Imaging the liver and biliary tract

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Abstract

A variety of modalities is available to image the liver and biliary tract, many offering complementary information, with a combination of techniques often being required to make the diagnosis or determine optimal patient management. Ultrasound is commonly used as the primary investigation as it is safe, cheap and widely available. Computed tomography has a central role for emergency imaging, cancer diagnosis and staging, and assessment of treatment response. Magnetic resonance imaging is excellent for interrogating the liver parenchyma, and is the modality of choice for characterizing a focal liver lesion and non-invasive investigation of the biliary tree. The addition of hepatobiliary contrast agents and diffusion-weighted imaging has further improved accuracy. This article describes the role of each of these modalities, highlighting several common, benign and malignant hepatobiliary disease processes. Other less commonly used modalities such as PET/CT and cholescintigraphy are described and various hepatobiliary interventional techniques are summarized.

Keywords Bile ducts; biliary tract diseases; cholangiography; computed tomography; liver; liver diseases; magnetic resonance imaging; positron-emission tomography; ultrasonography

What's new?

- Non-invasive quantitative US and MRI techniques are playing an increasing role in the assessment of fibrosis, fat and iron in parenchymal liver disease
- The combination of liver-specific contrast agents, diffusion-weighted imaging, and improved MRI technology has increased the accuracy of focal liver lesion detection and characterization, in many cases avoiding the need for biopsy
- CT dose-reduction techniques such as iterative reconstruction have been introduced, which can substantially reduce patient dose in multi-phase hepatobiliary examinations
- Image-guided ablative and endovascular treatments such as RFA now have an established role in the treatment of hepatocellular carcinoma and unresectable hepatic malignancy

Ultrasonography

Ultrasonography (US) remains the most widely performed primary investigation for suspected hepatobiliary disease, owing to its wide availability and avoidance of ionizing radiation.

Biliary disease

In the fasted state, the gallbladder appears on US as an oval hypo-echoic structure with a smooth thin wall. Gallstones usually appear as mobile echogenic foci with posterior acoustic shadowing, and are identified with >95% accuracy in the gallbladder, but less so in the common bile duct due to adjacent bowel gas.[1] The US findings in acute cholecystitis include mural thickening (>3 mm), pericholecystic fluid and a positive sonographic Murphy's sign (Figure 1).[2] Gallbladder polyps appear as fixed luminal defects without acoustic shadowing. Adenomyomatosis and chronic cholecystitis are other common benign causes of mural thickening demonstrated on US. Carcinoma of the gallbladder can present as a polypoid luminal tumour or as diffuse wall thickening and is often difficult to differentiate from benign conditions. Gallbladders containing polyps >1 cm are generally resected due to such difficulties.

US has a major role in identifying biliary dilatation in the context of jaundice or right upper quadrant pain, which may be caused by obstructive pathology (duct stones, benign or malignant strictures), but dilatation is also found after cholecystectomy, prolonged fasting or with sphincter of Oddi dysfunction. The common hepatic duct (CHD) normally measures up to 6 mm until age 60, with a further allowance of 1 mm per decade thereafter.[3] The double duct sign refers to dilatation of the pancreatic (>4 mm) and common duct, which is suggestive of a pancreatic head or ampullary tumour and is usually further investigated by multiphasic computed tomography (CT).

Liver disease

The normal liver has a uniform and homogenous echotexture. Fatty infiltration gives a diffusely echogenic liver, with attenuation of the US beam as it passes deep into the organ. With the recognition of non-alcoholic fatty liver disease as a cause of chronic liver disease there is interest in using US attenuation parameters to quantify steatosis, although this is not established as a clinical tool at present.

In cirrhosis the liver usually appears coarse and echogenic. Common features include surface nodularity, atrophy of the right lobe, hypertrophy of the caudate lobe and enlargement of the gallbladder fossa and umbilical fissure. Associated findings related to portal hypertension include reduced, reversed or absent portal vein flow, varices, splenomegaly and ascites.[4] Changes in stiffness correlate with fibrosis, currently assessed by invasive liver biopsy, and can now be quantified using US (or magnetic resonance imaging; MRI) via techniques such as transient elastography (FibroScan®), performed without generating images, or shear-wave elastography, where stiffness is measured in a region of interest while imaging the liver.[5]

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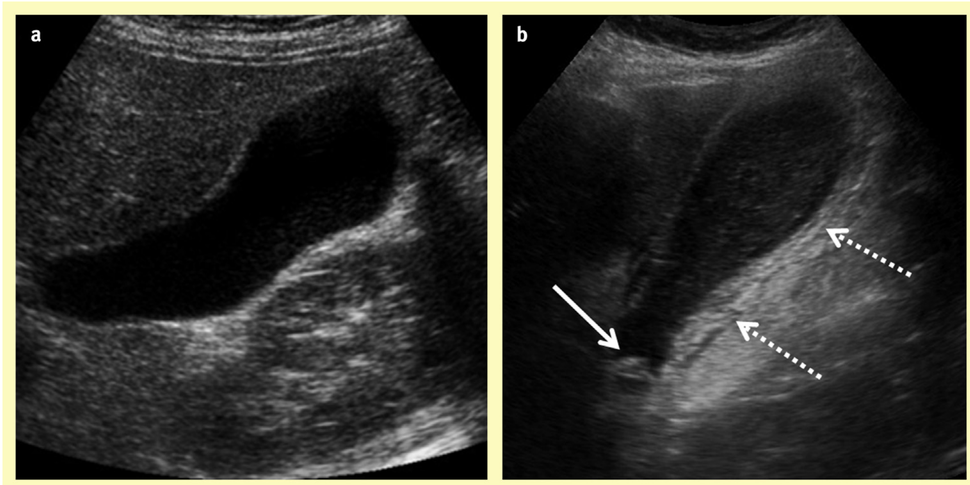

Figure 1 (**a**) US image showing normal thin walled gallbladder. (**b**) acute calculous cholecystitis. The gallbladder wall is diffusely thickened (dashed white arrows) and contains echogenic bile, with a gallstone impacted in the neck (solid white arrows).

Doppler ultrasound

The frequency shift of an ultrasonic wave (Doppler effect) that occurs when it is reflected from a moving target (such as blood) can be used to create a colour map of blood flow and direction (colour Doppler) or a targeted waveform of blood flow (spectral Doppler). This is commonly used to interrogate the major hepatic vessels in chronic liver disease and after liver transplantation.

Contrast-enhanced ultrasound (CEUS)

Grey-scale US has modest sensitivity (50–65%) for metastatic disease and hepatocellular carcinoma (HCC).[6,7] It can differentiate simple cysts reliably but is limited in the characterization of solid focal lesions. CEUS improves both lesion detection and characterization.[8] It involves the intravenous injection of microbubble contrast media. Benign lesions are usually iso- or hyper-echoic to background liver in the late phase of enhancement (Figure 2). Although comparable to CT and MRI for lesion detection and characterization in ideal circumstances,[9] multiple lesions and lesions near the diaphragm or obscured by bowel gas are difficult to evaluate.

Computed tomography

Modern multi-detector CT is widely used and versatile, allowing rapid imaging of a large volume with high spatial resolution, facilitating accurate multi-phase imaging of the liver and biliary tree. Iodinated contrast is used for most examinations; it is contra-indicated in those with severe renal impairment or a history of anaphylactic reaction. The high-radiation dose of CT should be considered (especially with multiphase imaging), but can be reduced by decreasing scanning dose parameters, peak kVp and mA. Increased computing power has enabled iterative reconstruction techniques to further reduce dose.[10]

Imaging the acute abdomen

CT retains an important role for imaging in the emergency situation. In major trauma, dual phase imaging or a military protocol with a single biphasic contrast injection has a high accuracy for traumatic liver injuries and active arterial bleeding.[11,12] High-quality 3D reformats of hepatobiliary vascular anatomy are useful for planning endovascular intervention in cases of vascular injury.

CT demonstrates complications of cholecystitis such as necrosis, perforation, or pericholecystic abscess (Figure 3). Intrahepatic or perihepatic fluid collections and abscesses are accurately depicted and CT can facilitate drainage. In severe acute pancreatitis CT is widely used for identifying complications such as necrosis, collections or bleeding.

Hepatobiliary oncology imaging

Metastases are by far the most common malignant liver lesions, exceeding primary liver tumours by a factor of at least twenty. CT is used for staging and to assess response to treatment for the majority of malignancies that metastasize to the liver and primary tumours arising from the liver, pancreas and biliary tree. The blood supply to the liver is via the hepatic artery (25%) and portal vein (75%), with most tumours taking their blood supply from the hepatic artery and displaying a varying degree of vascularity. Hypervascular tumours such as hepatocellular carcinoma (HCC) or neuroendocrine malignancy should be imaged in the arterial phase to maximize contrast enhancement between tumour and background liver.

The majority of metastases from other sources (such as colorectal cancer) are hypovascular and best depicted on the portal venous phase scan. Triple-phase CT (unenhanced, arterial and portal venous phase) is used to clarify the cause of biliary obstruction identified on US (when stones are not suspected) and to stage pancreatic malignancy.[13]

Characterization of liver lesions

In cases where MRI is contraindicated or unsuitable, multi-phase CT may be used to characterize liver lesions. European and American Liver Associations allow multiphasic CT to be used as a non-invasive means of diagnosing HCC in patients with cirrhosis. Key diagnostic criteria include arterial hypervascularity with ‘washout’ demonstrated on a portal venous or 3-minute delayed acquisition.[14,15] Benign lesions, such as

