Imaging the liver: use of different modalities

Introduction

The liver, the largest internal organ in the body, is situated in the right upper quadrant of the abdominal cavity. It plays a major role in the metabolism (proteins, carbohydrates and lipids), hormone production, decomposition of red blood cells, drug deactivation and several immunological functions.

The complex structure, double blood supply (portal vein and hepatic artery) and sophistication of the physiological function make the diagnostic process extremely difficult. Using a combination of radiological findings and clinical information, the correct diagnosis can be achieved.

Diagnostic imaging

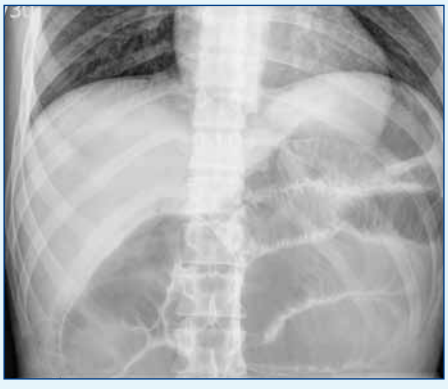
Plain radiography

For many years, plain radiography remained the main modality for liver imaging.

The liver is visible on the abdominal X-ray as a homogeneous shadow, projecting in the right upper quadrant, just below the diaphragm. Information available from a plain X-ray is limited to the size and shape of the liver, with no further information about focal or generalized parenchymal abnormalities (*Figure 1*).

Other imaging techniques are now easily accessible and have replaced plain radiography for the evaluation of liver pathology.

Figure 1. Abdominal X-ray showing liver as a homogeneous shadow in the right upper quadrant of the abdomen.



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Ultrasound and computed tomography now provide first-line diagnostic examinations for patients with suspected hepatic disease. Aside from visualization of the hepatic and biliary structures, these techniques may demonstrate extra-hepatic features which are useful in diagnosis; the presence of splenomegaly, ascites and venous collaterals in the epigastrium, all of which can point to a diagnosis of liver cirrhosis and portal hypertension in patients with a diffusely abnormal liver (*Figure 2*).

Ultrasonography

Ultrasonography is the most common examination used in the initial assessment of the liver disease. It is usually performed in patients with right upper abdominal pain, abnormal liver function tests or a palpable enlarged liver.

Ultrasound does not involve ionizing radiation, making it the preferred choice of GPs as a first-line investigation for the above complaints. Additionally, ultrasound can demonstrate the detailed structure and any abnormality within the gall bladder and biliary tree.

Ultrasound provides better visualization than computed tomography of calculi within the gall bladder and common bile duct, which often have a clinical presentation similar to liver pathology (*Figure 3*).

A strength of ultrasound is the ability to evaluate the texture of the liver parenchyma and to accurately assess infiltrative disease and perfusion discrepancies, including focal perfusion defects or various anatomical variations.

Figure 2. Liver cirrhosis with portal hypertension on computed tomography examination showing (a) multiple paraoesophageal varices, and (b) small liver with ascites, enlarged spleen and venous collaterals in the epigastrium.

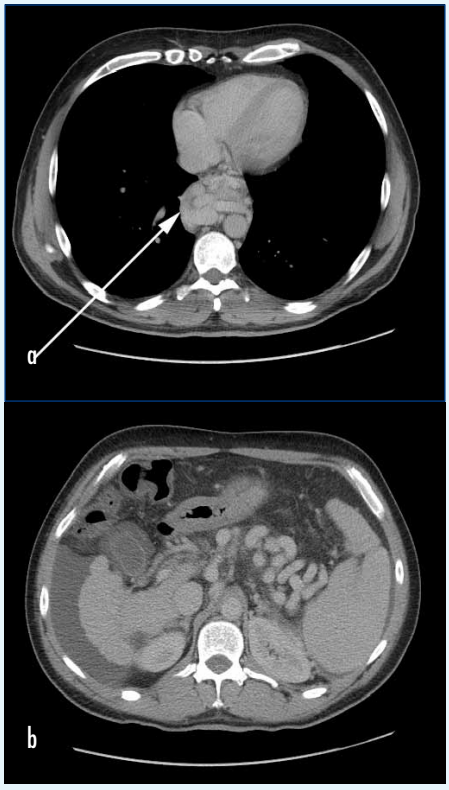
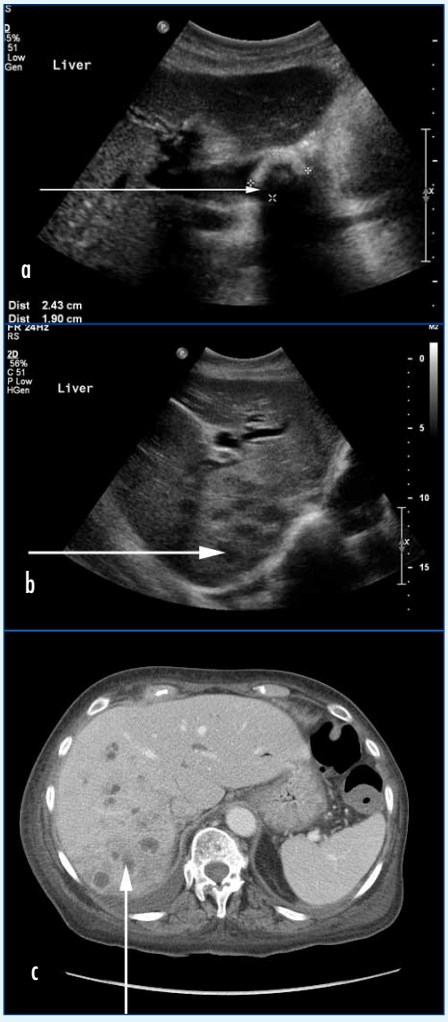


Figure 3. a. Ultrasound shows a large calculus in the dilated common bile duct. Obstruction of the biliary tree with multiple liver abscesses seen (b) on ultrasound and (c) on computed tomography.



Colour Doppler, especially power Doppler, allows assessment of the vascularity of focal liver lesions and aids further characterization. Intravascular contrast agents have been used to enhance colour flow signal in hepatocellular carcinoma, haemangioma and various metastases.

Focal hepatic lesions can be easily monitored with this technique, together with evaluation of the size and characteristics of the lesion in response to chemotherapy. It is also a useful screening test in medical conditions predisposed to development of hepatic malignancy (*Figure 4*).

The short scan time and dynamic technique make it extremely helpful for examining children and newborns for congenital defects and associated abnormalities, as well as evaluation of blood flow in the hepatic and portal vessels.

Despite its many strengths, ultrasound has definite limitations, including low specificity for characterization of liver lesions and subcentimetre lesions. Increasingly relevant is the poor penetration in obese patients or those with multiple overlying loops of bowel filled with air.

Computed tomography

The introduction of helical computed tomography scanning has greatly improved the quality of the images, with good demonstration of the liver parenchyma. Faster scanning with a single breath-hold acquisition allows the elimination of movement or breathing artifacts and detection of subcentimetre lesions. Evaluation of the size and contour of the liver can be performed on unenhanced examinations, while detailed assessment of the hepatic parenchyma requires contrast enhancement.

Rapid delivery of intravenous contrast and sequential scanning in different enhancement phases (arterial, portal venous and delayed phases) helps to differentiate the origin of the hepatic lesion (*Figure 5*).

Vascular neoplasms, such as hepatocellular carcinoma, enhance rapidly in the arterial phase (20–30 s) and become isodense to liver parenchyma in the portal phase (60–70 s). Typically, the benign changes and normal liver parenchyma have primarily a portal venous supply and enhance the most in the portal phase at 60–70 s.

Computed tomography is commonly used in staging of chest, abdominal and pelvic malignancy, with good resolution and delineation of the hepatic metastases. It will provide additional information about other abdominal organs and lymph node involvement, as well as evaluation of lung parenchyma and skeletal system in search for disseminated metastatic disease (*Figure 6*). Computed tomography is also

Figure 4. Multiple liver metastases on (a) ultrasound and (b) computed tomography examination.

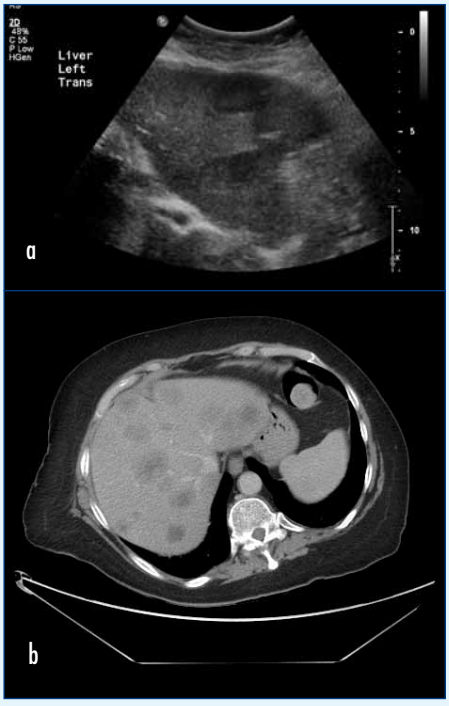


Figure 5. Computed tomography scan of the abdomen performed in different enhancement phases (a) arterial and (b) portal venous. c. Lesion in the left lobe with extensive and homogeneous enhancement, consistent with haemangioma.

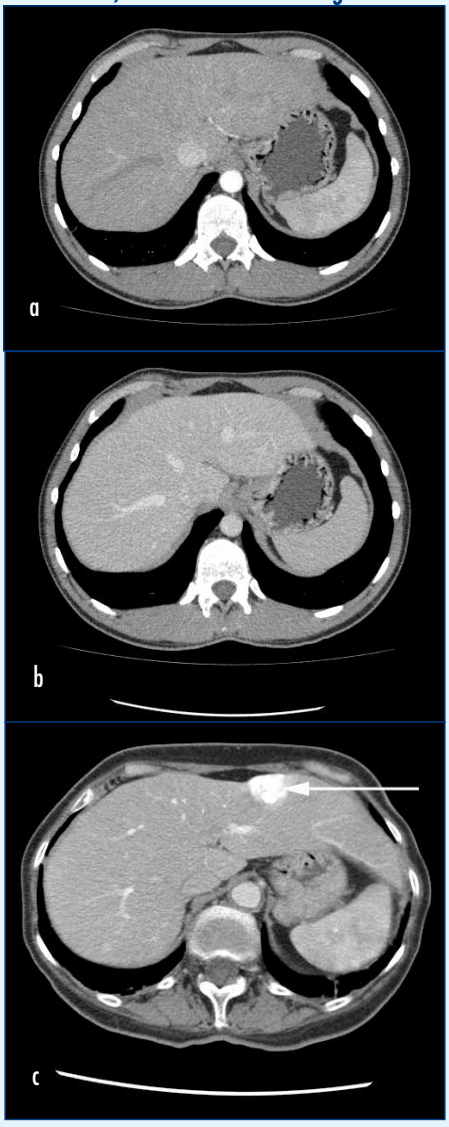
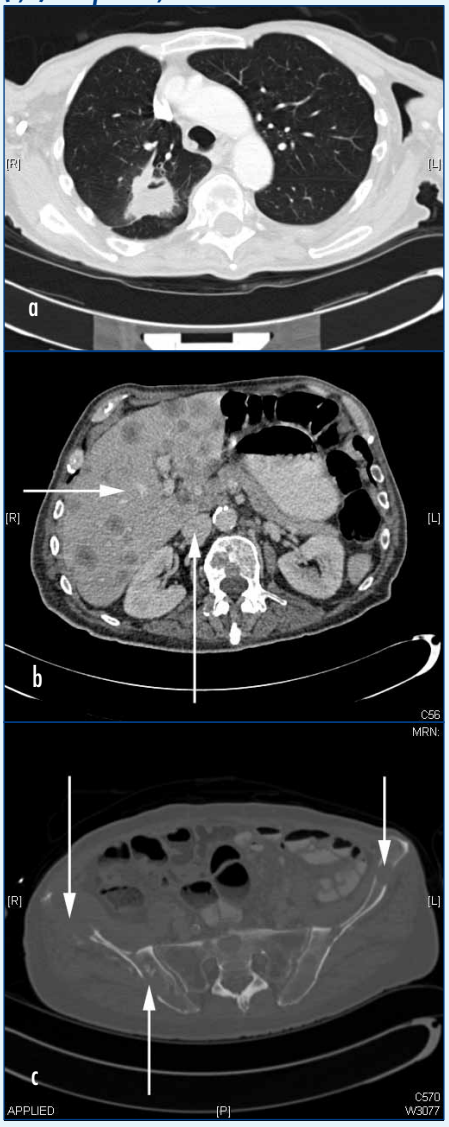


Figure 6. Computed tomography of the chest and abdomen shows (a) cavitating lung carcinoma with (b, c) multiple liver, skeletal and adrenal metastases.



used for interval scans to evaluate the response to treatment and monitor potential recurrence in oncology patients.

Magnetic resonance imaging

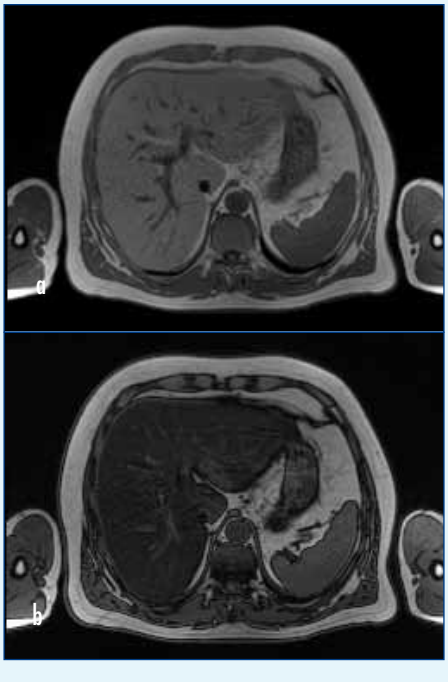
Magnetic resonance imaging is superior to ultrasound and computed tomography in detection and characterization of diffuse liver disease, such as a fatty infiltration, haemochromatosis or cirrhosis.

Use of chemical shift techniques and opposed-phase imaging allows visualization of the fatty contents and reduces the need for biopsies (*Figure 7*).

Recent developments in intravenous contrast agents and dynamic scanning allow further characterization of hepatic lesions.

One of the most common clinical dilemmas in oncology is differential diagnosis of hepatic lesions in patients with known primary malignant disease. A liver abnormality found on ultrasound or computed tomography may be a benign lesion, which does not require treatment, or a metastatic deposit, which would significantly influence a patient's treatment and prognosis. Dynamic gadolinium-enhanced magnetic resonance imaging can diagnose hepatic haemiangiomas with 100% specificity and 95% accuracy if the typical enhancement pattern occurs (Whitney et al, 1993).

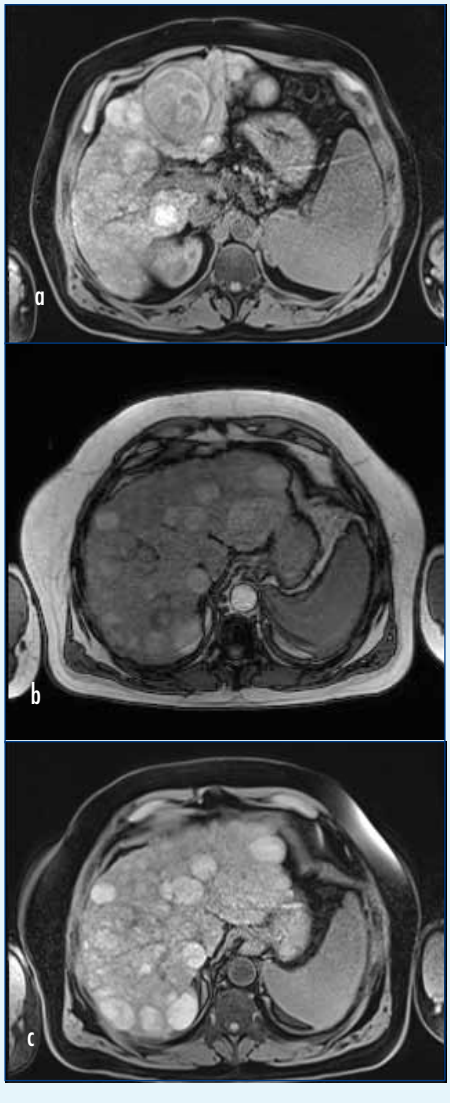
Figure 7. T1WI (a) in-phase and (b) out-of-phase images of the liver with diffuse fatty infiltration – look at the signal changes in the liver with comparison to the spleen.



The use of liver-specific contrast agents allows differentiation of the origin of the focal liver lesion at the hepatocellular level. Superparamagnetic iron oxide particles, which are taken up by reticuloendothelial cells of the liver, spleen, lymph nodes and bone marrow, enhance cells of hepatic origin, as focal nodular hyperplasia, while cells of other origins, such as metastatic deposits, remain unenhanced.

The biggest challenge magnetic resonance imaging presents is the detection and characterization of focal lesions in patients with diffuse liver disease. These patients are at much higher risk of developing hepatocellular carcinomas, which are associated with an increased mortality and morbidity and require prompt treatment. Regenerative and dysplastic nodules have very similar appearance to carcinomas, but these present a normal sequel of fibrotic process within a cirrhotic liver (*Figure 8*) and do not require surgical and/or oncological interventions.

Figure 8. Dynamic magnetic resonance imaging examination showing the heterogeneous and irregular appearance of regenerative and dysplastic nodules in cirrhotic liver (the same patient) in different phases of contrast enhancement.



The limitations of magnetic resonance imaging are the relatively long scan time (30–50 minutes depending on the contrast agent used) compared with other examinations and the substantial cost of the scan. As a result, magnetic resonance imaging remains a problem-solving technique used only in specific cases when other modalities have failed to provide a definite diagnosis. When magnetic resonance imaging cannot provide a diagnosis, percutaneous or surgical biopsy may be necessary.

Radionuclide imaging

The role of scintigraphy in evaluating liver disease has significantly decreased, being replaced by other imaging techniques, such as ultrasound, computed tomography and magnetic resonance imaging.

Radionuclide imaging is used in the evaluation of the size, shape and configuration of the liver and spleen. It produces images with poor spatial resolution, where a focal abnormality is visible only as an ill-defined area of decreased or increased tracer accumulation, without clear borders. To assess the location, size and nature of the abnormality (*Figure 9*), a further test is required.

Scintigraphy remains a sensitive technique for non-invasive examination of the parenchymal function and perfusion. Focal abnormalities can often be demonstrated before the onset of anatomical changes visible on computed tomography or magnetic resonance imaging.

Radiotracers used in hepatic imaging include technetium-99 (Tc99) (most common), gallium-67 citrate, indium-111 and iodine-131.

Radiopharmaceuticals labelled with Tc99 are Tc99 sulphur colloid, Tc99 hepatobiliary iminodiacetic acid, Tc-labelled red blood cells and TcO_4. Labelled colloids demonstrate the distribution of reticuloendothelial cells of the liver, spleen and bone marrow, when hepa-

tobiliary iminodiacetic acid (based on imidodiacetic acid) is taken up by functioning hepatocytes and excreted unchanged in the bile, allowing the direct evaluation of the hepatic parenchyma.

Positron emission tomography computer tomography is a new and developing technique within molecular imaging. It uses photon emission tomography to detect activity of an injected radionuclide labelled glucose analogue (fluorine-18-deoxyglucose) to discriminate benign from malignant tissue – malignant tissue typically shows a high level of glucose metabolism.

Positron emission tomography detectors and computed tomography scanners are combined into one machine, which allows simultaneous acquisition of images and evaluation of data from two different imaging modalities. Positron emission tomography data are superimposed onto the computed tomography images within one series, which significantly improves anatomical localization of the normal and abnormal tissue with increased fluorine-18-deoxyglucose activity (*Figure 10*).

Conclusions

Developments in imaging techniques have significantly improved detection and characterization of the liver pathology. Use of chemical shift techniques, dynamic contrast enhancement and liver-specific contrast agents allow a definite diagnosis to be reached, without the need for biopsy or surgical intervention.

Relevant clinical information has an important role in selecting the appropriate imaging modality and type of contrast enhancement, and guiding correct interpretation of the results. BJHM

Conflict of interest: none.

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Further reading

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Figure 9. Multiple areas of increased uptake within the liver on positron emission tomography scan in a patient with known lymphoma.

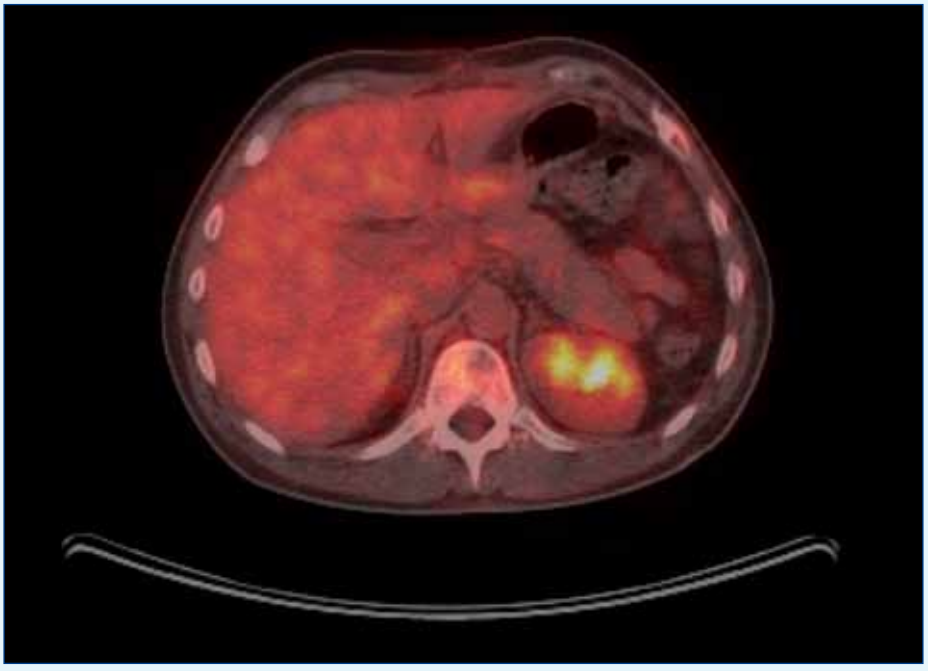
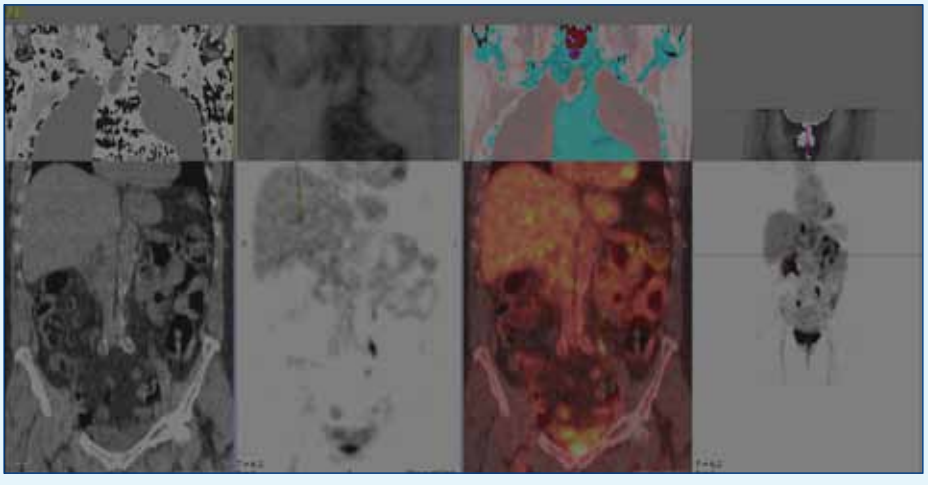


Figure 10. Positron emission tomography computed tomography in a patient with colorectal cancer shows a single lesion in the liver, with increased fluorine-18-deoxyglucose uptake, consistent with metastatic deposit.



KEY POINTS

- Recent advances in imaging techniques have improved the diagnostic process in patients with liver disease and decreased the number of percutaneous and open biopsies.
- Relevant clinical information is needed to choose the best imaging modality and guide diagnosis.
- Ultrasound remains the first-line investigation in patients with abnormal liver tests.
- Magnetic resonance imaging should be used in selected patients when ultrasonography and computed tomography cannot provide a definite diagnosis.