



eBook for Undergraduate Education in Radiology

| **CHAPTER:** Liver Imaging



Preface

Undergraduate teaching of radiology in Europe is provided according to national schemes and may vary considerably from one academic institution to another. Sometimes, the field of radiology is considered as a “cross-cutting discipline” or taught within the context of other clinical disciplines, e.g., internal medicine or surgery.

This e-book has been created in order to serve medical students and academic teachers throughout Europe to understand and teach radiology as a whole coherent discipline, respectively. Its contents are based on the *Undergraduate Level of the ESR European Training Curriculum for Radiology* and summarize the so-called **core elements** that may be considered as the basics that every medical student should be familiar with. Although specific radiologic diagnostic skills for image interpretation cannot be acquired by all students and rather belong to the learning objectives of the *Postgraduate Levels of the ESR Training Curricula*, the present e-book also contains some **further insights** related to modern imaging in the form of examples of key pathologies, as seen by the different imaging modalities. These are intended to give the interested undergraduate student an understanding of modern radiology, reflecting its multidisciplinary character as an organ-based specialty.

We would like to extend our special thanks to the authors and members of the ESR Education Committee who have contributed to this eBook, to Carlo Catalano, Andrea Laghi and András Palkó who initiated this project, and to the ESR Office, in particular Bettina Leimberger and Danijel Lepir, for all their support in realising this project.

We hope that this e-book may fulfil its purpose as a useful tool for undergraduate academic radiology teaching.

Minerva Becker
ESR Education Committee Chair

Vicky Goh
ESR Undergraduate Education Subcommittee Chair

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Based on the ESR Curriculum for Undergraduate Radiological Education

Chapter: **Liver Imaging**

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Anatomy for Liver Imaging



The Normal Liver

For general anatomical, histological and physiological information please refer to your knowledge obtained during your respective studies in the previous years.

We herewith provide only some imaging-specific additions to the subject (Figs. 1- 8).

For liver anatomy as seen at imaging, please also see the eBook chapters on bile ducts & computed tomography!



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The Normal Liver



The liver has a **dual blood supply** (Fig. 1): the majority of the blood arrives from the portal vein (75%), while the rest (25%) is provided by the hepatic artery.

The **portal vein blood** is oxygen-poor and nutrient-rich as it carries the blood from the gastrointestinal tract and spleen while the **blood from the hepatic arteries** (which supplies the biliary system) is oxygen-rich and nutrient poor.

The **venous liver drainage** takes place via the three hepatic veins (right, middle and left) into the inferior vena cava (Fig. 1).

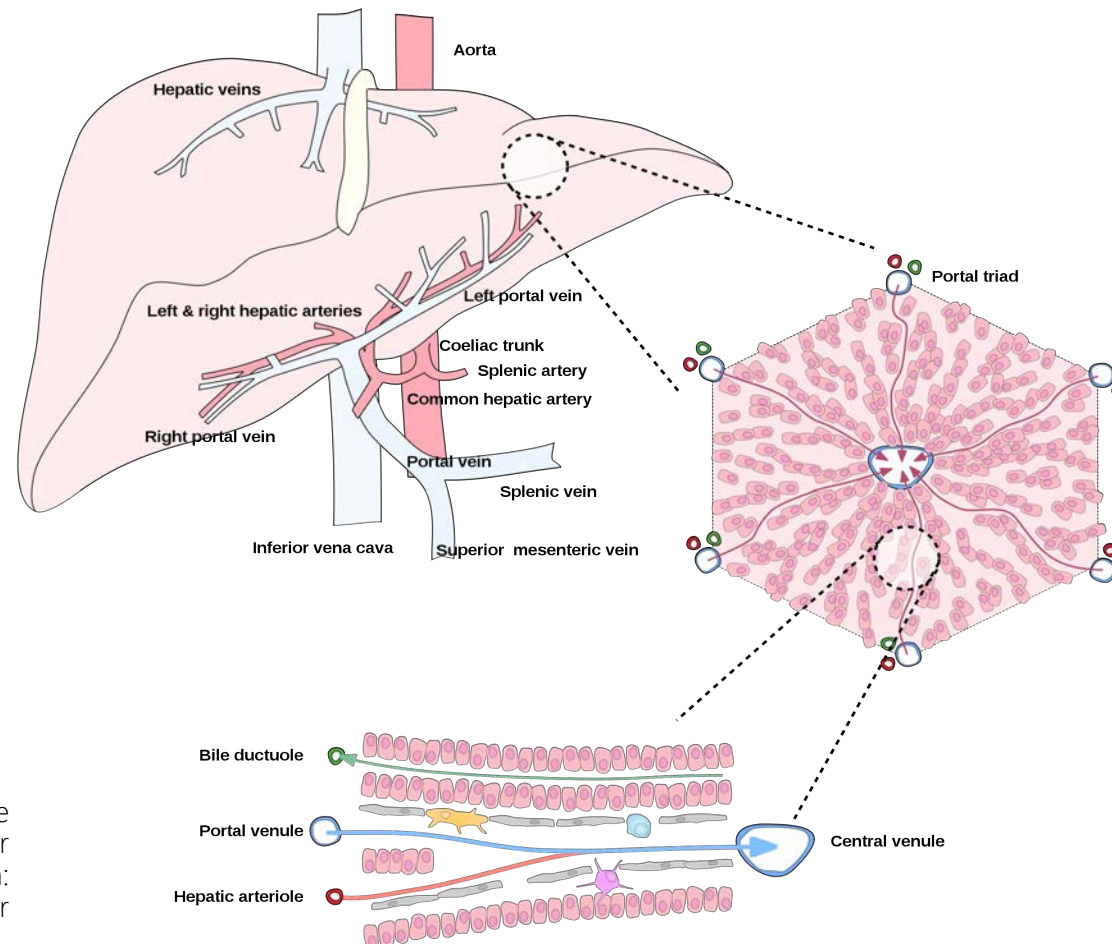


Fig. 1. Diagram of the dual blood supply of the liver, the liver lobule, the portal tract and their inter-relations. Image reproduced from: <https://en.wikipedia.org/wiki/Liver>

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The Normal Liver

According to the **Couinaud classification**, the liver is divided into **8 segments** (Fig. 2). Each segment is a functional unit which can be resected separately at surgery. Each segment is supplied by individual hepatic arteries, portal veins and bile ducts.

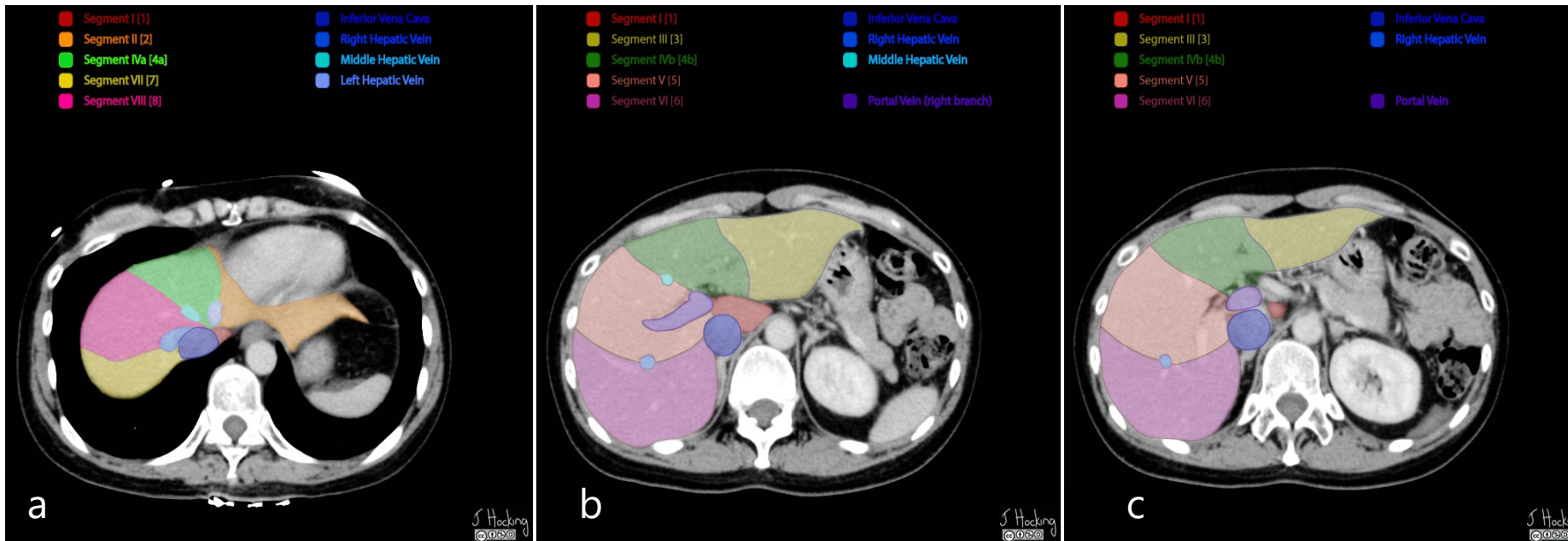


Fig. 2. Liver segments as seen on three axial CT images (a, b and c). Case courtesy of Jeffrey Hocking, Radiopaedia.org, rID: 45972



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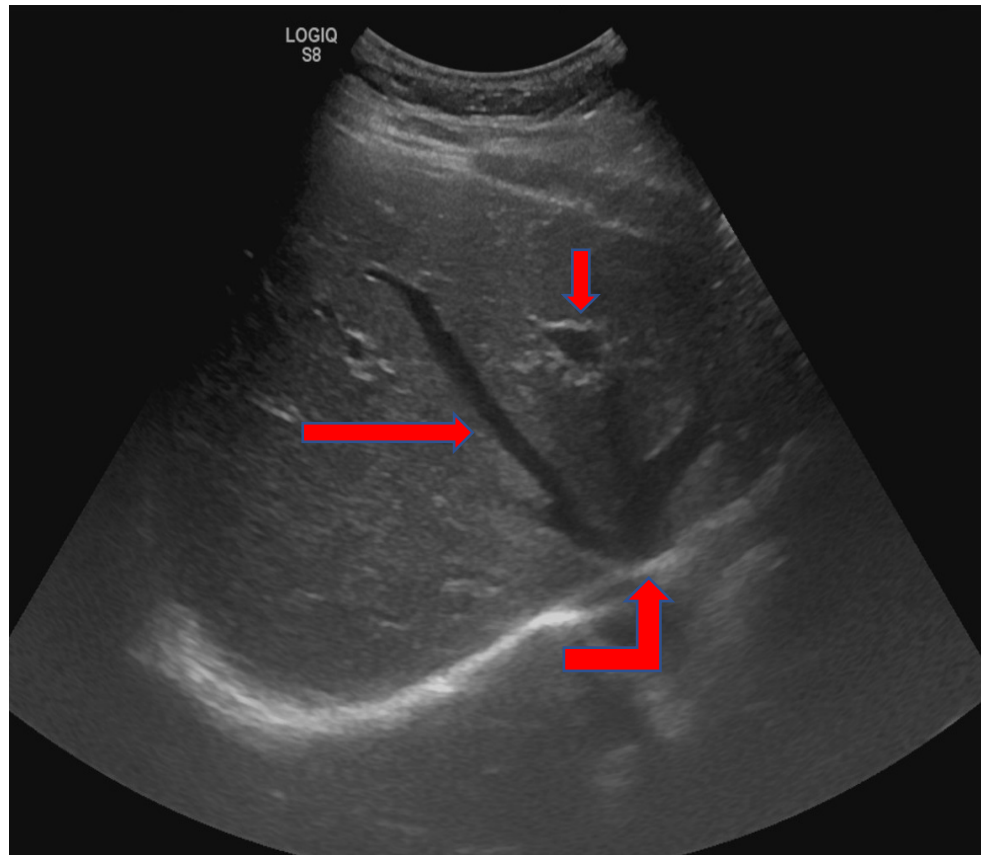


The Normal Liver

Ultrasonography (US) is an excellent first line examination tool to image the liver (Fig. 3).

The role of US consists in assessing the size, parenchymal echogenicity, capsular contour, vascularity, the biliary tree, liver masses or fluid collections.

Fig. 3. Normal liver US. Oblique axial scan through segments 4, 8 and 7 show normal parenchyma and vascular structures. Portal vein (short arrow), right hepatic vein (long arrow), Inferior vena cava (curved arrow)



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The Normal Liver

On MRI, the normal liver has a uniform signal intensity that is higher than the signal intensity of the spleen on T1 and lower on T2-weighted images (Fig. 4). Vessels usually have a low signal due to flow-related signal loss. MRI has the highest sensitivity and specificity for liver lesions in comparison to all other imaging techniques.

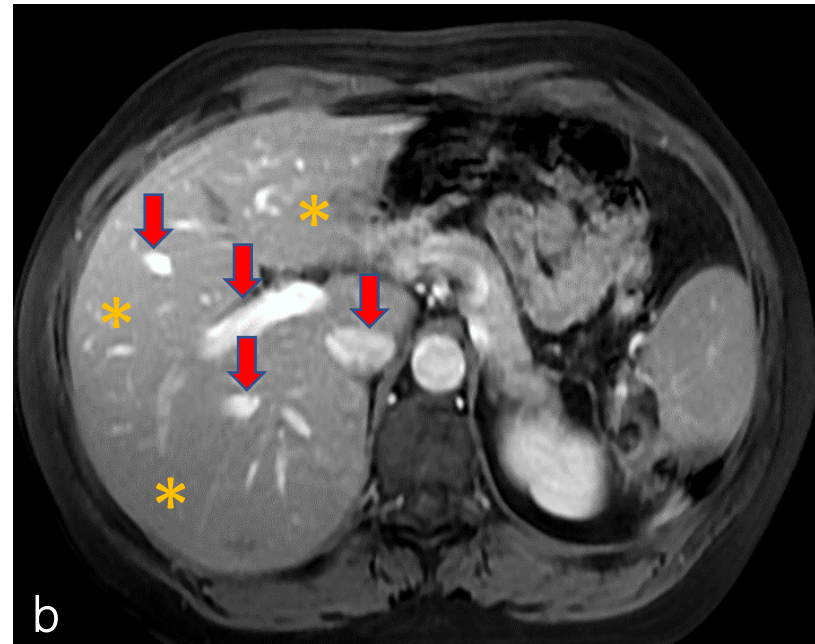
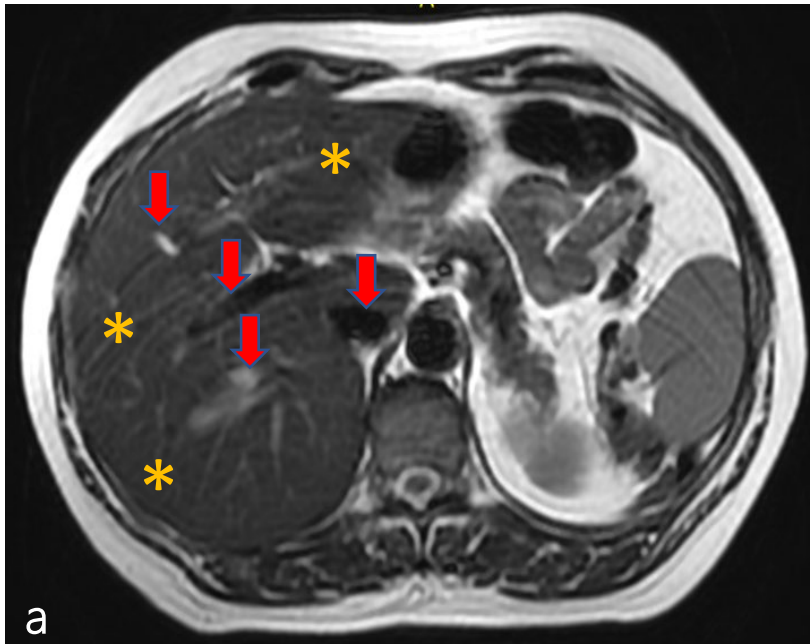


Fig. 4. a, b normal liver MRI. Axial T2 weighted (a) and T1 postcontrast (b) scans at the level of the liver hilum show normal parenchyma (asterisks) and vessels (arrows)

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Dual Blood Supply

Because of the dual blood supply, if multiphasic contrast-enhanced US-, CT- or MRI-examinations are performed, several phases of contrast enhancement can be distinguished. These are:

- **Arterial** phase (about 20 sec post injection for optimal enhancement of structures directly supplied by the arterial system): lesions with arterial blood supply enhance intensively but note that arterial supply is not necessarily equivalent to hypervascularity;
- **Portal** venous phase also known as the late portal or hepatic phase (approximately 60 sec post injection): normal liver parenchyma and lesions of portal blood supply are enhanced and branches of the portal and hepatic veins are best delineated;
- **Delayed** phase (about 2-3 min post injection): lesions with slow perfusion show enhancement

The acquisition time for each phase depends on several factors:

- Type of intravenous device used (central or peripheral catheter)
- Contrast medium concentration (see chapter on contrast media)
- Injection rate



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Dual Blood Supply

After injection of an intravenous contrast material, in the arterial phase, there is opacification of the hepatic artery and its branches, whereas in the portal venous phase, the portal vein is opacified (Figs. 5 and 6). Liver parenchyma enhances most in the parenchymal phase.

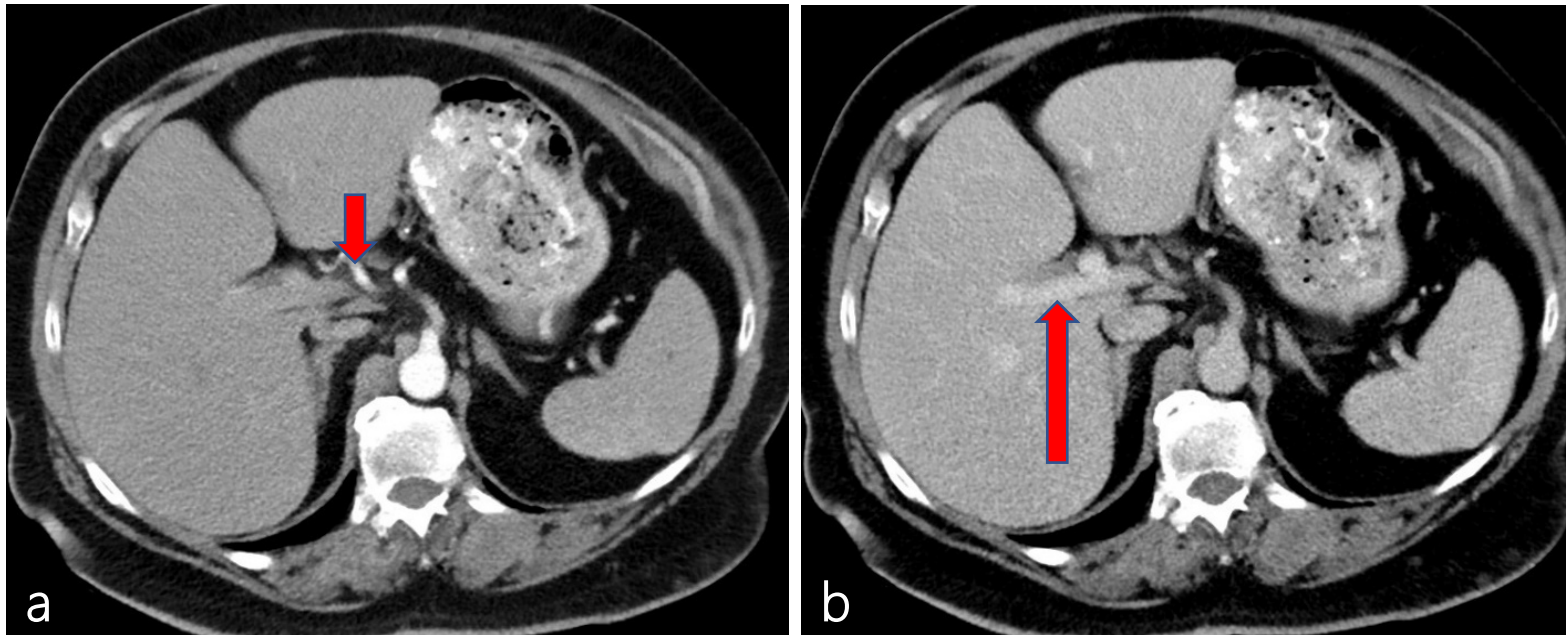


Fig. 5.. Normal liver CT. Arterial phase postcontrast (a) and portal phase postcontrast scans at the level of the liver hilum show homogeneous parenchyma and normal vessels. Hepatic artery (short arrow), portal vein (long arrow)

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Dual Blood Supply

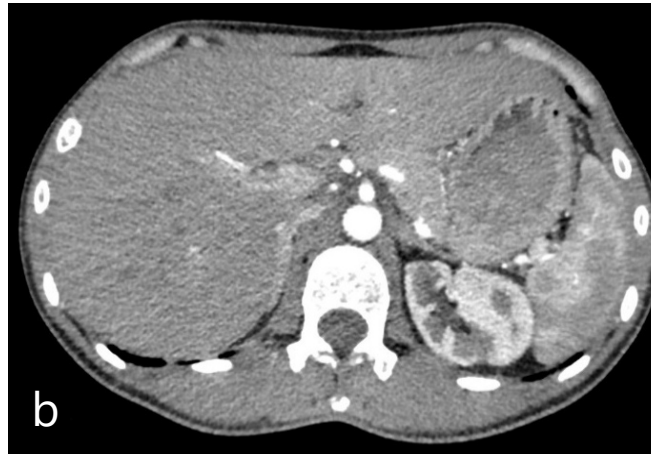


Fig. 6. Non-contrast (a), arterial (b) and portal (c) phase postcontrast CT-scans at the level of the liver hilum. Liver parenchyma shows the strongest enhancement in the parenchymal (portal) phase

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Biliary Excretion



Active membrane-transport in hepatocytes plays a key role in biliary excretion. If MRI (Gd-based) contrast media are bound to proper carrier molecules, excretion through the same pathways takes place (**hepato-biliary contrast agents**). In consequence, significant contrast enhancement is seen in **normal liver parenchyma** (Fig. 7), whereas lesions without normal hepatocytes do not show normal biliary excretion.

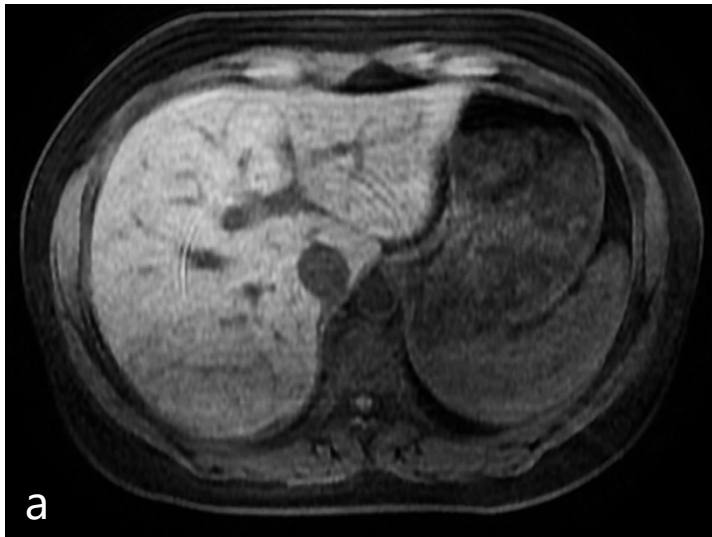


Fig. 7. Non-contrast (a) and hepatobiliary contrast-enhanced (b) phase of a liver MRI: the contrast material accumulates in normal hepatocytes which results in an increase in signal intensity in b. See also e-book chapter on contrast media!



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Sinusoids

Special liver capillaries called **sinusoids** (common end-branches of the portal venous and the hepatic arterial circulation) serve for mixing the oxygen-rich hepatic arterial blood with the nutrient-rich portal vein blood.

Their lining contains liver **sinusoidal endothelial cells (LSEC)** and **Kupffer cells** (macrophages with a scavenging function, belonging to the reticuloendothelial system). LSEC have fenestrations, which allow communication between the sinusoids and the **space of Disse**. The space of Disse separates hepatocytes from sinusoids (Fig. 8 and 9).

If **RES-specific contrast agents** are used, normal liver parenchyma will enhance due to selective accumulation of these contrast agents in Kupffer cells, while in areas without normal sinusoids no enhancement is seen.

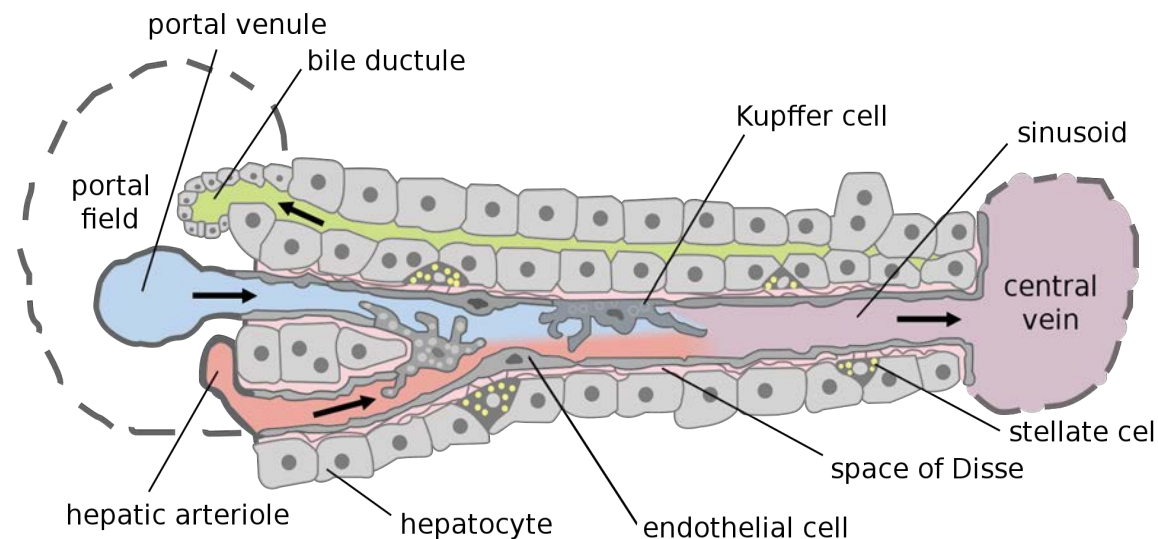


Fig. 8. Schematic illustration of the liver sinusoid (see explanation in the text). Figure based on the research article by Frevert U, Engelmann S, Zougbedé S, Stange J, Ng B, et al. "Intravital Observation of Plasmodium berghei Sporozoite Infection of the Liver", PLoS Biology, doi:10.1371/journal.pbio.0030192.g011

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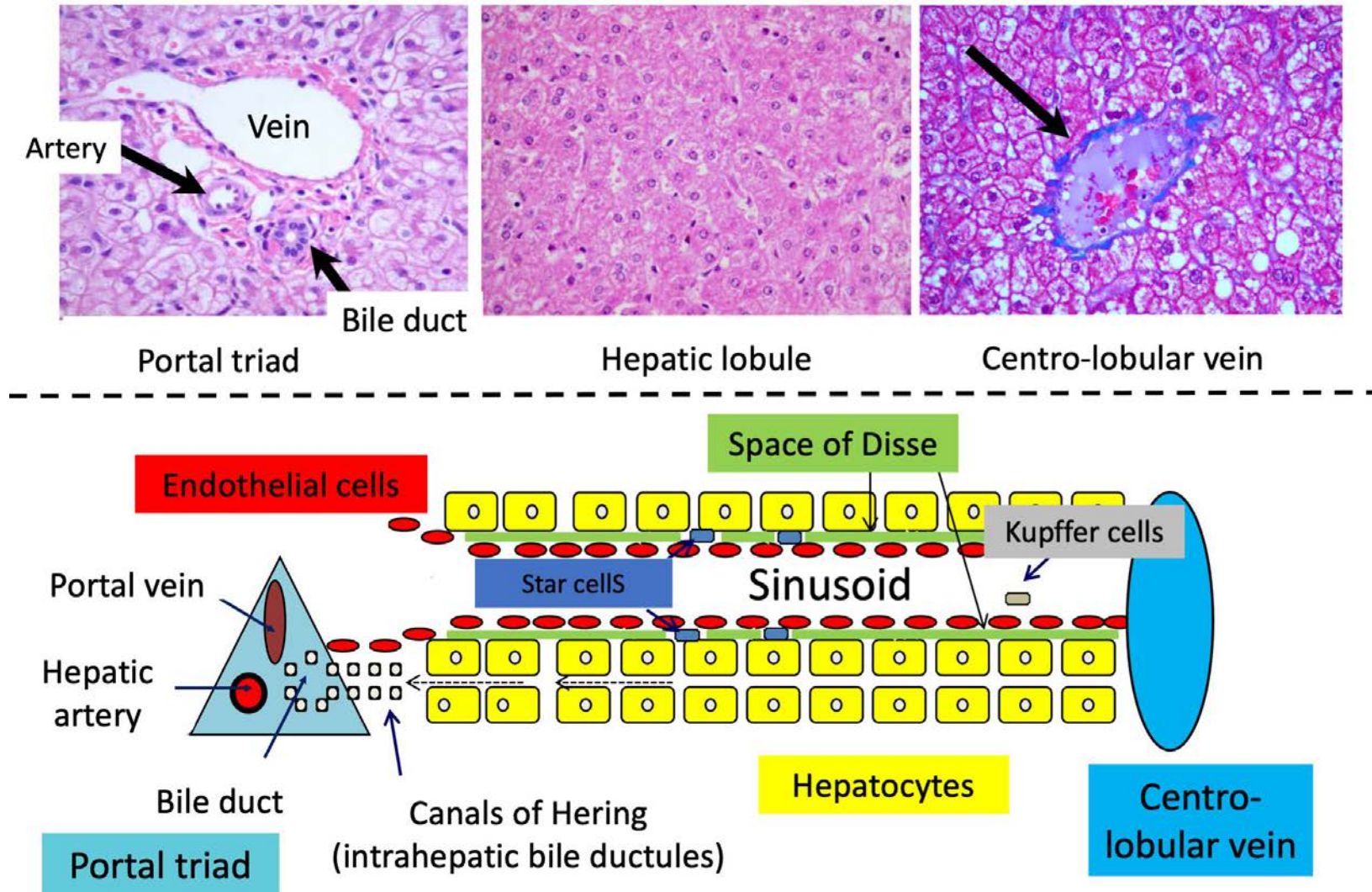
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Fig. 9. Schematic illustration including histology of the hepatic lobules, portal triads and liver sinusoids. Figure courtesy of Prof. Laura Rubbia Brandt, MD, Diagnostic Department, Geneva University Hospitals.



Strengths, Weaknesses and Role of Imaging Modalities



X-Ray



X-ray examinations do not play any role in the evaluation of the liver, because liver x-ray absorption is homogeneous and very similar to that of the surrounding organs.

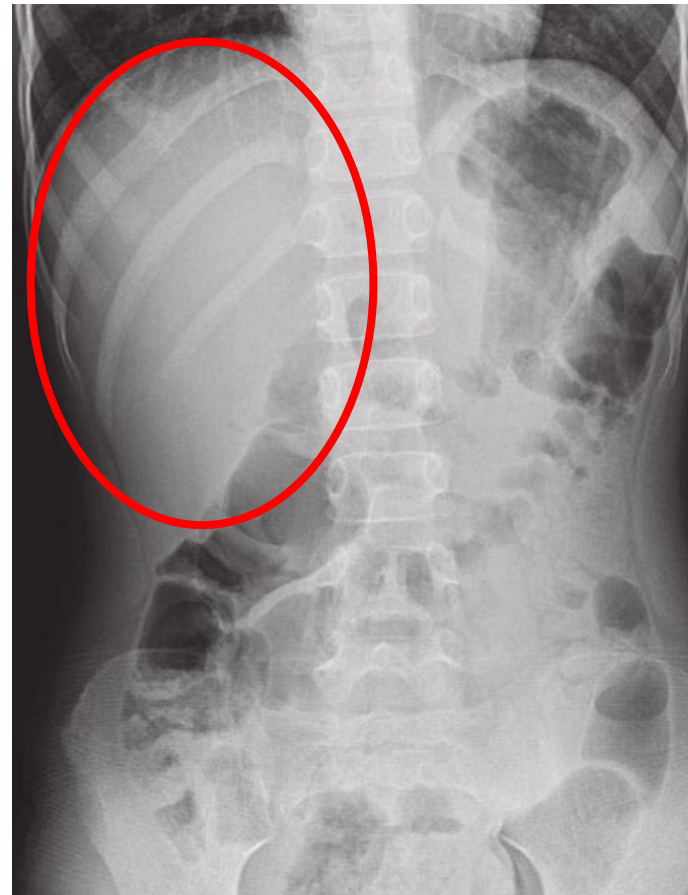


Fig. 10. Normal plain abdominal X-ray demonstrating the gasless area corresponding with the liver in the right upper quadrant

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Ultrasound

Ultrasound (US) is the first line imaging examination for liver lesions.



On B-mode US scans, liver parenchyma, portal and hepatic venous branches are easily depicted (Fig. 11) while normal **intrahepatic** arteries and **intrahepatic** bile ducts are not visible.

Doppler-ultrasound (Doppler-US) provides information regarding liver circulation, whereas US elastography provides information regarding parenchyma elasticity.

Information about vascularity of focal lesions can be acquired by contrast-enhanced ultrasound (CEUS).

US examinations are often diagnostic, however, further examinations may be necessary to exclude or confirm the presence/absence of focal lesions, define their number and characterise them.



Aparna Srinivasa Babu et al, RadioGraphics 2016; 36:1987–2006

Burrowes DP et al, RadioGraphics 2017; 37:1388–1400



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Ultrasound

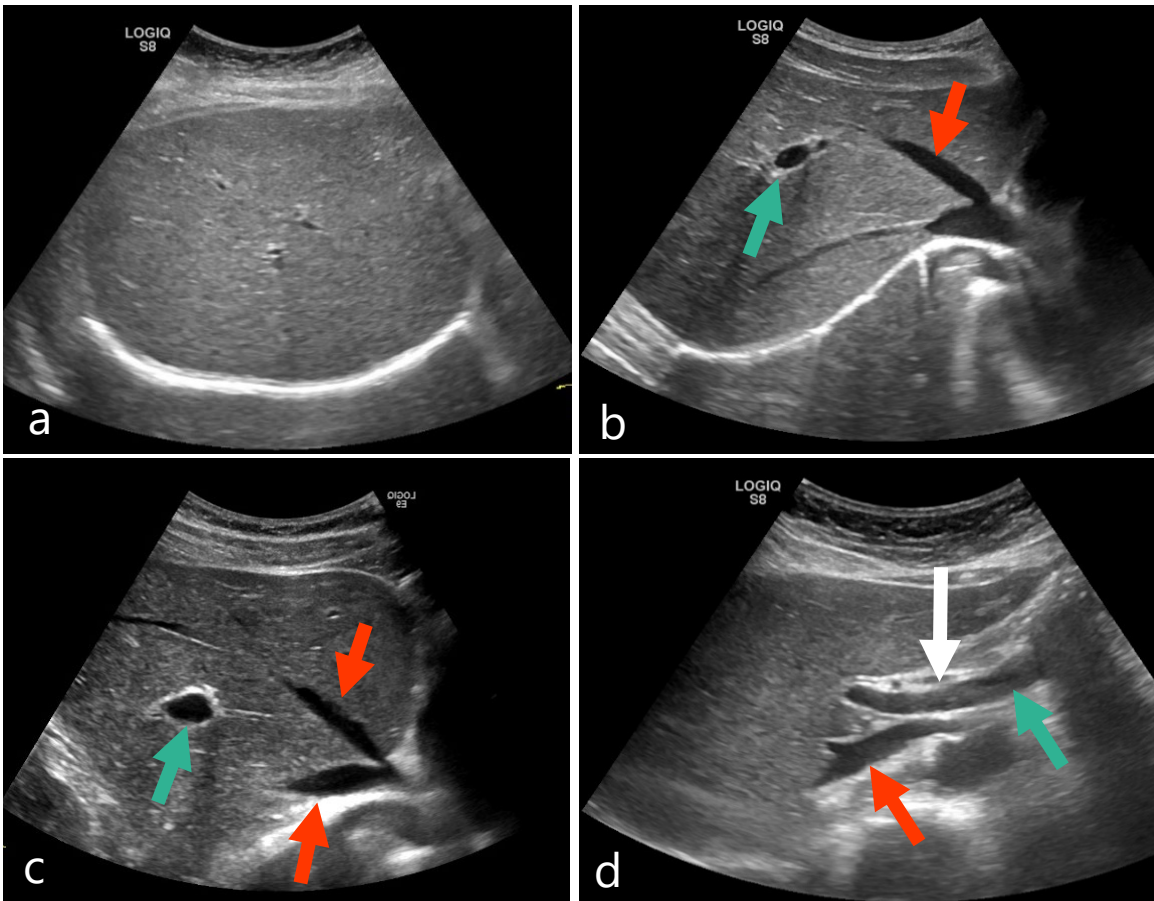


Fig. 11. Normal US (B-mode) showing normal homogenous liver echo structure and vessels in the liver. Hepatic veins are indicated by red arrows, portal vein branches by green arrows and the hepatic artery by a white arrow.

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Computed Tomography

Computed tomography (CT) is always performed using a multiphasic contrast-enhanced technique (pre-contrast + arterial + portal and, if necessary, delayed phase).

Normal liver parenchyma is of homogenous density with a peak enhancement in the portal phase, the blood vessels are clearly visible, while the normal intrahepatic bile ducts are not delineated (Fig. 12).



CT may help to recognise **diffuse changes** in liver density (fat, iron deposition, etc). It can also detect and characterise lesions, that are not well depicted by US based on their distinctive absorption and enhancement patterns.

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Computed Tomography

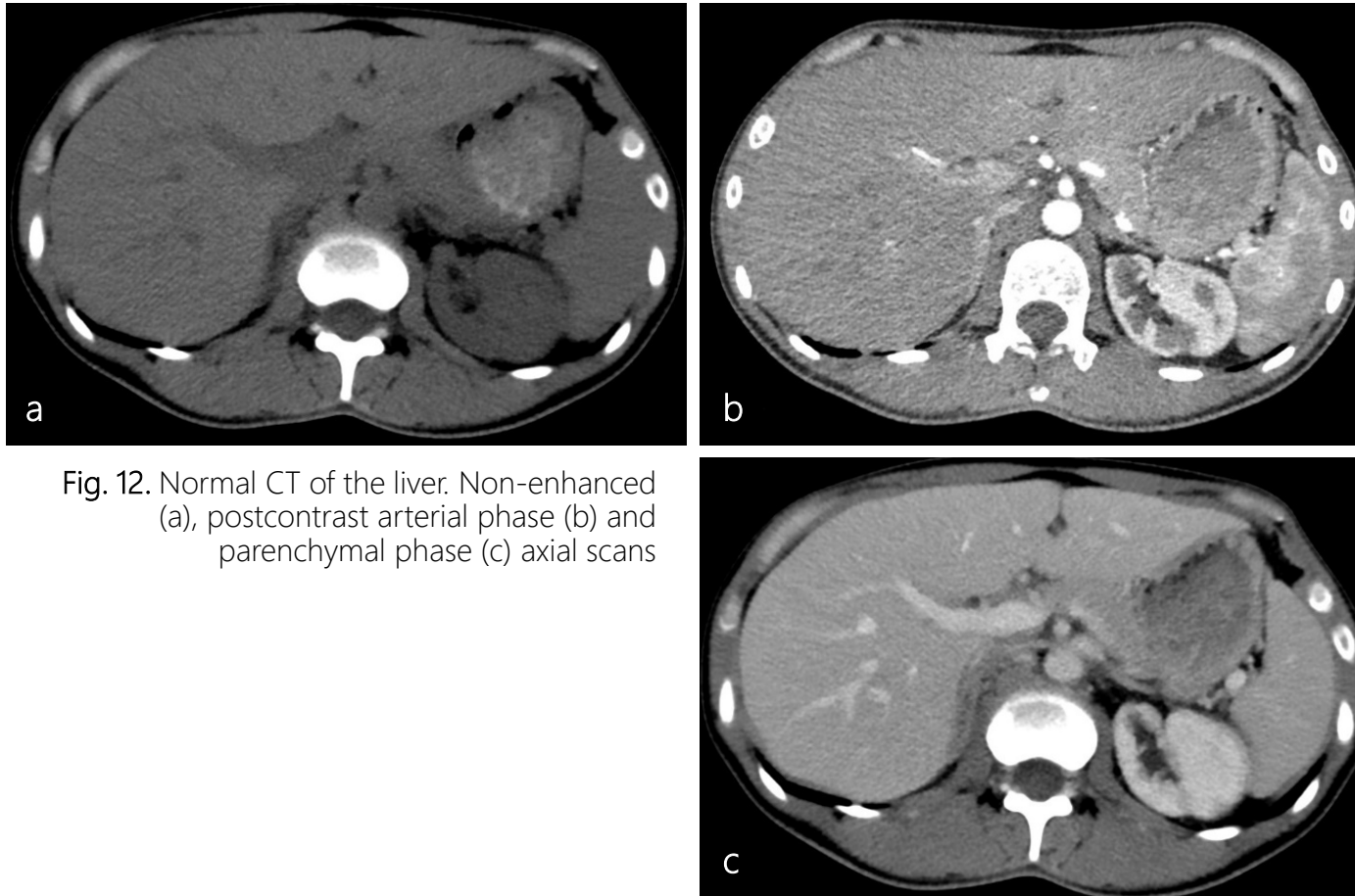


Fig. 12. Normal CT of the liver. Non-enhanced (a), postcontrast arterial phase (b) and parenchymal phase (c) axial scans

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Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is the most reliable and accurate test for the evaluation of the liver. Normal liver parenchyma is homogeneous (Figs. 13 and 14), and – depending on the used sequence – blood vessels and bile ducts can be easily identified.



Multiphasic contrast-enhanced sequences play the same role as in CT. However, MRI has many advantages:

- **Fat-sensitive MRI sequences** (Fig. 14) allow the evaluation of parenchymal fat content (steatosis),
- **Diffusion-weighted sequences** improve the detection and characterisation of certain focal lesions,
- Sequences for the **semiquantitative evaluation of metallic content** allow improved lesion detection and characterisation.

Using special contrast materials (see chapter on contrast media) it is also possible to evaluate the presence/absence of hepatobiliary excretion, thus better detecting and characterising focal lesions .

MR-elastography gives information about the elasticity of liver parenchyma and of focal liver lesions.

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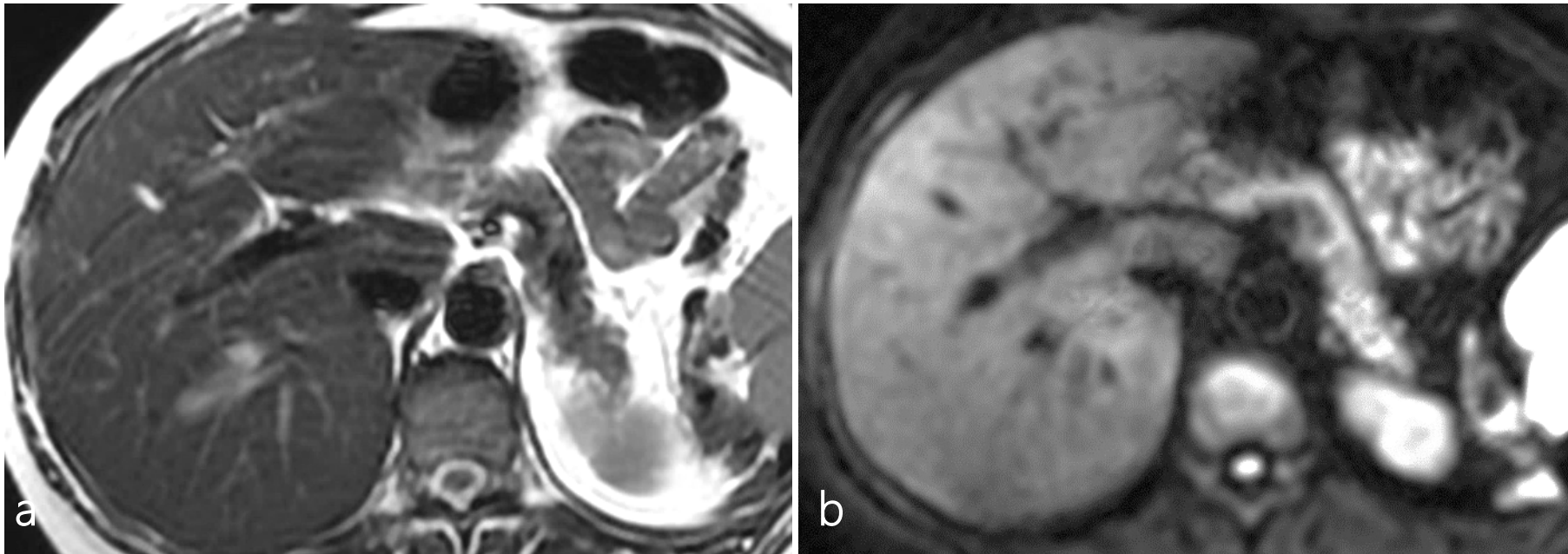


Fig. 13. Normal MRI of the liver with T2 weighted (a) and diffusion-weighted (b) sequences.

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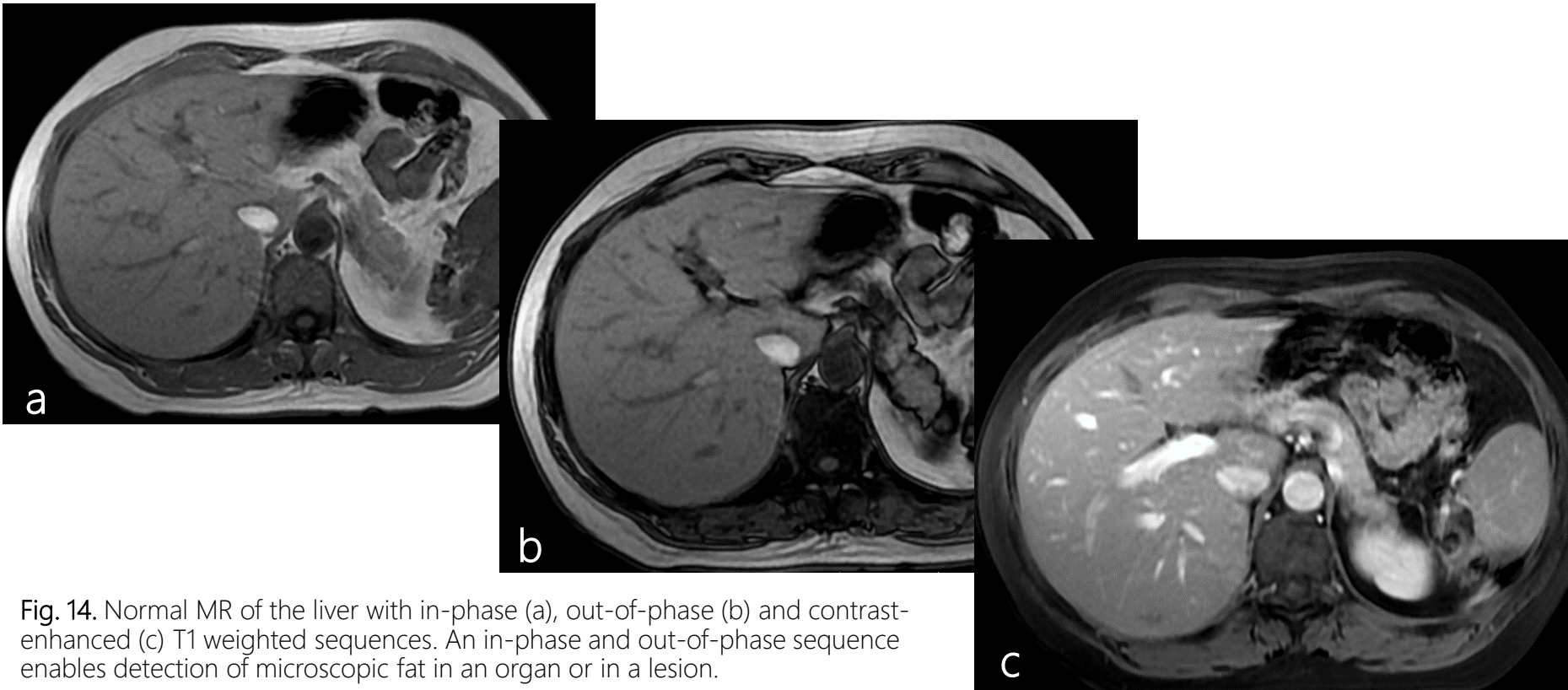


Fig. 14. Normal MR of the liver with in-phase (a), out-of-phase (b) and contrast-enhanced (c) T1 weighted sequences. An in-phase and out-of-phase sequence enables detection of microscopic fat in an organ or in a lesion.

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Interventional Procedures

Catheter angiography is **not** used for diagnostic purposes, however it has an important role in the guidance of therapeutic oncologic interventions, e.g., trans-arterial chemoembolisation (TACE) of malignant lesions.



Patients with severe portal hypertension can be treated by a transjugularly implemented portosystemic shunt (TIPSS).

Image-guided biopsies are useful for the characterisation of lesions with equivocal appearance on US, CT, or MRI.

Percutaneous ablative treatment (radiofrequency, microwave, laser, etc.) of malignant lesions under imaging guidance is a valuable alternative of surgery for the therapy of smaller solitary lesions.

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Interventional Procedures

Interventional radiology procedures in the liver are either performed under US, CT or MRI guidance (Figs. 15-17).

Interventional radiologists treat a wide range of liver conditions including the following:

- Liver biopsy to diagnose or confirm a diagnosis
- Abscess drainage to drain pus
- Biliary drain placement and biliary stent placement to drain built-up bile in the presence of bile drain blockage
- Transjugular intrahepatic portosystemic shunt (TIPS) to treat complications of portal hypertension
- Transarterial embolization of liver tumours (injecting substances into a liver artery to block tumour blood flow as liver tumours are fed by the hepatic artery, whereas normal liver parenchyma is fed by the portal vein)

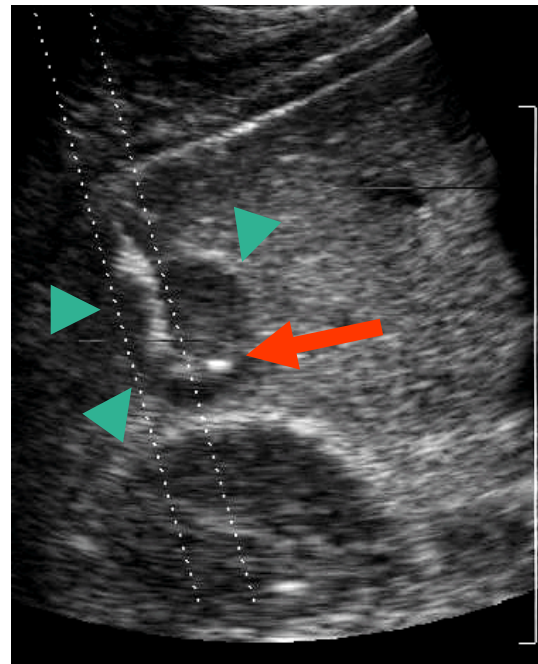


Fig. 15. US-guided fluid aspiration. The tip of the catheter (arrow) is seen in the abscess (green arrowheads) of the right liver lobe as a hyper-echoic structure.

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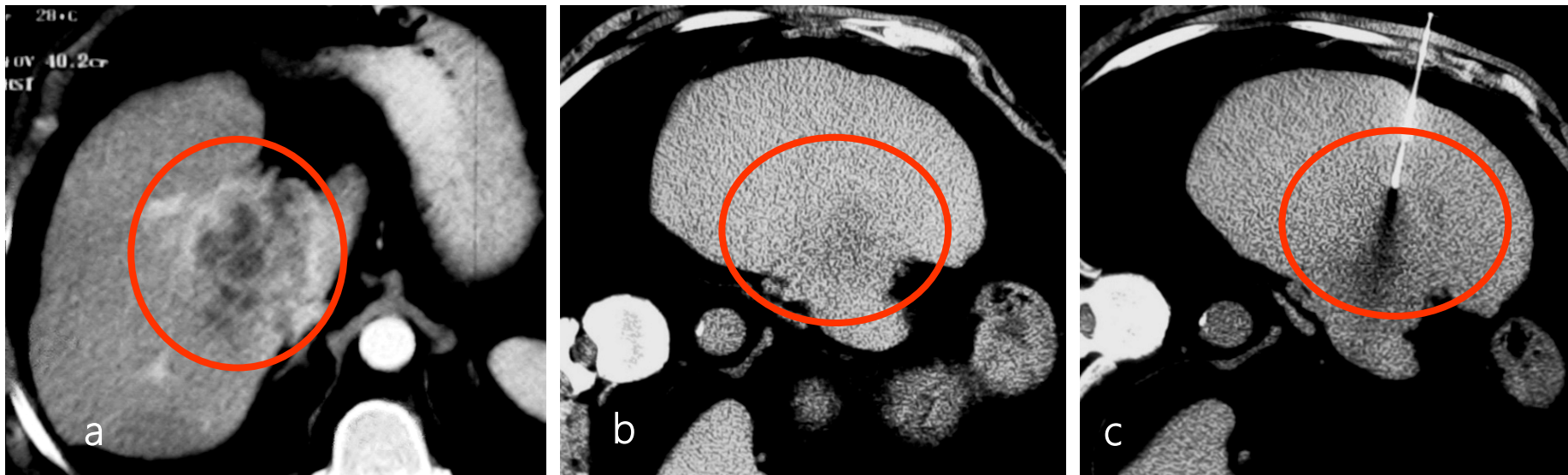


Fig. 16. Contrast-enhanced CT (a) depicts an inhomogeneous mass in the liver; non-enhanced preprocedural CT made in the left decubitus position (b) shows the lesion as an ill-defined hypodense area; a snapshot CT-scan taken during the biopsy procedure (c) shows the tip of the needle in the periphery of lesion.

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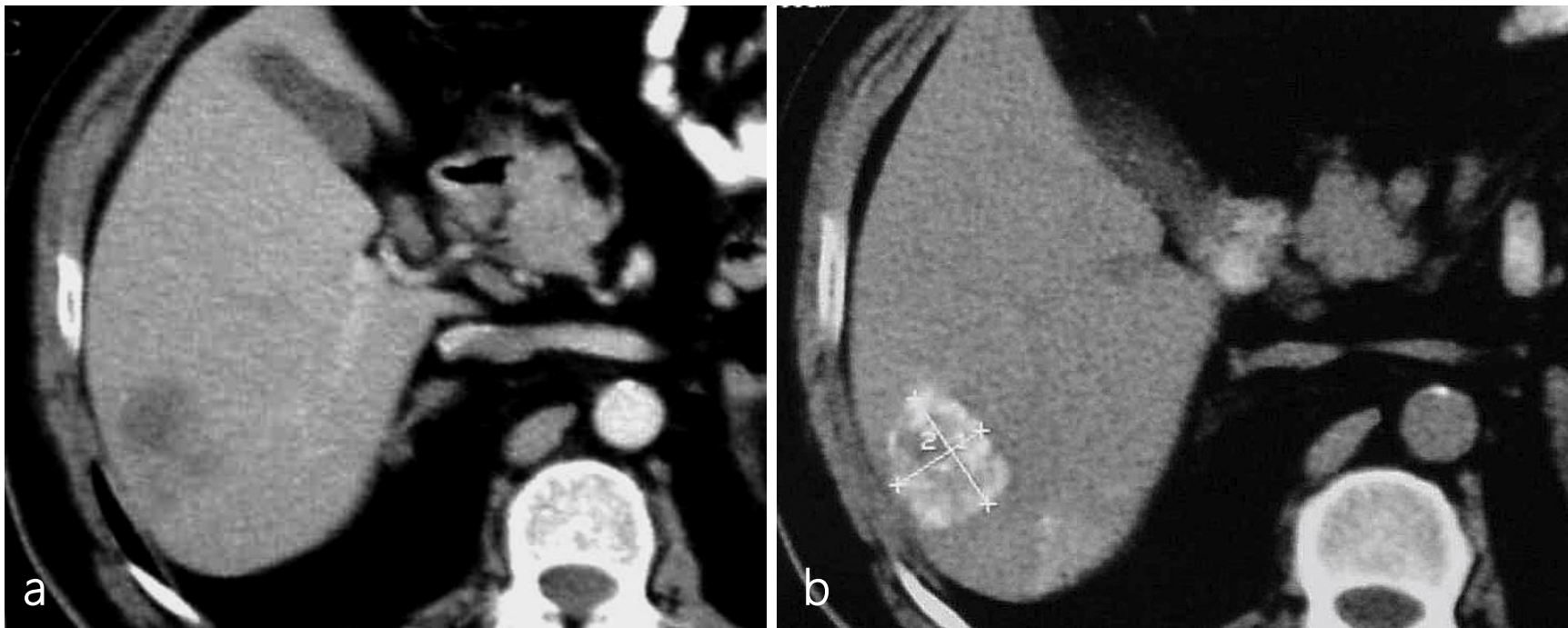


Fig. 17. CT-scan taken before (a) and after (b) transarterial chemoembolization (TACE) of a liver mass: the hyperdense embolising material (Lipiodol UltraFluid) accumulates in the small vessels of the lesion (b).

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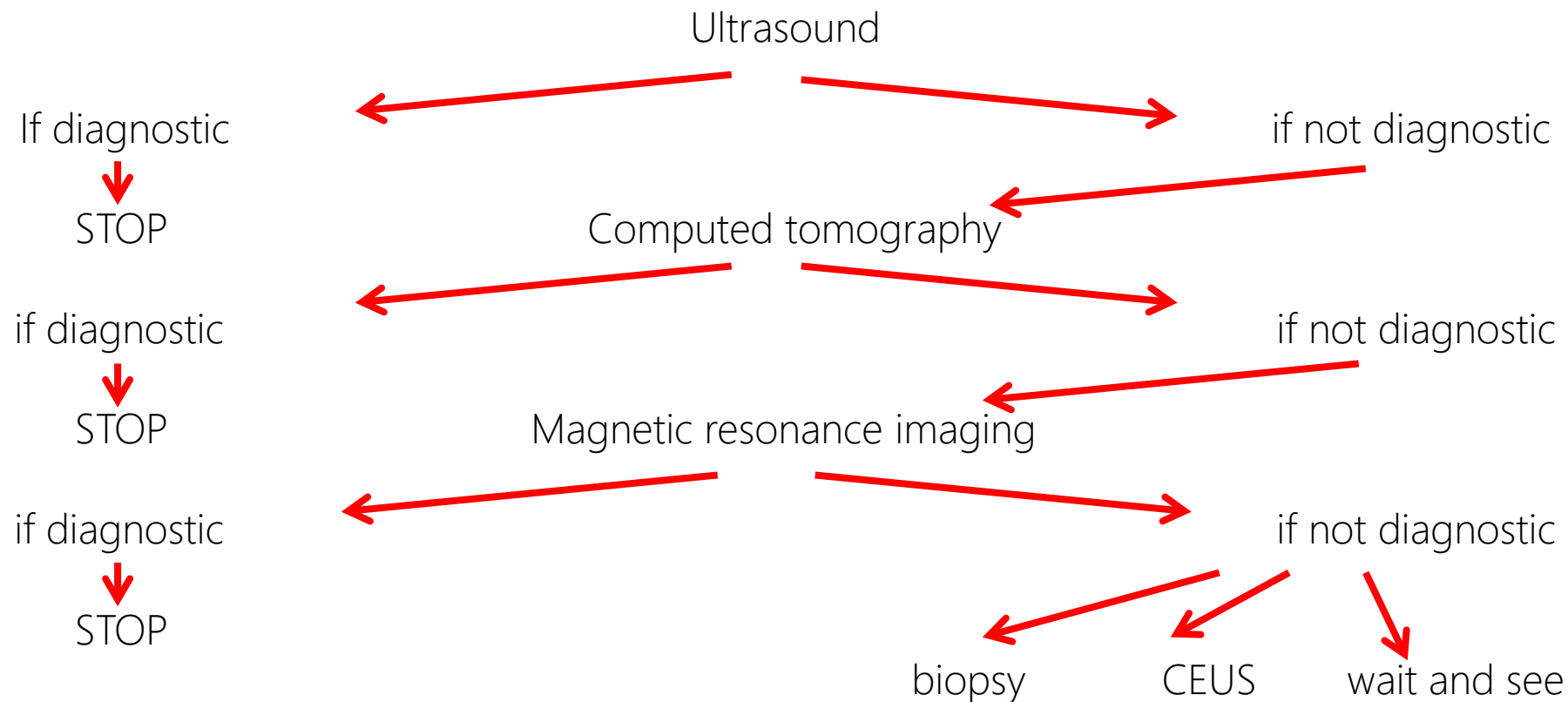
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Simplified Diagnostic Algorithm (Focal Lesion Detection / Characterisation)



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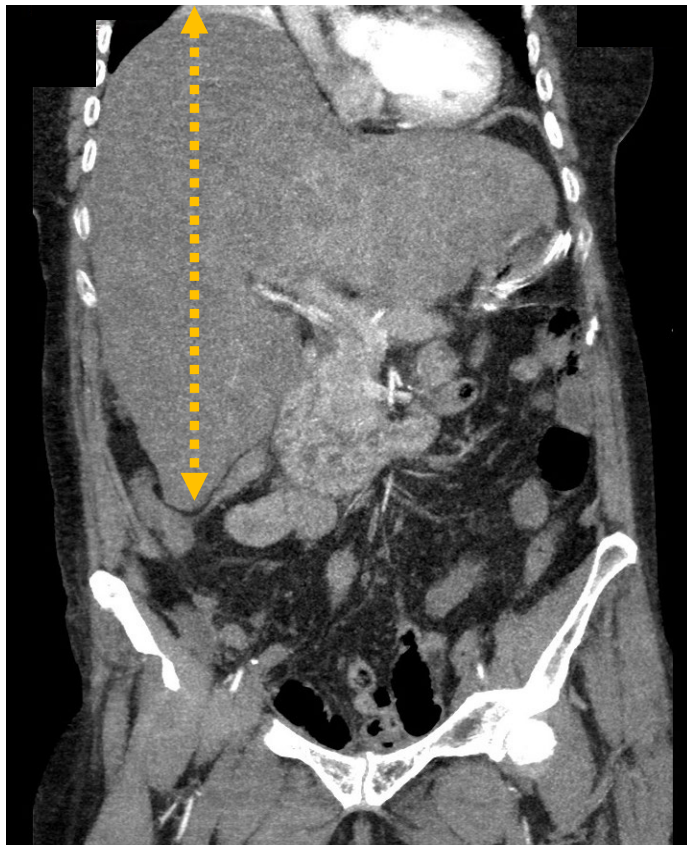
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Main Indications by Pathology - Parenchymal Disease



Hepatomegaly



It is the consequence of many diffuse parenchymal conditions and extensive focal lesions alike; however, it is difficult to objectively define its degree due to the variability of the shape and size of the normal liver.



US, CT and MRI are all able to estimate the size of the liver, especially with the assistance of automatic segmentation techniques which are able to calculate not only the dimensions but also the volume of the whole organ or its individual segments.

Roloff am et al, Abdom Radiol (2016) 41:1293–1299

Gotra A, Insights Imaging (2017) 8:377–392



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Fig. 18. Coronal CT reformatted image shows a significantly enlarged liver



Main Indications by Pathology - Parenchymal Disease



Steatosis

The most frequently seen diffuse liver condition is **steatosis**, caused by a variety of pathologic conditions (metabolic disease, right heart failure, congenital or acquired venous flow disorders, toxic parenchymal defects, non-alcoholic steatohepatitis, etc.). See Figs. 19 and 20.

In **severe steatosis** US may demonstrate diffuse or map-like hyperechogenicity in large areas of the liver, while CT and MRI may depict lower degree of fatty infiltration and provide semiquantitative data defining the level of degeneration.

Steatosis may also be **focal**, or it may happen that there is no fat deposited in circumscribed areas of the diffusely fatty liver (**focal sparing**) – these cases may cause differential diagnostic difficulties to be clarified by CT or MRI.

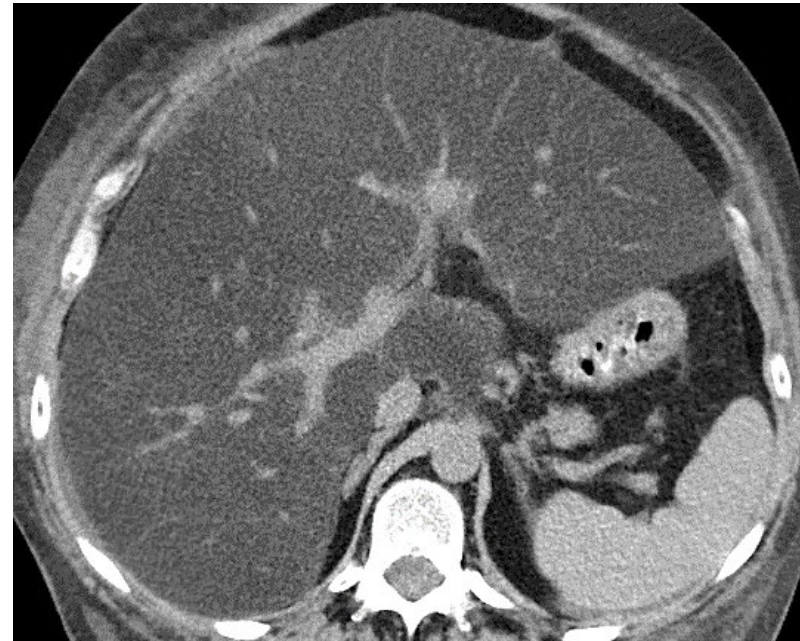


Fig. 19. Non-enhanced CT shows uniform hypodensity and enlargement of the liver allowing for depiction of vascular structures which are normally visible only on contrast-enhanced scans.

See for comparison Fig. 12a (normal liver parenchyma on non-enhanced CT image).

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Steatosis

In phase and out of phase MRI sequences are gradient echo sequences obtained with the same repetition time value but different echo time values (see e book chapter on MRI). The main indication for these types of sequences is to identify **microscopic fat content** in tissues as the signal intensity of tissues containing fat drops on the out of phase images in comparison to the in phase images (Fig. 20).

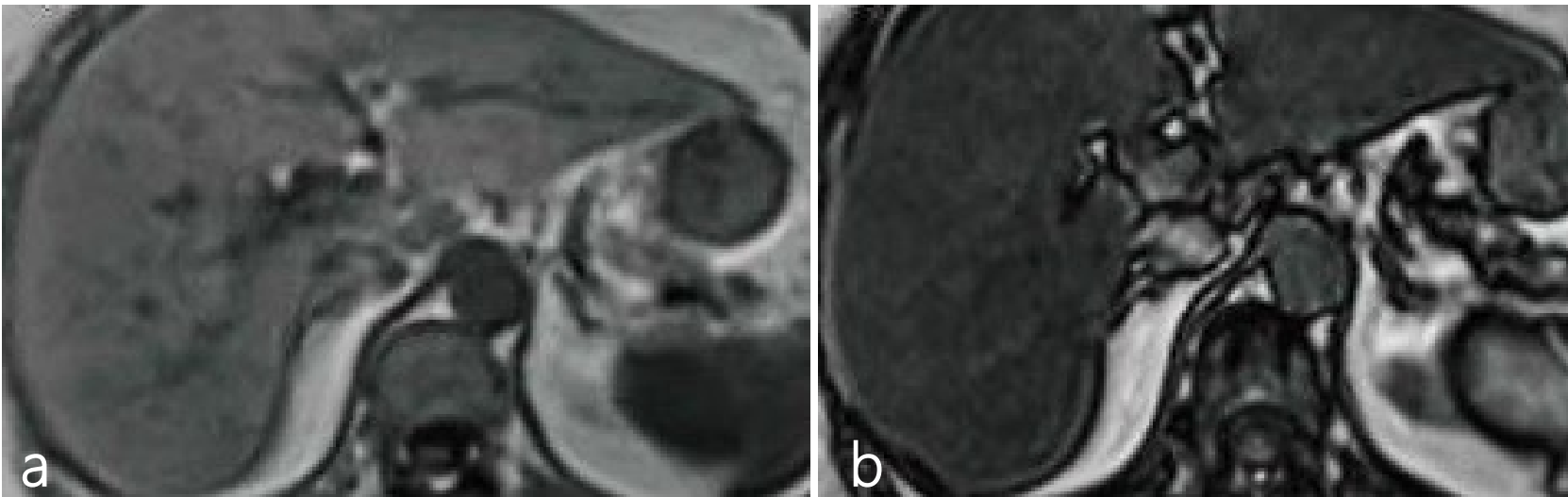


Fig. 20. In-phase (a) and opposed-phase (b) T1-weighted MR-scans show significant signal loss in the liver parenchyma on the opposed-phase image due to high concentration of microscopic/intracellular fat deposition

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Main Indications by Pathology - Parenchymal Disease



Cirrhosis

Chronic intoxications (alcohol, drugs) or **chronic progressive conditions** (virus hepatitis C, steato-hepatitis, etc.) can eventually lead to cirrhosis. The condition is characterised by diffuse degeneration, within which focal areas of regenerating liver parenchyma can occur.

Depending on the type of cirrhosis, the US appearance can be fine granular or macronodular, the size of the organ may be reduced and its contour may be irregular (**Fig. 21**). The caudate lobe is typically not affected by the overall volume loss; on the contrary, it can appear as relatively enlarged (**Fig. 22**). In advanced cases, signs of portal hypertension (ascites, splenomegaly, oedematous thickening of the bowel- and gall bladder wall) can be seen. Doppler US demonstrates the vascular consequences of cirrhosis (e.g., dilatation of the portal vein and of the periumbilical venous plexus, peri-gastric and splenic collaterals).



CT and especially MRI play important role in the **early detection** of focal malignant lesions, frequently occurring in cirrhotic livers (see later).

Oesophageal varicosity is well detectable by endoscopy, but its **extraluminal extent** can be evaluated only by CT. In bleeding varices **interventional radiology** may offer a temporary solution by creating a trans-jugular intrahepatic portosystemic shunt.

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Cirrhosis

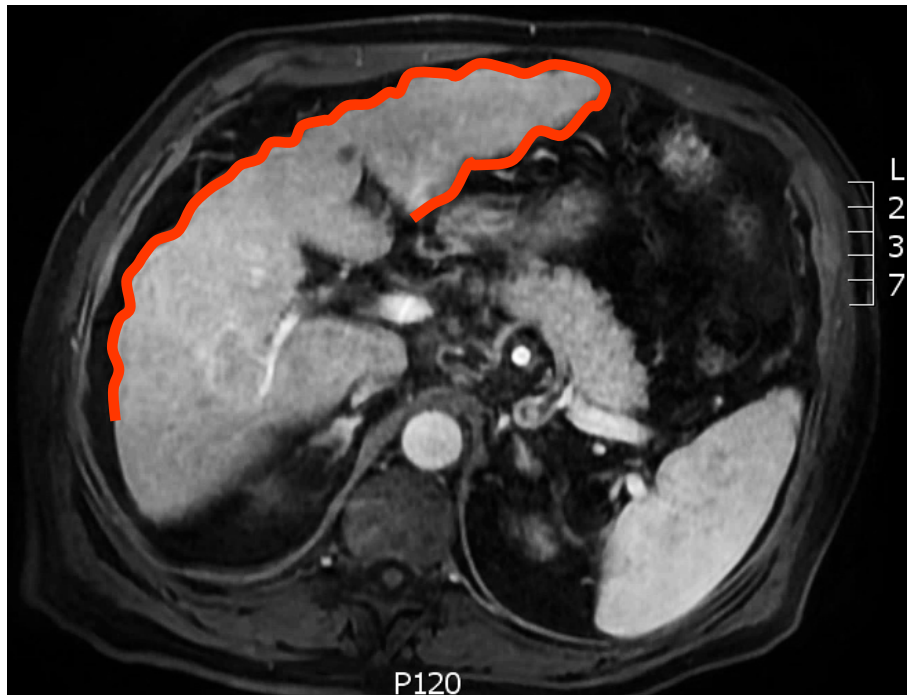


Fig. 21. Contrast-enhanced T1 fat-suppressed MRI shows a small liver with irregular contours (red line).

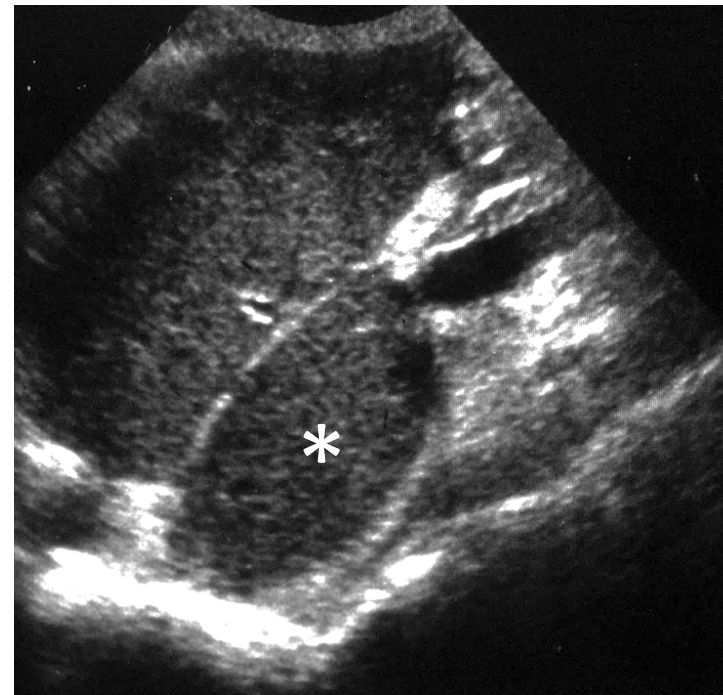


Fig. 22. Ultrasound image shows coarse liver structure and enlargement of segment 1 (caudate lobe) of the liver. (asterisk).

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Benign

- Cystic
 - simple cyst
 - abscess
 - parasitic cyst
 - biliary hamartoma
- Vascular
 - haemangioma
 - peliosis
 - veno-occlusive disease
 - THAD / vascular pseudolesions
 - focal steatosis and sparing
- Hepatocellular
 - focal nodular hyperplasia (FNH)
 - adenoma

Malignant

- HCC
- Hepatoblastoma
- Fibrolamellar HCC
- CCC
- Bile duct cystadenocarcinoma
- Angiosarcoma
- Malignant epitheloid
haemangioendothelioma
- Undifferentiated sarcoma
- Rhabdomyosarcoma
- Kaposi's sarcoma
- Metastasis
- Lymphoma



Main Indications by Pathology – Focal Liver Disease

Cysts



- Most cystic liver lesions are **simple cysts**. US reveals rounded lesions of variable size, with thin walls and clear fluid content in an otherwise normal liver (Fig. 23). On CT and MRI, cysts have water density/signal and no enhancement (Figs. 24 and 25).
- Similar lesions but in much bigger number are seen in **hereditary polycystic disease**, which simultaneously affects the liver, pancreas and kidneys. The US diagnosis is usually straightforward and no further examinations are required.
- Multiple cystic lesions in the liver can be the consequence of **rare biliary developmental disorders**. In these cases it is important to differentiate between cystic hamartomas, which do not communicate with bile ducts (**Von Meyenburg disease**), and cystic lesions communicating with the biliary system (**Caroli disease**). The latter can be associated with chronic inflammation and fibrosis, which can lead to liver function insufficiency necessitating transplantation. MR imaging (including MRCP) is the method of choice to assess Caroli cysts communicating with bile ducts (often containing stones), and chronic inflammation and fibrosis surroundings the cysts. The „central dot sign“, representing an associated portal vein branch traversing the lumen of the cyst, is pathognomonic (Fig. 26). ERCP can be used to confirm cyst connection to the biliary system. See chapter on biliary ducts.

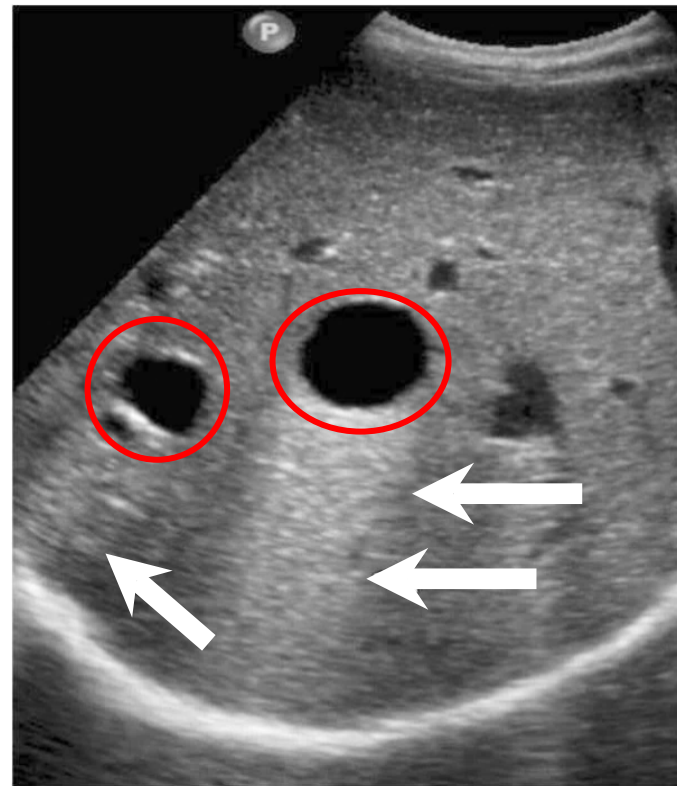


Fig. 23. Ultrasound image demonstrates two simple cysts with typical posterior “echo enhancement” (arrows)

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Cysts

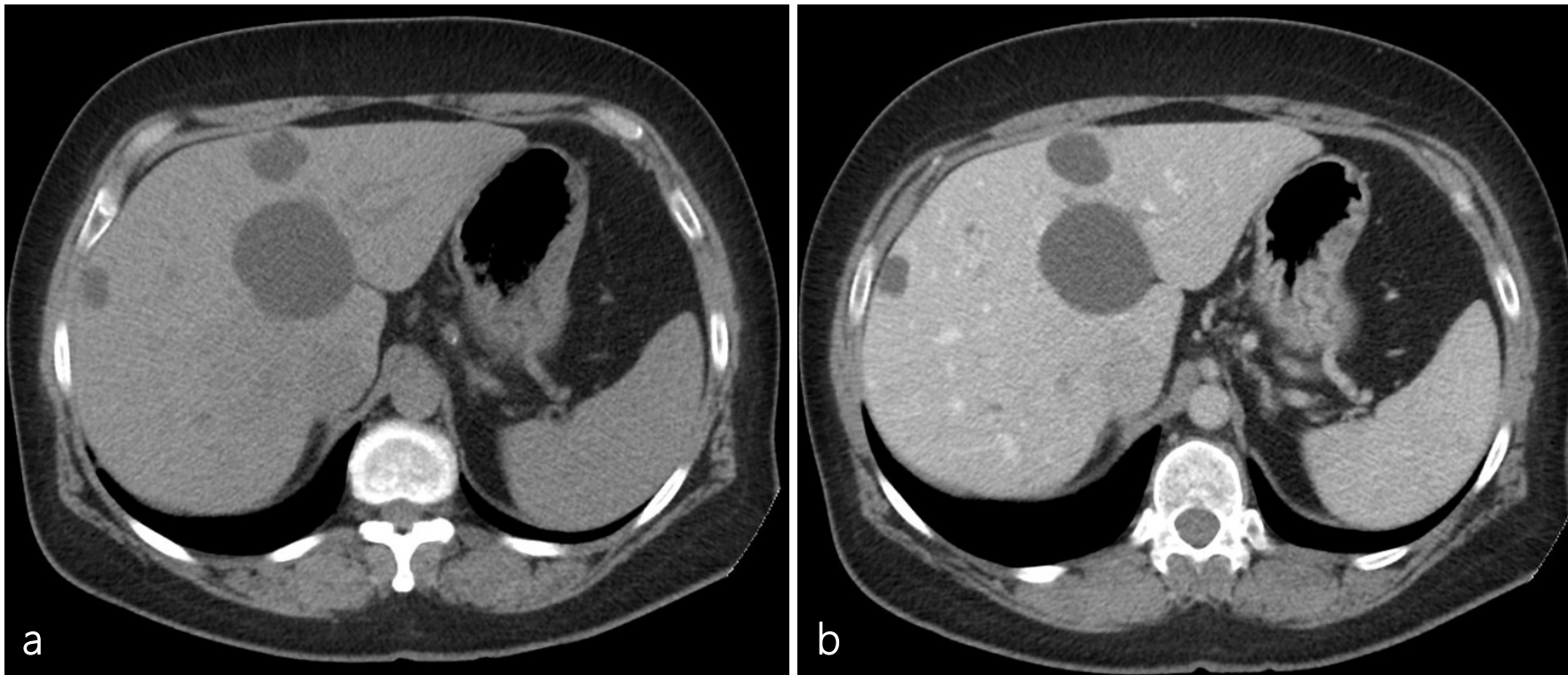


Fig. 24. Non-enhanced (a) and contrast-enhanced (b) CT scans demonstrate multiple benign cysts (water density, well-defined, no enhancement)

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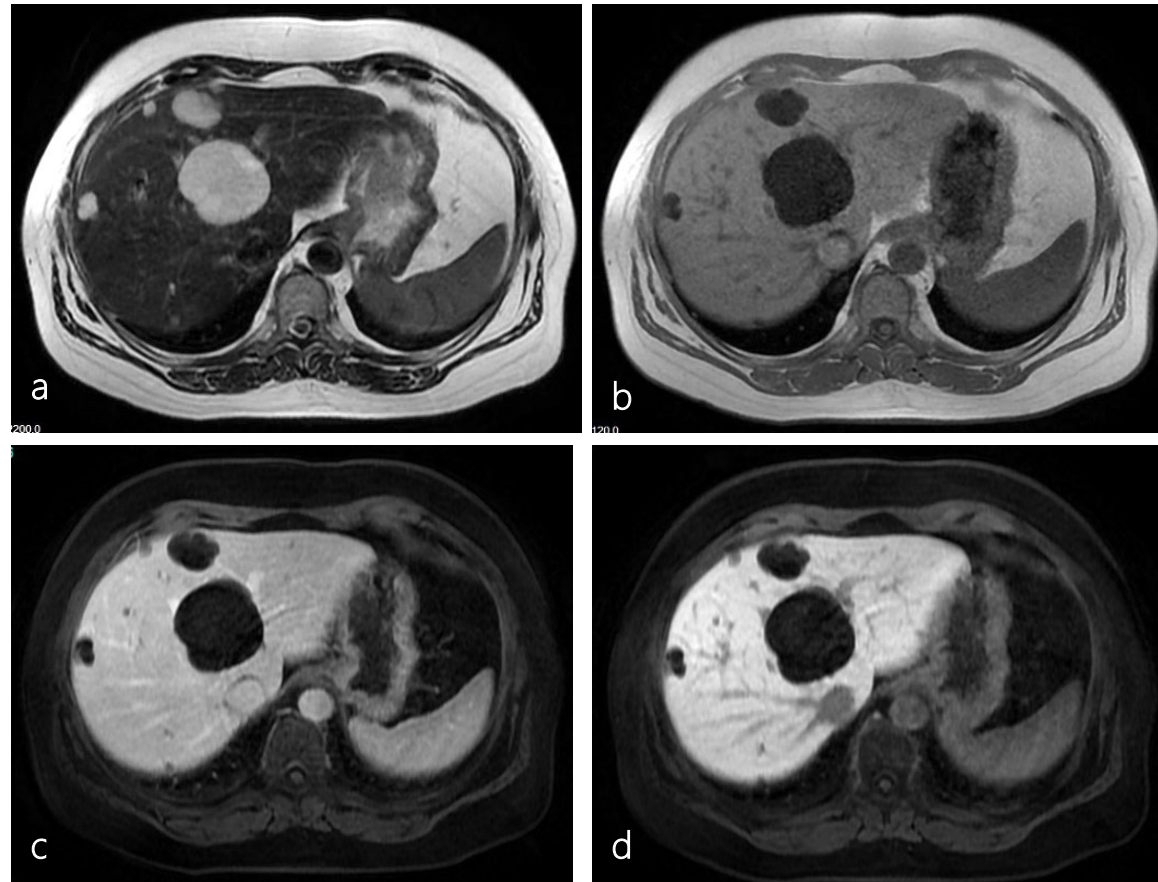


Fig. 25. Same patient as in Fig. 24. T2-weighted (a), T1-weighted (b), postcontrast parenchymal phase (c) and hepatobiliary phase (d) 3D GRE fat-suppressed MRI shows multiple benign cysts (water signal intensity, no enhancement)

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Cysts

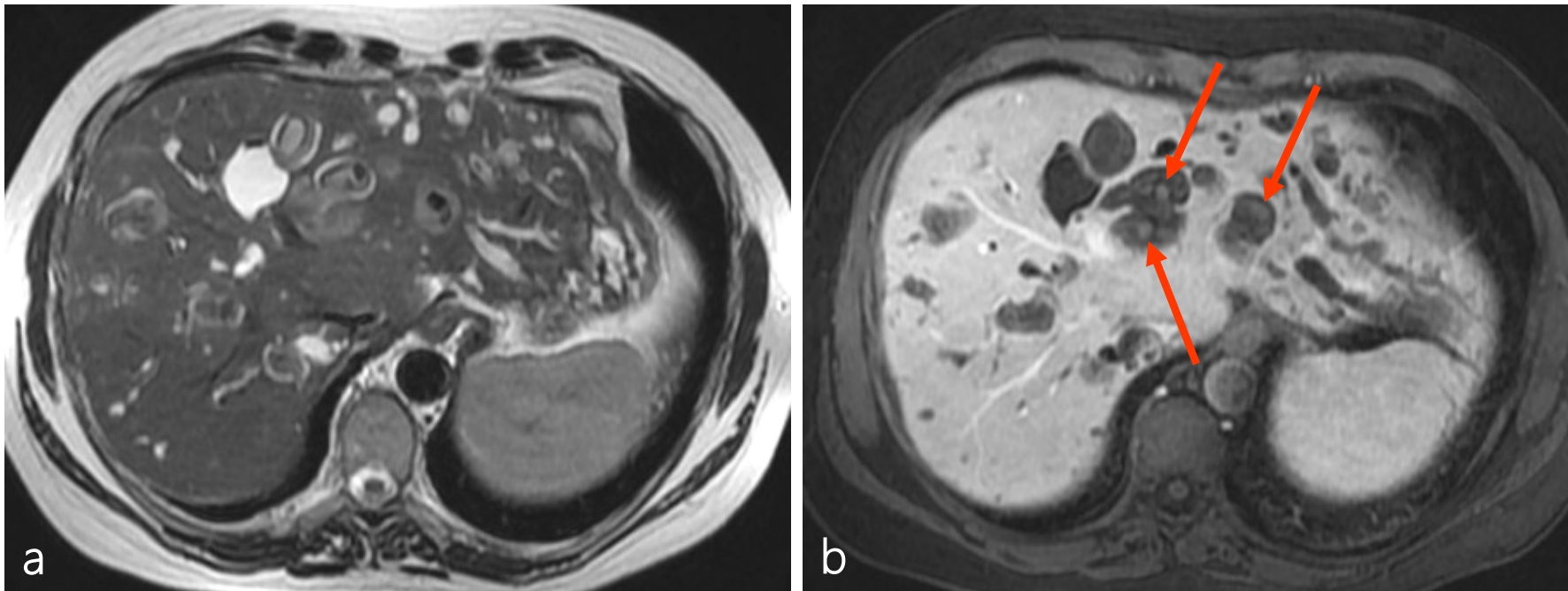


Fig. 26. T2-weighted (a) and T1-weighted (b) MRI sequences demonstrate multiple complex cysts with features characteristic of Caroli disease. Arrows point at the central dot sign.

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Cysts

- **Echinococcus (hydatid) cysts** have two subtypes. One subtype is characterised by a big cyst with a thick and sometimes calcified wall, including a partially detached endoluminal germinative layer, often associated with smaller, „daughter“-cysts. The multilocular subtype consists of multiple small cysts, separated by thick, frequently calcified walls and septa, giving the impression of a neoplastic lesion. Laboratory data and US, CT and MRI results are often diagnostic but rarely a percutaneous biopsy is necessary for the final diagnosis. However, puncturing a hydatid cyst can result in a severe hypersensitivity reaction due to cyst content leaking along the needle track into the abdomen.
- **Liver abscesses** are typically thick-walled, round-shaped or irregular focal lesions with thick walls, a dense fluid content and an ill-defined external contour. US is mostly diagnostic; in case of doubt, CT reveals mild to moderate wall enhancement and MR shows diffusion restriction of the purulent content. US can be used to guide percutaneous aspiration and drainage.
- **Certain neoplastic conditions** (necrotic tumours, metastases from GIST, cystadenocarcinoma, certain squamous cell carcinomas) can present as cystic focal lesions. Ill-defined contour, thick fluid content, wall enhancement, detectable by CT or MR evoke a possible malignant background.



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Main Indications by Pathology – Focal Liver Disease



Solid Benign

- In some cases **US-characteristics** of a solid lesion can predict its nature but most of the time contrast-enhanced US, CT or MRI are needed for proper characterisation.
- Smaller, isoechoic foci **may be missed by US**, therefore, if the clinical situation requires clarification (e.g. prior to planning an oncologic treatment), **MRI must be performed** even after a negative US examination!
- The most common benign solid liver lesions are:
 - haemangioma,
 - focal steatosis / focal sparing ,
 - focal nodular hyperplasia and
 - adenomas.



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Solid Benign – Haemangioma

- The most frequent solid focal lesion of the liver is **haemangioma** (Figs. 27 and 28). At US, it typically appears as a well-defined, rounded hyperechoic area. **Cavernous haemangioma** demonstrates a characteristic enhancement pattern at US, CT and MRI: the initial peripheral, irregular contrast accumulation slowly moves centripetally, and eventually involves the whole lesion (Figs. 27 and 28); the MRI signal intensity is also typical: high T2 and low T1 with moderate diffusion restriction. **Capillary haemangioma** is typically small and shows fast and intensive central enhancement.



Fig. 27. Arterial phase (a), portal phase (b) and delayed phase (c) postcontrast CT shows a typical haemangioma, initially enhancing at its periphery and gradually filling in later

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Solid Benign – Haemangioma

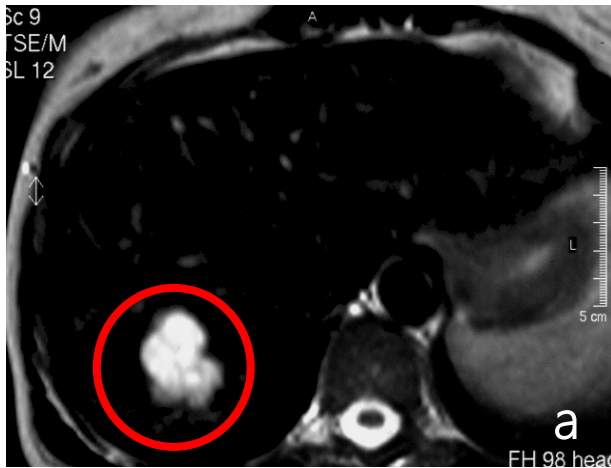
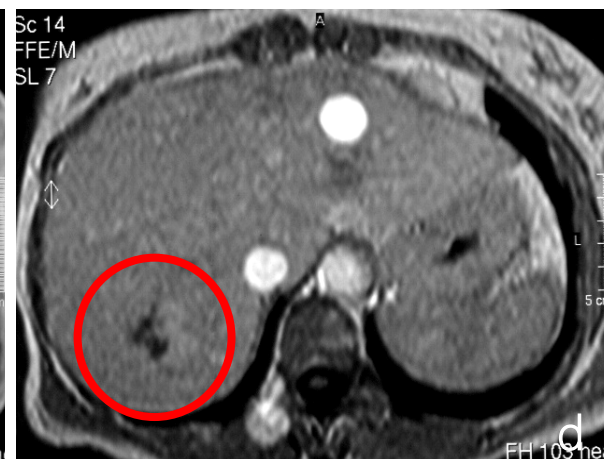
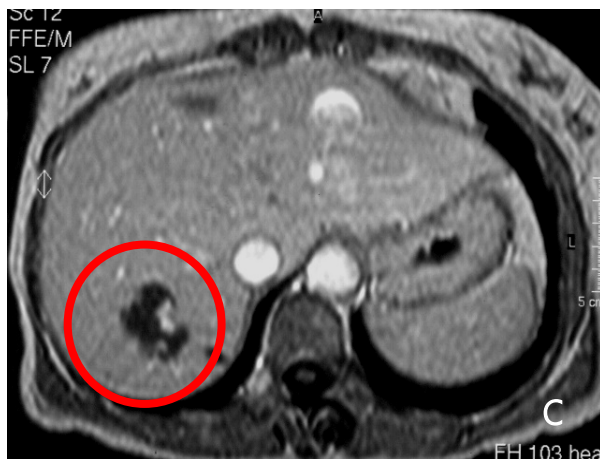
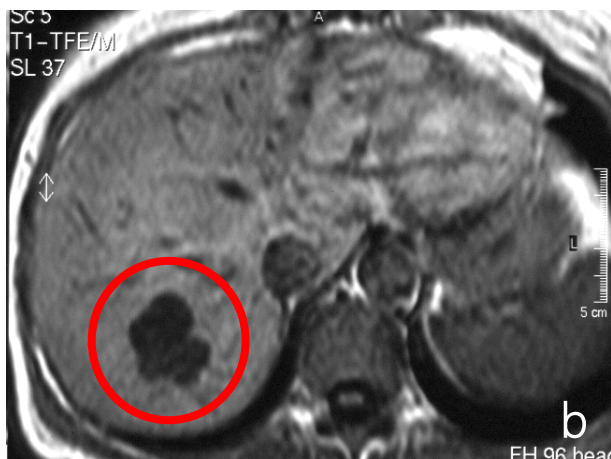


Fig. 28. T2-weighted (a), T1-weighted non-enhanced (b), arterial phase (c) and portal phase (d) MRI shows a typical haemangioma (T2 high, T1 low signal intensity, gradual centripetal enhancement)



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Main Indications by Pathology – Focal Liver Disease



Solid Benign – Focal Sparing

- **Focal steatosis** appears as a hyperechoic, but less regular, sometimes geographical area on US, while on CT low density and on MRI signal loss on out-of-phase images are characteristic. In case of any doubt, MRI allows the definitive diagnosis as focal steatosis lesions never show restricted diffusion and they normally enhance after hepatobiliary contrast agent administration.
- **Focal sparing** (normal parenchymal areas in fatty liver) appears less echogenic than the fatty environment at US, CT and MRI. CT and MRI depict liver steatosis and also areas lacking fat (= focal sparing, **Figs. 29 and 30**), while diffusion-weighted MRI and contrast-enhanced measurements – similarly to focal steatosis – do not detect any alteration in the target area.

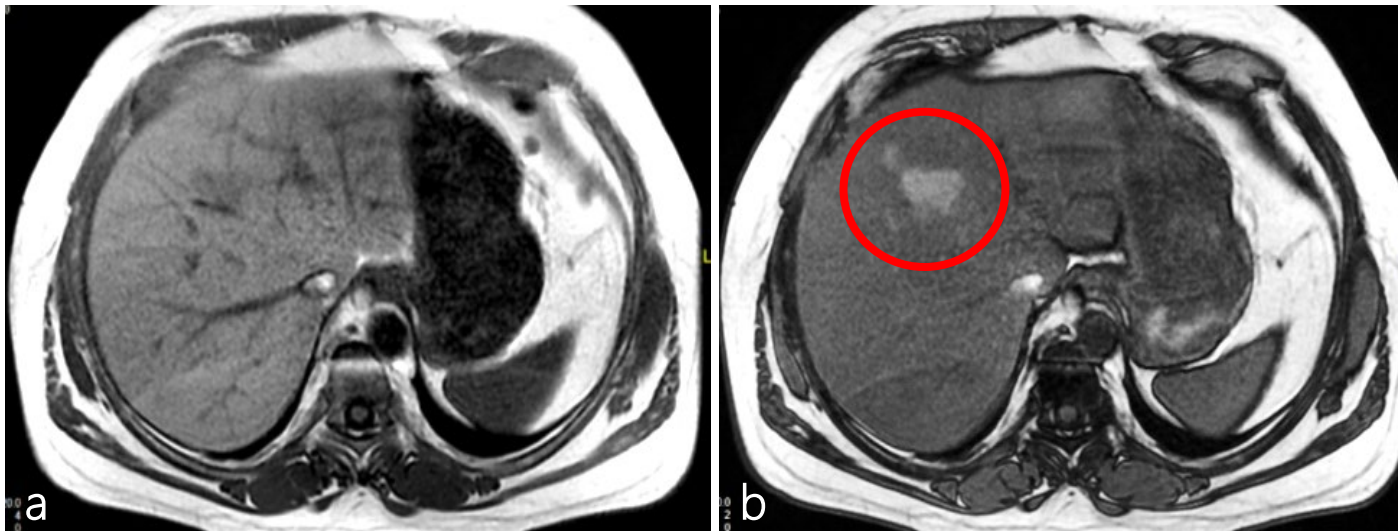


Fig. 29. In-phase (a) and out-of-phase (b) MR images show signal loss in the steatotic liver parenchyma, with the exception of a small area of focal sparing

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Solid Benign – Focal Sparing

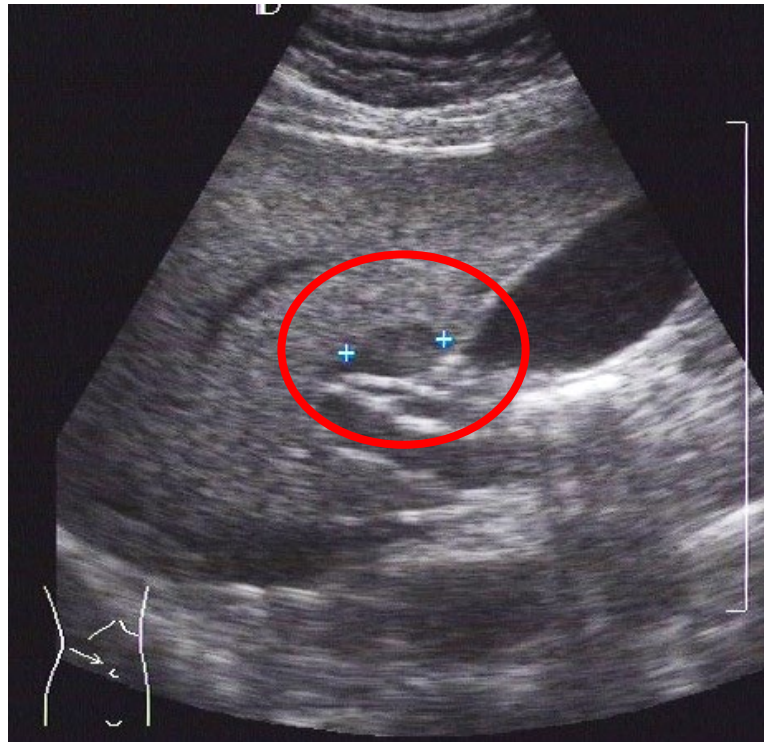


Fig. 30. US image shows small hypo-echoic area within the homogeneously hyperreflective liver, consistent with focal sparing within diffuse steatosis

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Solid Benign – Hepatobiliary - FNH

- Focal nodular hyperplasia (FNH, Figs. 31 -33), if detected by US, is well-defined, often subcapsular or exophytic and of variable echogenicity; however, it can be almost invisible at non-enhanced US, CT and MRI. After contrast administration, it has a characteristic enhancement: almost homogeneous, very fast and intensive in the arterial phase, a similar enhancement as normal liver parenchyma in the portal phase,, thus making the lesion hardly visible (**vanishing lesion**). In most cases a slow and prolonged enhancement in the centre of the lesion (**central scar**) is seen, which represents a connective tissue rich vascular bundle. FNH enhances after hepatobiliary contrast agents similarly to normal liver parenchyma.
- **Adenomas** may have a similar appearance with FNH (isoechoic on US, intensive arterial contrast enhancement, levelling off in the portal phase at CT and MR), but unlike FNH, adenomas have the tendency to grow, accumulate fat, develop a capsule, and contain haemorrhage, and/or undergo rupture, depending on the lesion subtype. Another important difference is that biliary excretion is reduced or missing, thus enhancement after hepatobiliary contrast agents is significantly lower than in FNH.

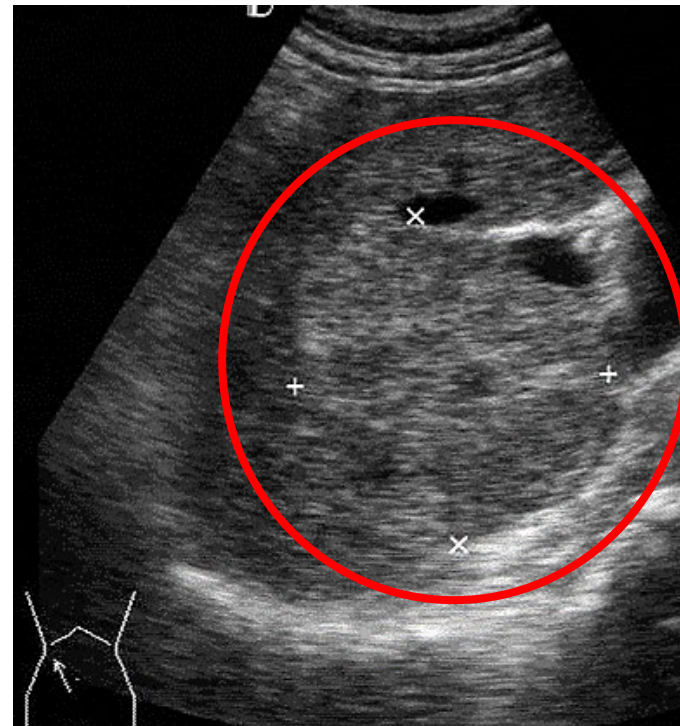


Fig. 31. US shows a large, well-defined, moderately hyperechoic mass behind the liver hilum

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Solid Benign – Hepatobiliary - FNH

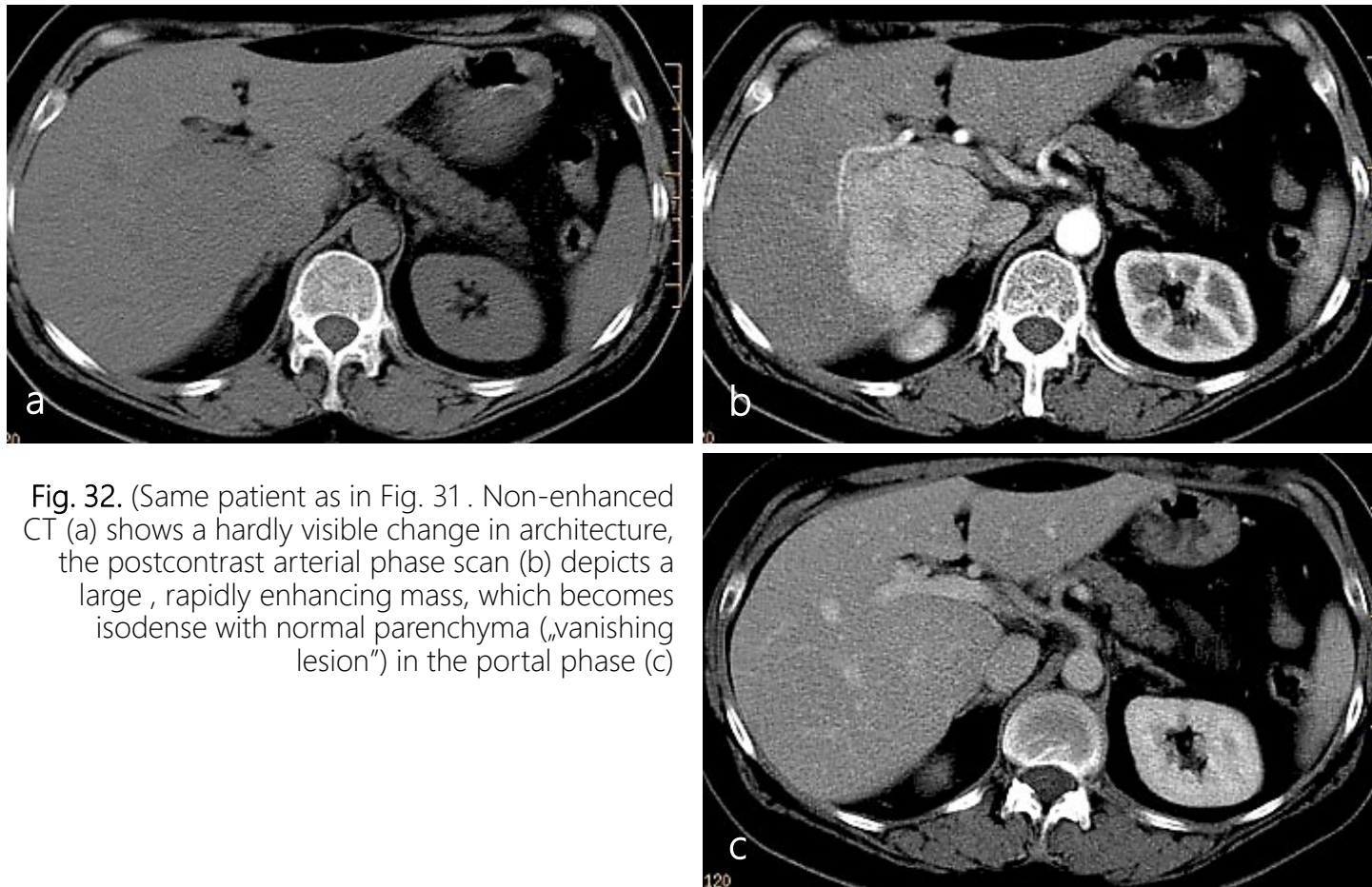


Fig. 32. (Same patient as in Fig. 31 . Non-enhanced CT (a) shows a hardly visible change in architecture, the postcontrast arterial phase scan (b) depicts a large , rapidly enhancing mass, which becomes isodense with normal parenchyma („vanishing lesion“) in the portal phase (c)

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Solid Benign – Hepatobiliary - FNH

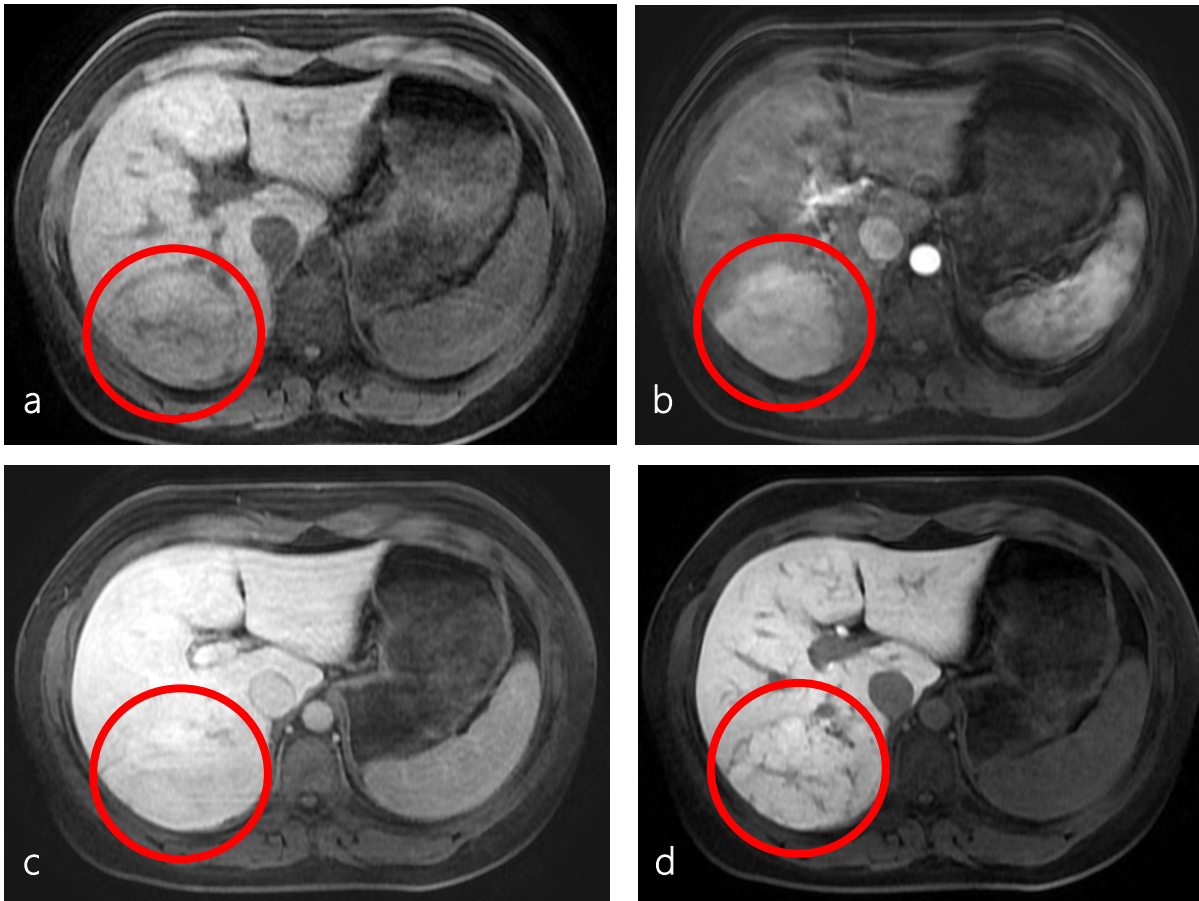


Fig. 33. Non-enhanced (a), postcontrast arterial phase (b), parenchymal phase (c) and hepatobiliary phase (d) MRI shows a large mass in the right lobe of the liver, showing intensive arterial enhancement, becoming isointense with normal liver parenchyma in the portal and hepatobiliary phase

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Main Indications by Pathology – Focal Liver Disease



Primary Malignant

- **Hepatocellular carcinoma (HCC)** is the **most frequent primary liver malignancy**, mostly developing from hyperplastic-dysplastic nodules in a **cirrhotic liver**. Hyperplastic nodules have a portal blood supply (as normal liver parenchyma). Depending on the level of dysplasia, arterial blood supply increasingly takes over and becomes exclusive in overt HCC. HCC can also develop in the non-cirrhotic liver, and this type of HCC also has intensive arterial-phase contrast enhancement.

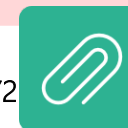


- The **difference** between the enhancement pattern of **HCC** and **adenoma/FNH** is that in HCC a very fast contrast agent washout in the portal or early delayed phase is seen, as opposed to the much slower washout in benign lesions (Figs. 34, 35). HCC also demonstrates restricted diffusion and lack of enhancement in the hepatobiliary phase. Vascular invasion and satellite lesions are best detected on MRI. In bigger, more advanced lesions enhancement may be less intensive, and the structure more inhomogeneous, due to necrosis, bleeding and calcification, all easily depicted by CT and MRI.
- The **fibrolamellar HCC subtype** is usually a bigger, infiltrative lesion with a characteristic calcification in the central parts.
- Interventional radiology plays an important role in the **treatment of HCC** by performing percutaneous thermal (radiofrequency, cryo- or laser-) ablation, transarterial chemo- or radioembolisation..

- **Intrahepatic cholangiocellular carcinomas (ICCC)** also occur more frequently in the **cirrhotic liver** but can also develop in the normal liver.



- The intraductal papillary and periductal infiltrative forms are difficult to visualise at imaging. At US only localised, segmental dilatation of the affected bile ducts is often seen. The lesion itself is best detected by diffusion-weighted MRI. Detection of the mass-forming ICCC type is easier, but many times it is difficult to identify its biliary origin. ICCC shows slow, progressive, late enhancement due to extensive, dense connective tissue components. The contour of the liver may show indentation in the proximity of the lesion, but the sign is not specific. See also chapter on biliary ducts.



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Primary Malignant - HCC

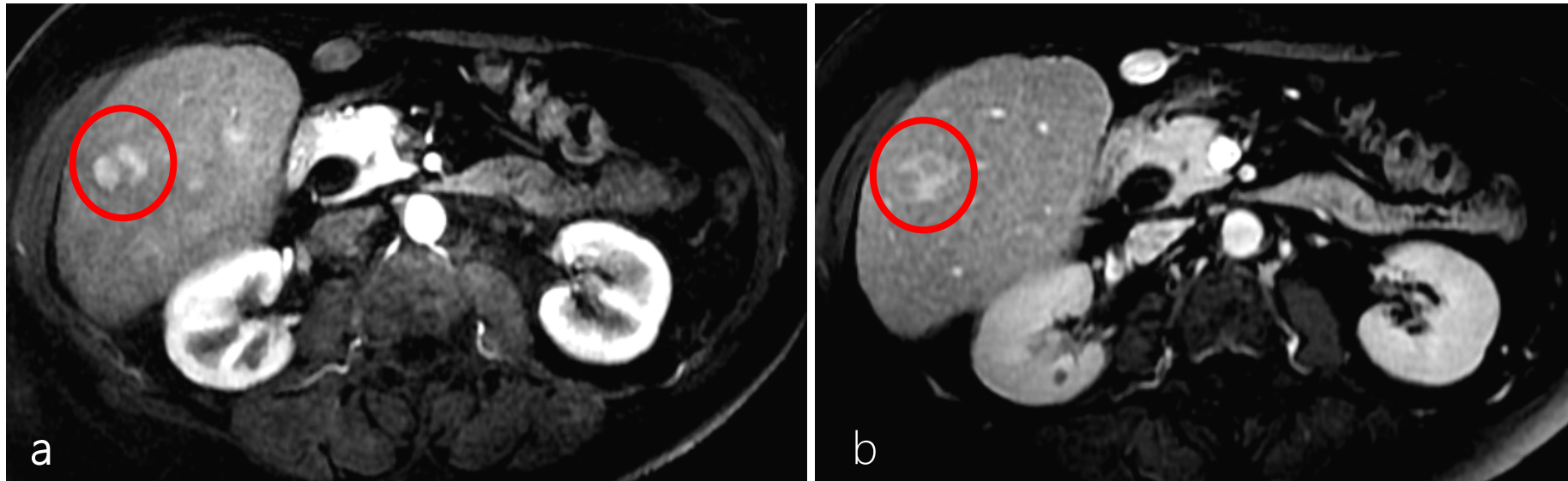


Fig. 34. Arterial phase (a) and parenchymal phase T1-weighted MRI shows a lesion which enhances centrally in the arterial phase and in the periphery in the portal phase („nodule in nodule”: early HCC)

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Primary Malignant - HCC

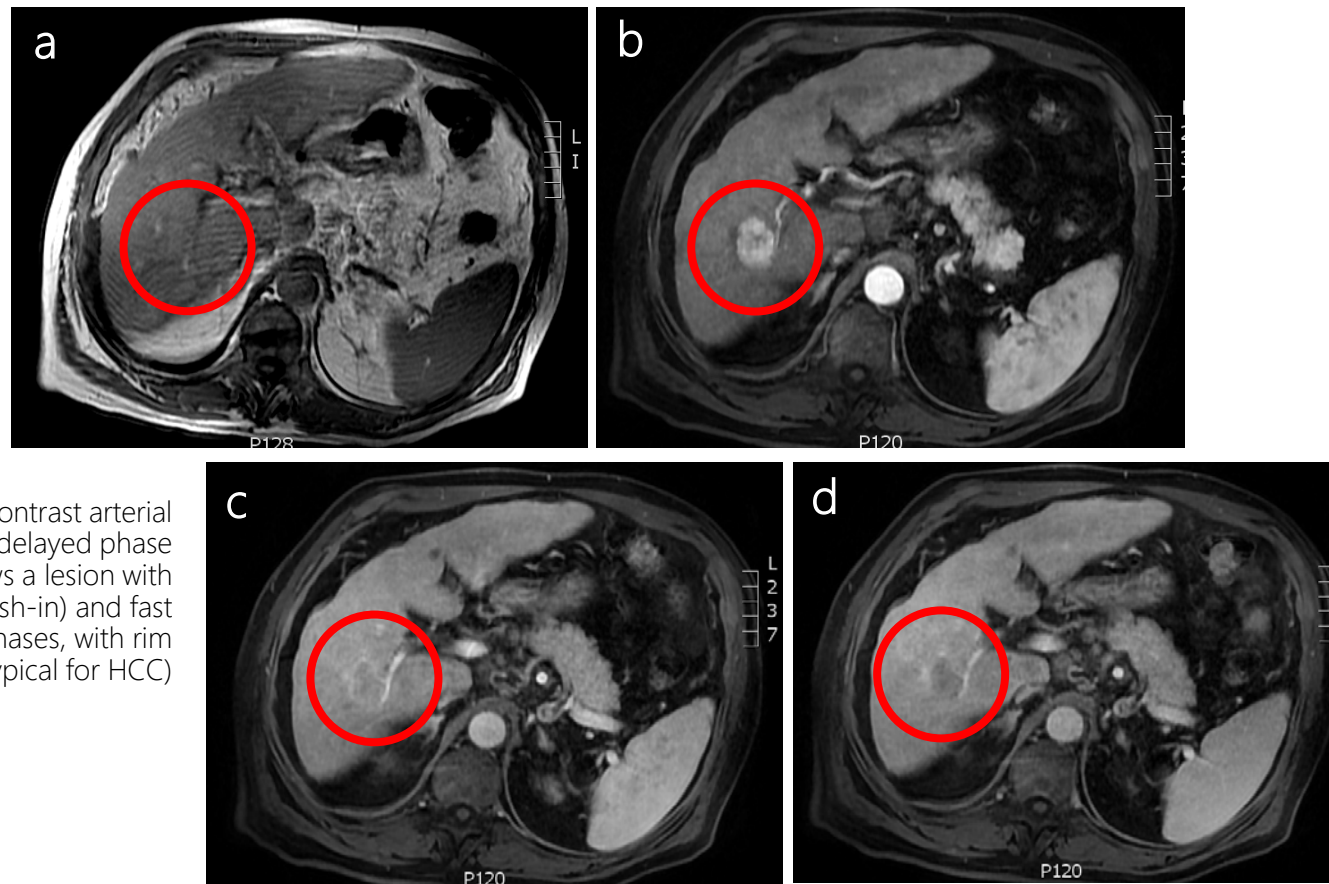


Fig. 35. Non-enhanced (a), postcontrast arterial phase (b), portal phase (c) and delayed phase T1-weighted MRI sequences shows a lesion with rapid arterial enhancement (wash-in) and fast wash-out in the later phases, with rim enhancement (the pattern is typical for HCC)

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Secondary Malignant

- The most frequent hepatic malignant lesions are the **haematogenous metastases** (20-40 times more common than HCC). At US they are typically hypoechoic (in 65% of cases), round-shaped, well defined lesions of various diameters (Fig. 36.). As they have an arterial blood supply but typically a low level of vascularity, they show minimal to moderate, inhomogeneous (often peripheral) enhancement in the arterial phase, and despite central filling in the portal phase, there is **slow wash-out in the delayed phase**, which helps to distinguish them from haemangioma (Fig. 37).
- 
 - The presence or absence of metastases is **best assessed by MRI** (Fig. 38), on which metastatic lesions appear as areas of diffusion restriction (lower ADC than surrounding liver parenchyma), with no enhancement in the hepato-biliary phase.
 - The primary tumour type influences the **appearance of metastases** (hypervascular tumours tend to have hypervascular metastases, melanoma metastases have a special MRI signal profile due to their melanin content, cystic tumours tend to have cystic metastases, etc.)
- 
 - **US-guided biopsy** is necessary to clarify the origin of an unknown primary cancer or to understand changes in the genetic profile of the tumour during the process of haematogenous dissemination.
 - Metastases can also be **treated by image-guided ablative interventions** if their number and size does not exceed a certain limit)
- Liver manifestations of **malignant lymphomas** are rare. Lymphomas are typically large, sometimes confluent, hypoechoic, hypodense lesions with minimal enhancement.

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Secondary Malignant – Metastasis

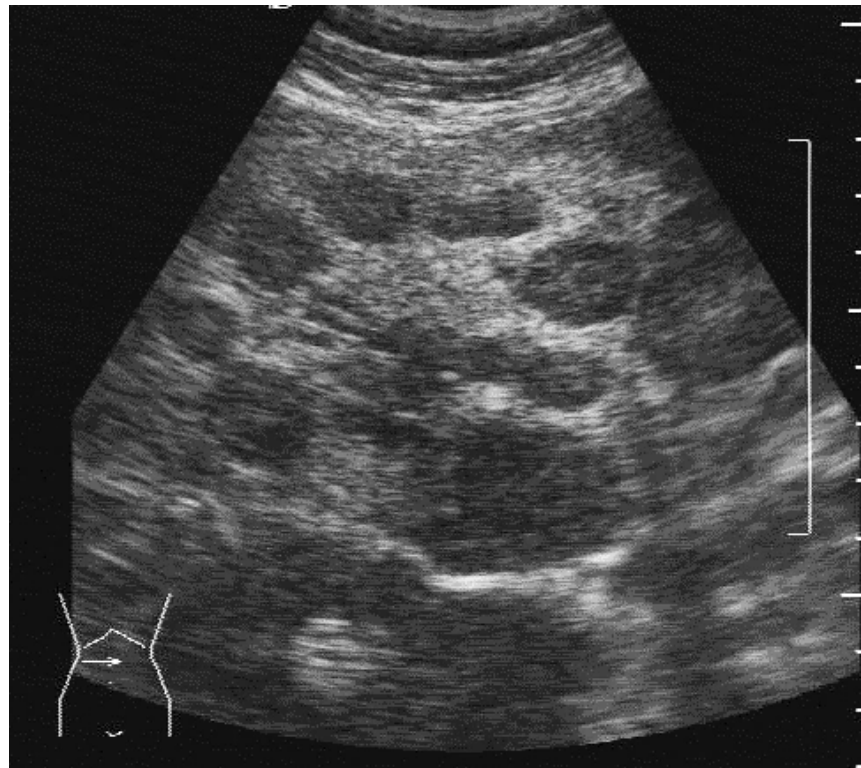


Fig. 36. Ultrasound examination reveals multiple well-defined round-shaped/oval hypo-echoic metastatic lesions in the liver

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Secondary Malignant – Metastasis

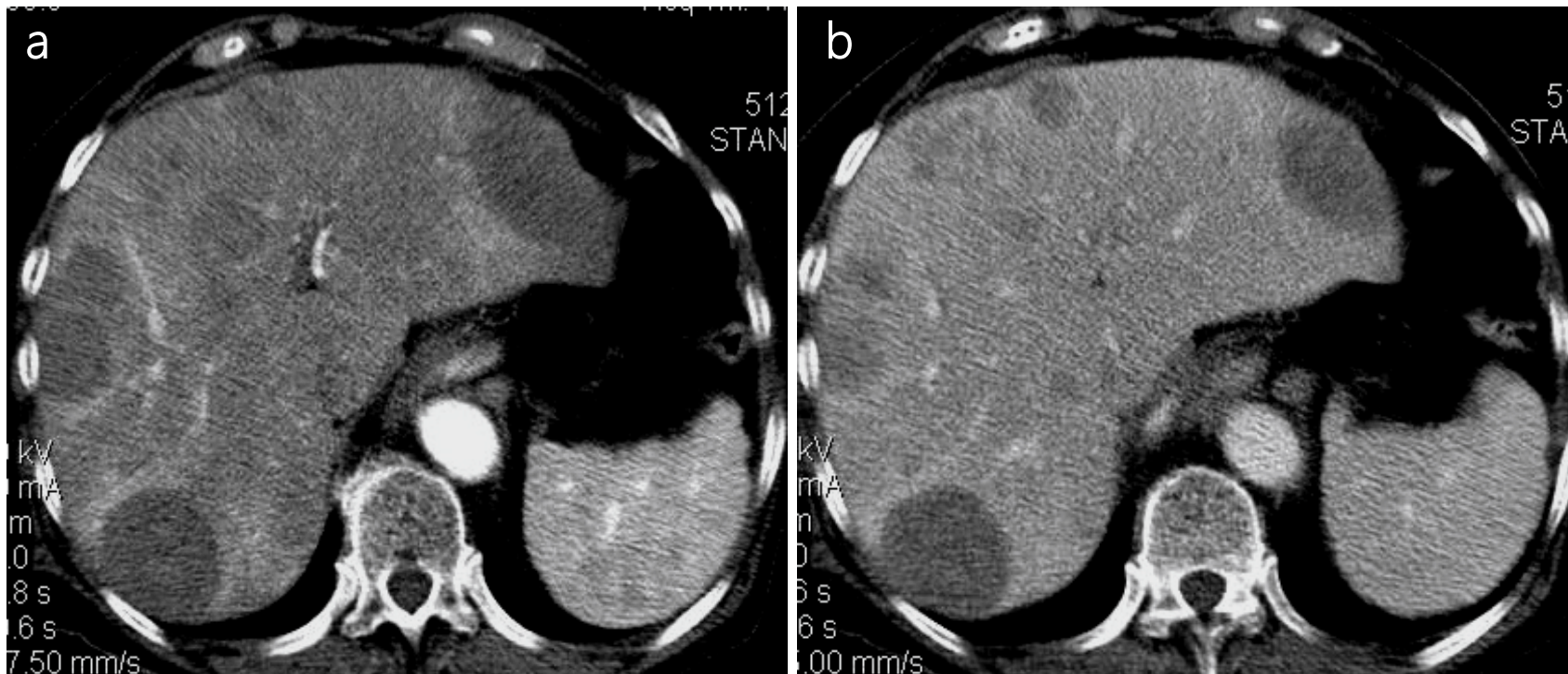


Fig. 37. Arterial (a) and portal (b) phase CT scans depict multiple well-defined, round-shaped, hypodense metastatic lesions, showing only minimal peripheral enhancement in the arterial phase

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Secondary Malignant – Metastasis

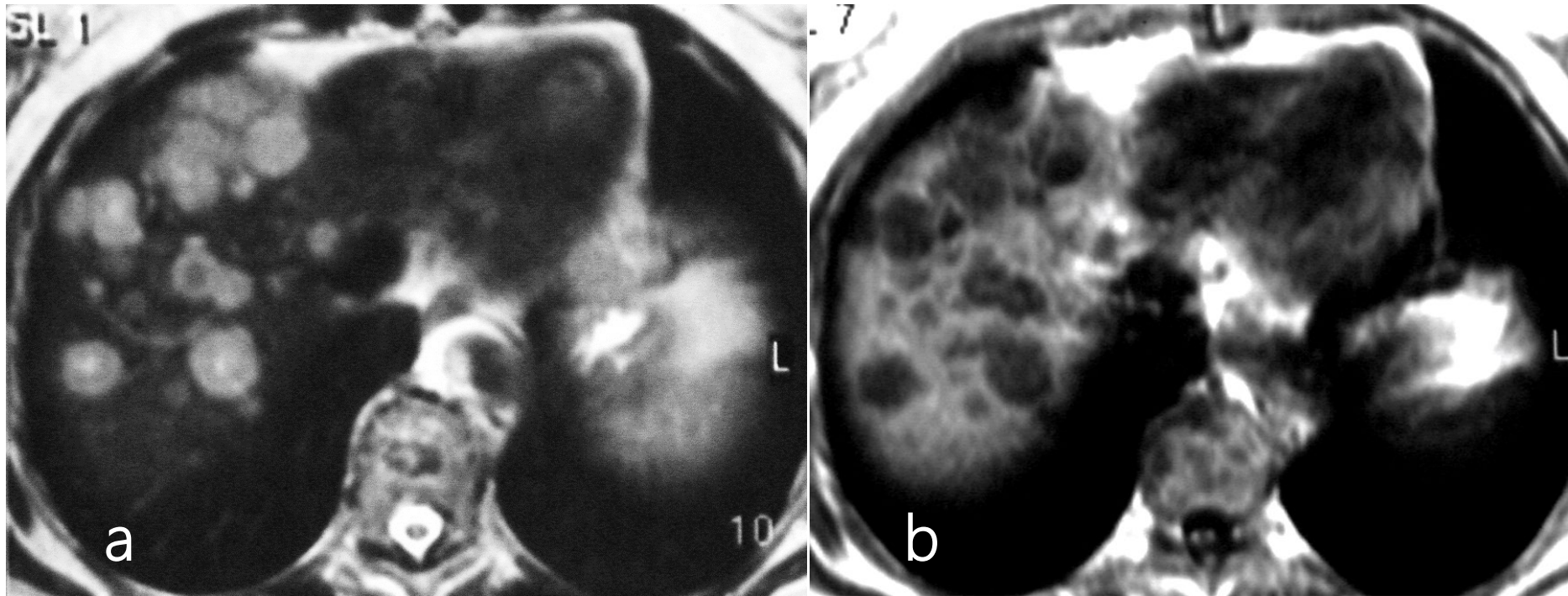


Fig. 38. T2-weighted (a) and T1-weighted (b) MRI scans show multiple round-shaped metastases in the liver

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Secondary Malignant – Metastasis

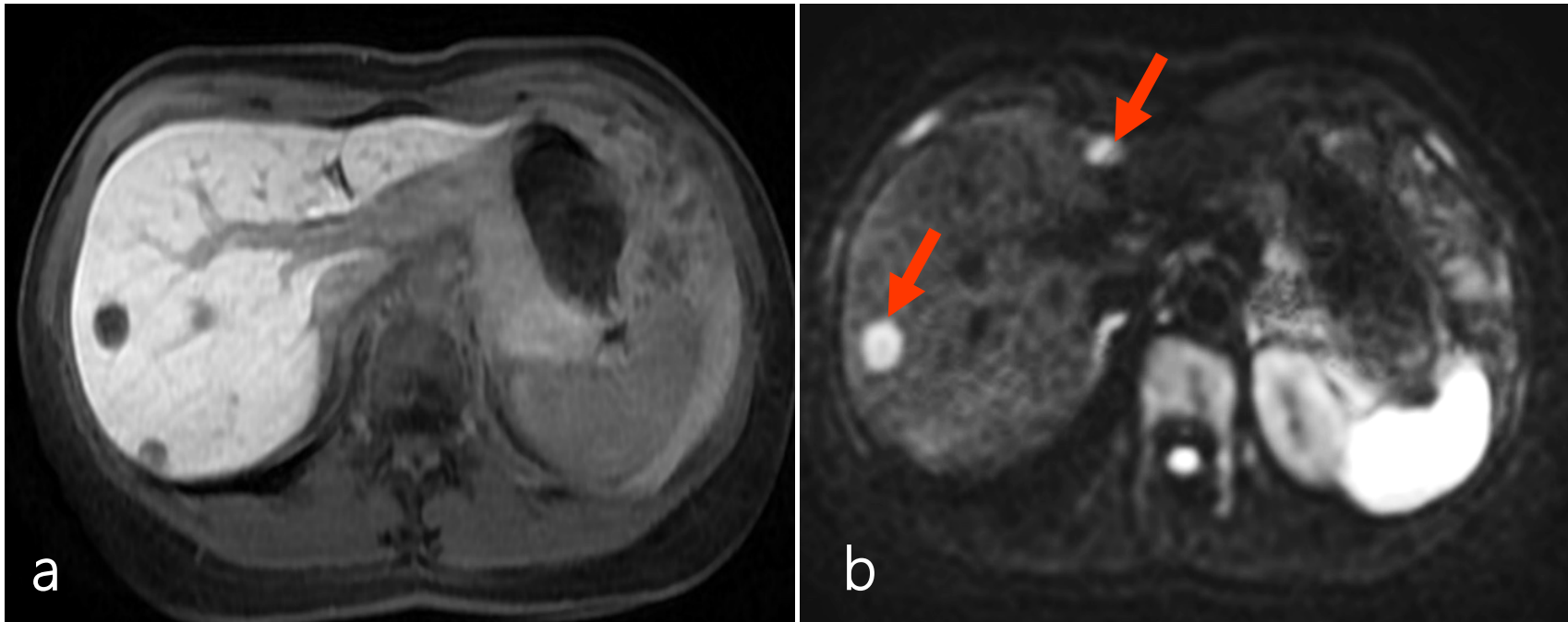


Fig. 39. Hepatobiliary phase contrast-enhanced T1- (a) and diffusion-weighted (b) MR images show small non-enhancing metastatic lesions with diffusion restriction (bright signal in b, arrows).

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Take-Home Messages



- Ultrasound (US) is usually the first-- line imaging modality for the liver. Because of its wide availability and since focal and diffuse parenchymal lesions are common, US has an important role in liver imaging.
- Contrast-enhanced multiphasic CT and MRI (with unenhanced, arterial, portal and late phase acquisitions) are essential for the detection and further characterisation of focal liver lesions. Due to their characteristic perfusion patterns cysts, haemangiomas, and many other focal liver lesions may often be detected and diagnosed reliably.
- MRI is the most accurate imaging modality for the evaluation of both diffuse and focal liver disease. Beyond perfusion imaging, dedicated MR sequences including diffusion-weighted imaging as well as hepato-specific contrast materials (based on hepatobiliary excretion) enable interrogation of liver tissue by many different methods during the same examination, thus leading to improved detection and characterisation of hepatic pathologies as compared to US and CT.
- US, CT and MRI are all used to estimate the size and volume of the liver and its segments, especially with the assistance of automatic segmentation techniques.
- Interventional radiological procedures are complementary to more invasive techniques in many instances. These include liver biopsy, biliary drainage and stent placement, TIPS, tumour ablation with thermal (radiofrequency, cryo- or laser-) ablation, as well as transarterial chemo- or radioembolisation.

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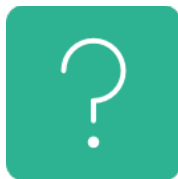
► **Test Your Knowledge**

Q1: Which of the following statements is correct ? (Several correct answers are possible)

1. The Couinaud classification divides the liver into 6 segments
2. Each liver segment is a functional unit
3. Liver segments can usually be resected separately
4. Liver segments cannot be identified with cross- sectional imaging



Test Your Knowledge



Q1: Which of the following statements is correct ? (Several correct answers are possible)

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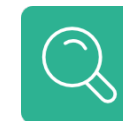
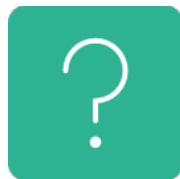
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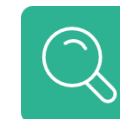
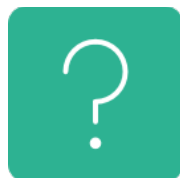
Q2: Which of the following statements regarding the hepatic blood supply is correct ?

The liver has

1. a single blood supply and a common venous drainage system
2. a dual blood supply and a common venous drainage system
3. a single blood supply and a dual venous drainage system
4. a dual blood supply and a dual venous drainage system



Test Your Knowledge



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Q3: Which of the following statements regarding diagnostic hepatic imaging is correct ?

(Multiple correct answers are possible)

1. US is usually indicated only after CT and MRI
2. Dynamic, contrast – enhanced (multiphasic) CT is well suited to evaluate disturbances of the hepatic blood perfusion
3. Compared with CT and contrast- enhanced US, MR imaging offers more options to detect and characterise liver nodules.
4. Semi-automated segmentation techniques can be used to estimate the volume of the liver or its individual segments using CT or MRI.

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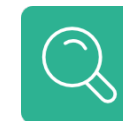
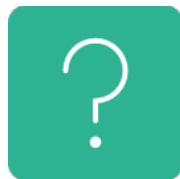
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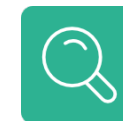
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Test Your Knowledge



Q4: Which of the following statements regarding invasive, image – guided procedures is correct ?
(multiple correct answers are possible)

1. Catheter angiography of the liver is mainly indicated for diagnostic purposes
2. Transjugular portosystemic shunt (TIPSS) placement can be used to treat steato-hepatitis
3. US-guided biopsy is usually done to distinguish hepatic cysts from haemangioma
4. Percutaneous ablative treatment under imaging guidance can be used for treatment of small solitary hepatocellular carcinoma.

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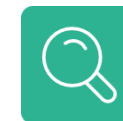
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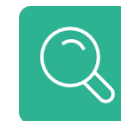
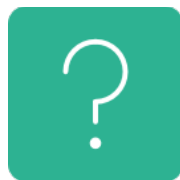
Q5: Which of the following statements is correct ?

The most frequent malignant hepatic nodules are due to

1. Hepatocellular carcinoma
2. Lymphoma
3. Haematogenous metastases
4. Cholangiocarcinoma



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Q6: Among the following, which is the most frequent hepatic benign lesion ?

1. Hepatocellular adenoma
2. Haemangioma
3. Focal nodular hyperplasia
4. Peliosis

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Test Your Knowledge



Q7: Among the following, which statement is correct ?

On dynamic (multiphasic) CT, hepatocellular carcinoma (HCC) is best visualised

1. in the arterial phase
2. in the portal venous phase
3. in the late (parenchymal) phase
4. on unenhanced images, due to a central calcification

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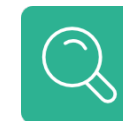
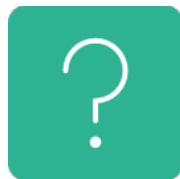
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Q8: Among the following, which statement is/are correct ? (Multiple correct answers are possible)

In the presence of cirrhosis, the appearance of the liver at US can include the following:

1. A fine, granular appearance of the parenchyma
2. Decreased organ size
3. Irregular liver contours
4. Enlarged caudate lobe caudate

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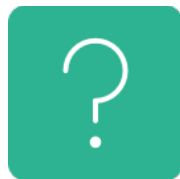
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Test Your Knowledge



Q9: Among the following, which statement is/are correct ? (Multiple correct answers are possible)

1. Liver steatosis can be detected in early stages by US
2. Focal sparing in a steatotic liver can mimic a tumour on US
3. MRI can be used to distinguish between focal steatosis and neoplastic nodules
4. Both CT and MRI can provide semiquantitative data on steatosis

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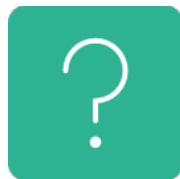
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Q10: Among the following, which statement regarding liver metastases is/are correct ? (Several correct answers possible)

1. On US, liver metastases are most often hyperechoic
2. On dynamic CT, liver metastases are usually best seen in the portal venous phase
3. MRI with hepatobiliary contrast materials improves the conspicuity of liver metastases on T1 weighted late-phase parenchymal images
4. Diffusion-weighted MRI, can be used to distinguish between liver metastases and benign liver nodules (based on ADC values)

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