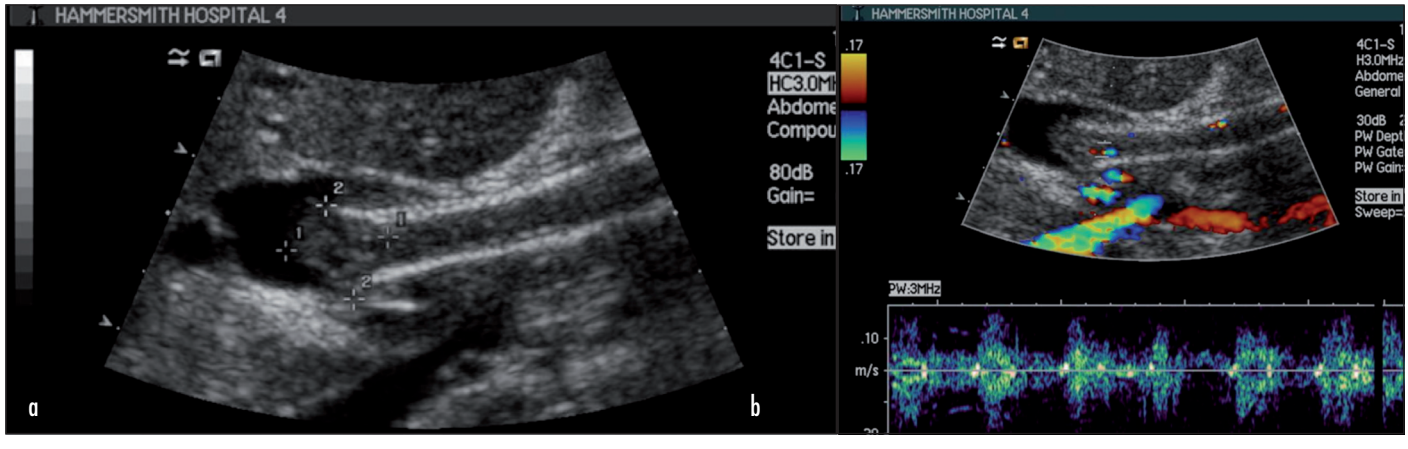


Figure 13. Cholangiocarcinoma. a. Ultrasound shows a biliary stent in a dilated common bile duct with echopoor material within the intrahepatic end of the stent (callipers) as well as within the stent, causing obstruction with upstream biliary dilatation. b. Colour Doppler shows arterial flow in the soft tissue, suggesting tumour invasion of the stent.

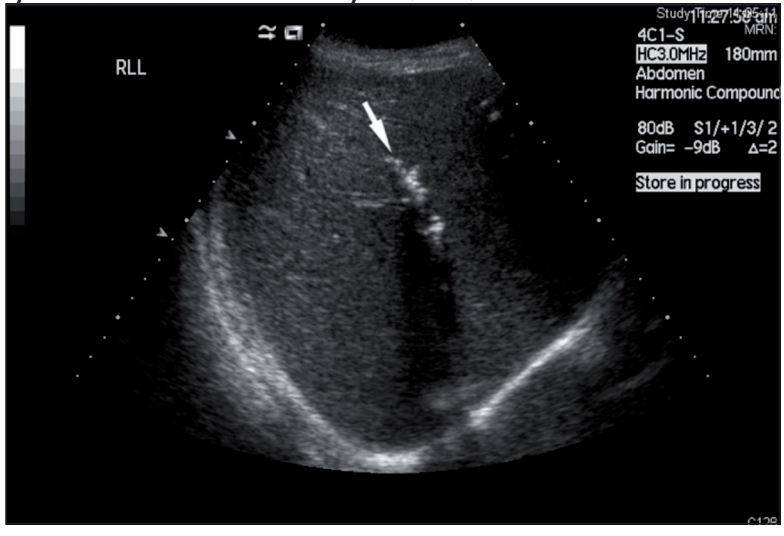


Interventional and surgical problems

Ultrasound is usually the modality of choice for guiding and monitoring interventions of the biliary tree (and elsewhere in the abdomen). Examples include placing drains in a dilated system and assessing the patency of biliary stents. The latter can pose a difficult problem because the duct calibre is not a good guide to the patency of a stent since the biliary tree may remain dilated despite adequate drainage. Indirect signs of patency are aerobilia (*Figure 14*) and visualization of both ends of the stent, usually at the porta and at the duodenum, but neither is sufficient alone. Aerobilia can persist for long periods after a stent has become obstructed and merely demonstrating that a stent is correctly positioned does not in itself prove that it is draining effectively.

External drains inserted to drain a biloma or other collections can be assessed by instilling a small dose of a microbubble contrast agent. One drop of SonoVue (Bracco, Milan, Italy) in 20 ml of saline provides adequate contrast and this can be injected into any catheter to demonstrate the extent of the cavity being drained (*Figure 15*). Often it becomes apparent that the entire cavity is not being drained and the drain may need to be repositioned or steps taken to irrigate with streptokinase to break up a multiloculated collection.

Figure 14. Aerobilia. In this patient with an internal biliary stent, patency is suggested by the demonstration of air in the biliary tree (arrow).



KEY POINTS

- Ultrasound is widely used as the first-line imaging modality in the assessment of the gall bladder and biliary tree.
- Ultrasound is very sensitive (better than computed tomography) in the detection of gall-stones.
- Ultrasound has the advantages of low cost, real-time bedside imaging, accessibility, portability, lack of ionizing radiation, non-invasiveness, and multiplanar imaging.
- Ultrasound is very sensitive in the detection and characterization of intra- and extrahepatic biliary duct dilatation.
- Ultrasound can also be used to guide interventions such as biliary intervention (percutaneous transhepatic cholangiography, drainage and stenting) and gall bladder drainage in empyema.
- Ultrasound can assess the extent of biliary dilatation following intervention (e.g. stent insertion).

Conclusions

Ultrasound is the initial modality of choice to image the gall bladder and biliary tree. A range of benign and malignant pathologies affects the biliary tree. Particularly for the more aggressive pathologies, ultrasound can be extended to evaluate the entire upper abdomen, and should be supplemented by magnetic resonance cholangiopancreatography or computed tomography. **BJHM**

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Conflict of interest: none.

Bamber J, Cosgrove D, Dietrich CF et al (2013) EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 1: Basic principles and technology. *Ultraschall Med* **34**(2): 169–84
Bennett G, Balthazar E (2003) Ultrasound and CT evaluation of emergent gallbladder pathology. *Radiol Clin North Am* **41**: 1203–16
Cosgrove D, Piscaglia F, Bamber J et al (2013) EFSUMB Guidelines and Recommendations on the Clinical Use of Ultrasound Elastography. Part 2: Clinical Applications. *Ultraschall Med* **34**(3): 238–53
Hayes R (2004) Abdominal pain: general imaging strategies. *Eur Radiol* **14** (Suppl 4): L123–37
Smith J (2011) Gallbladder and biliary tree. In: Allan P, Baxter G, Weston M, eds. *Clinical Ultrasound*. 3rd edn. Churchill-Livingstone, Edinburgh: 227–72
Wills M, Harvey C, Kuzmich S, Afaq A, Lim A, Cosgrove D (2014a) Characterizing benign liver lesions and trauma with contrast-enhanced ultrasound. *Br J Hosp Med (Lond)* **75**(2): 91–5
Wills M, Harvey C, Kuzmich S, Afaq A, Lim A, Cosgrove D (2014b) Characterizing malignant liver lesions with contrast-enhanced ultrasound. *Br J Hosp Med (Lond)* **75**(3): 151–4

Figure 15. Contrast-enhanced ultrasound of a biliary stent. A small amount of SonoVue diluted in 20 ml saline was instilled into an external biliary drain in this patient with biliary obstruction. The contrast flowed freely, indicating patency.