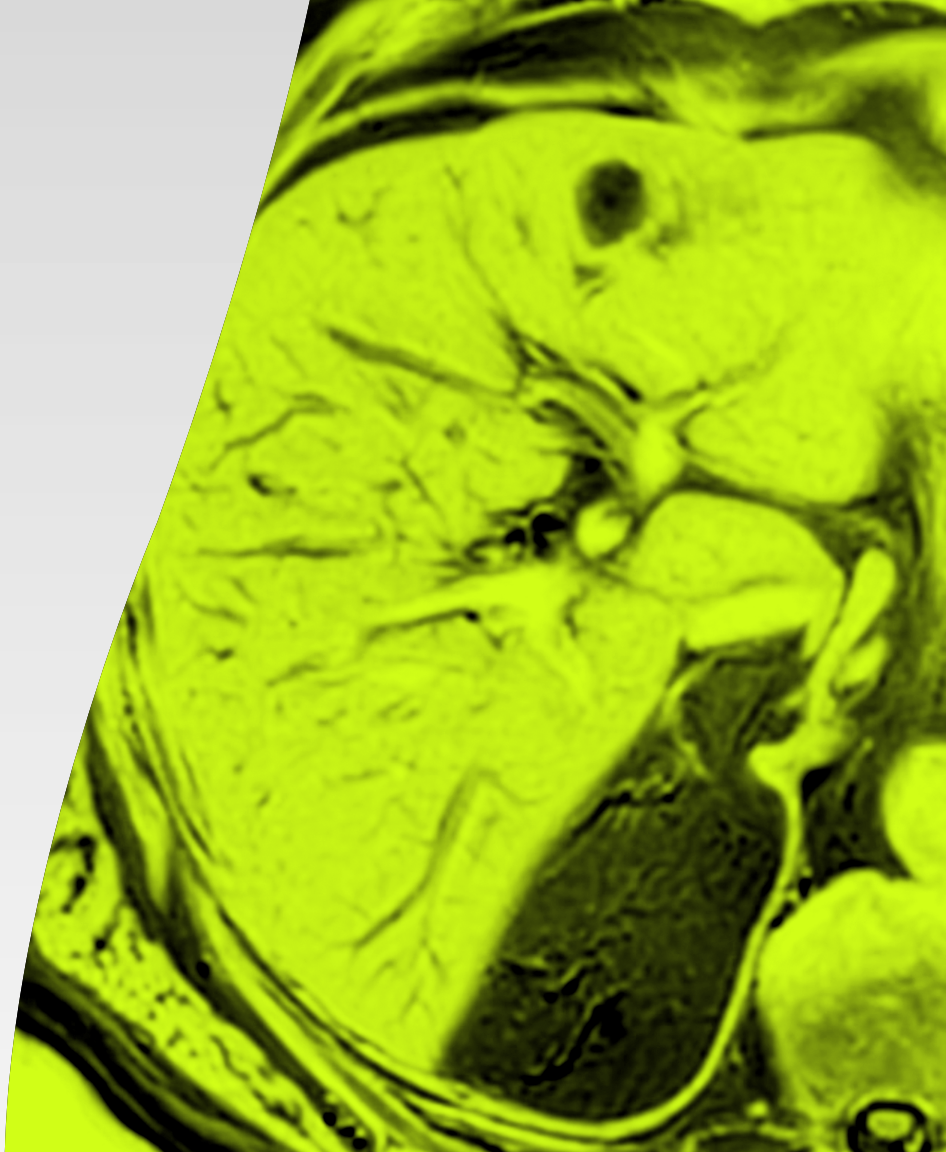
MODERN RADIOLOGY eBook

Liver Imaging



ESR EUROPEAN SOCIETY OF RADIOLOGY

Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the ***ESR eBook*** with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the ***ESR eBook*** was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to 'dig deeper'. As a result, *Modern Radiology* covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the ***ESR eBook*** across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an ***ESR eBook***, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this ***educational*** tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor

Liver Imaging

CHAPTER OUTLINE:

Copyright and Terms of Use

How to cite this work:

European Society of Radiology, András Palkó (2024)
ESR Modern Radiology eBook:

- **Liver Imaging. DOI 10.26044/esr-undergraduate-ebook-13**

Signage

 **CORE KNOWLEDGE**

 **ATTENTION**

 **HYPERLINKS**

 **FURTHER KNOWLEDGE**

 **COMPARE**

 **REFERENCES**

 **QUESTIONS**

Liver Imaging

CHAPTER OUTLINE:

MODERN RADIOLOGY eBook

Based on the ESR Curriculum for Radiological Education

Liver Imaging

AUTHORS

András Palkó

AFFILIATION

University of Szeged, Hungary

palkoand@gmail.com

CHAPTER OUTLINE:

<↑> HYPERLINK

Chapter Outline

Anatomy

- The Normal Liver
- Blood Supply
- Biliary Excretion
- Sinusoids
- Normal US-, CT- and MRI-Anatomy

Strengths, Weaknesses and Role of Imaging Modalities

- X-Ray Examinations
- Ultrasound
- Computed Tomography
- Magnetic Resonance Imaging
- Catheter Angiography and Image-Guided Interventions

Main Indications to Liver Imaging by Pathology

- Parenchymal Diseases
  - Hepatomegaly
  - Steatosis
  - Cirrhosis
- Focal Liver Disease
  - Cystic Lesions
  - Benign Solid Lesions
  - Primary Malignant Lesions
  - Secondary Malignant Lesions

Take-Home Messages

References

Test Your Knowledge

CHAPTER OUTLINE:

Anatomy

CHAPTER OUTLINE:

/ 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).

<!> ATTENTION

For liver anatomy as seen at imaging, please also see the eBook chapters on Bile Ducts & Computed Tomography!

<!> ATTENTION

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**).

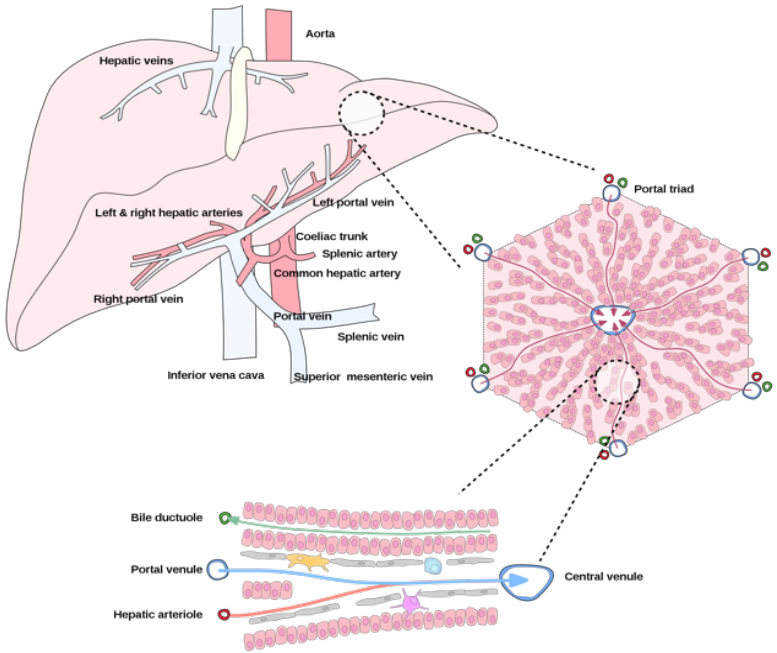


FIGURE 1

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

CHAPTER OUTLINE:

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.

>=< FURTHER KNOWLEDGE

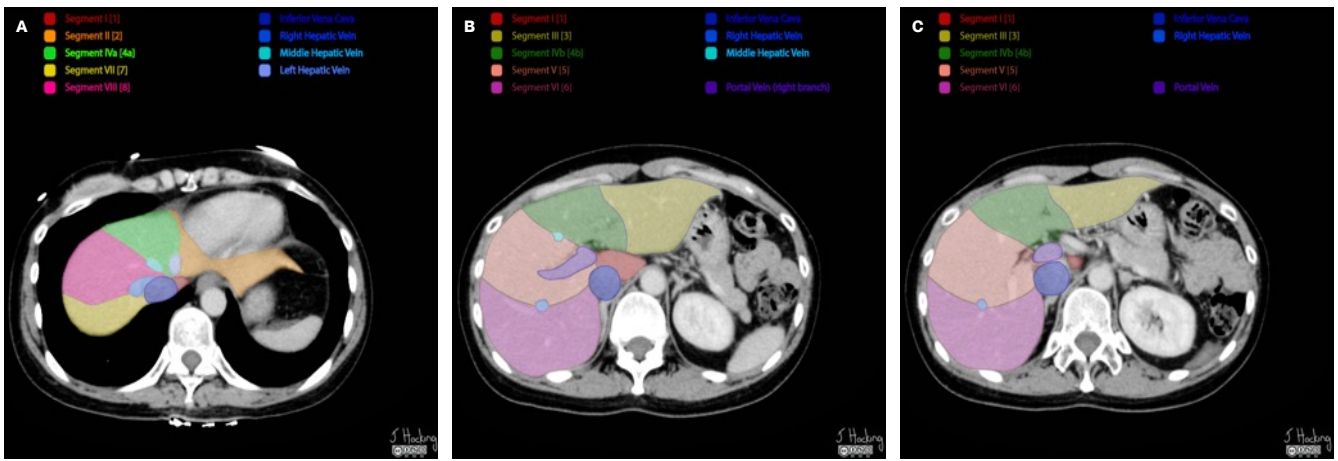


FIGURE 2

Liver segments as seen on three axial CT images (**A**, **B** and **C**).
Case courtesy of Jeffrey Hocking, Radiopaedia.org, rID: 45972

CHAPTER OUTLINE:

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.

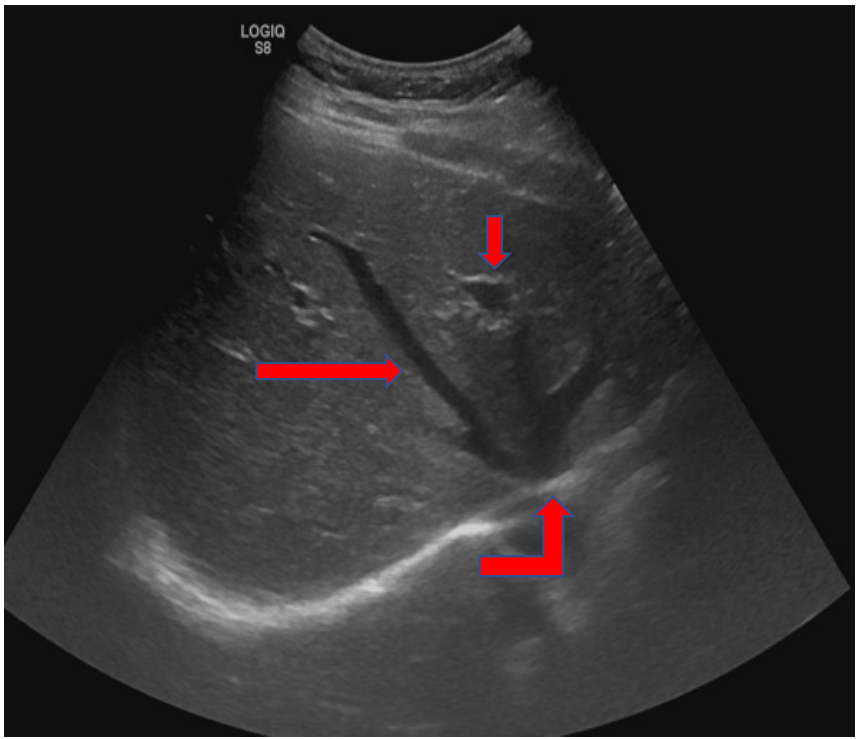


FIGURE 3

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 (**upwards arrow with tip rightwards**).

CHAPTER OUTLINE:

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.

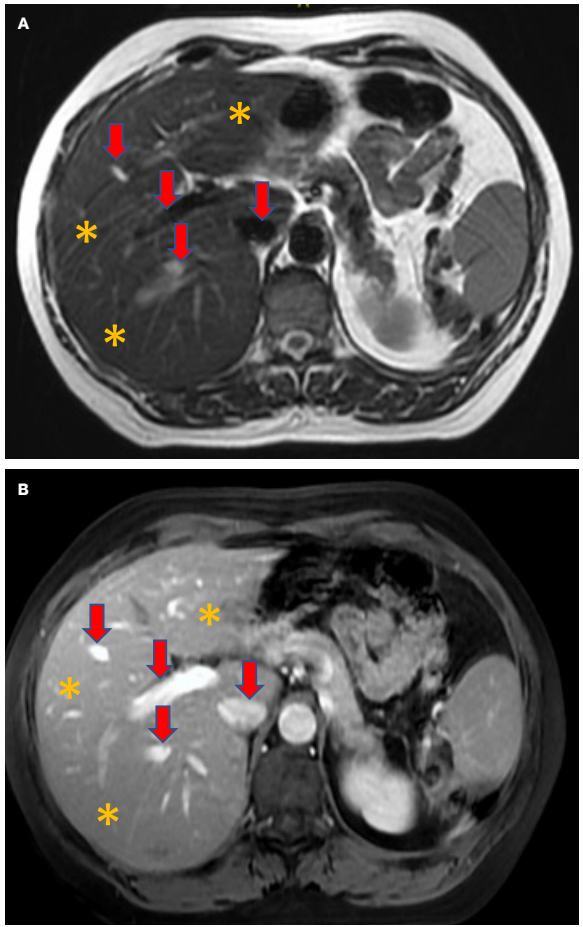


FIGURE 4

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**).

Liver Imaging

CHAPTER OUTLINE:

/ 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

<!> ATTENTION

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

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.

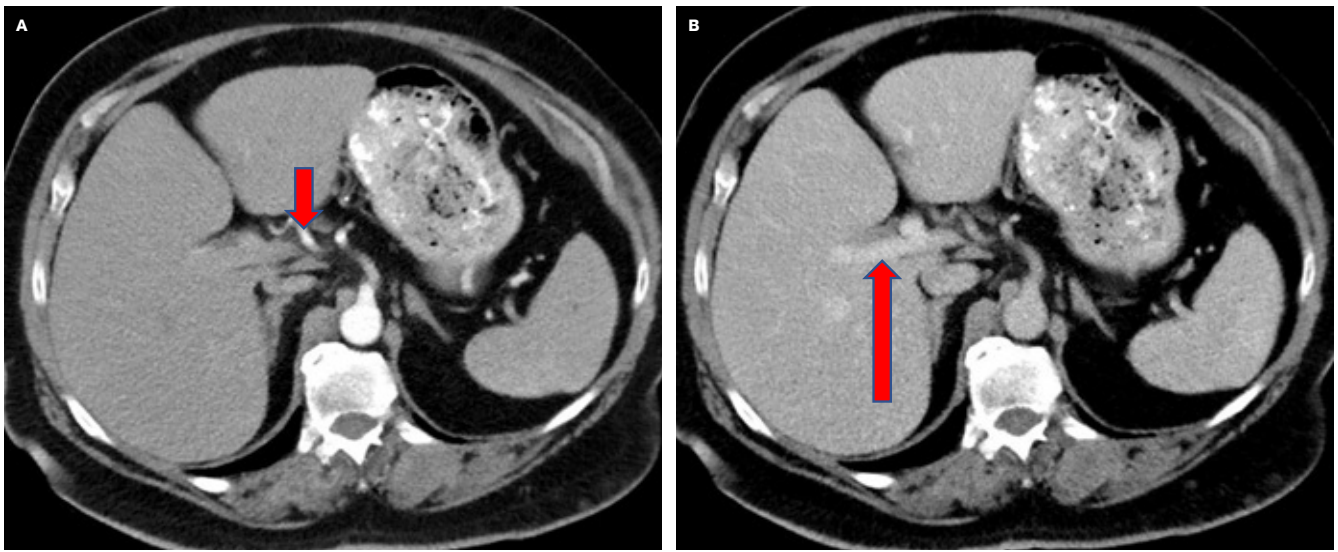


FIGURE 5

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

CHAPTER OUTLINE:

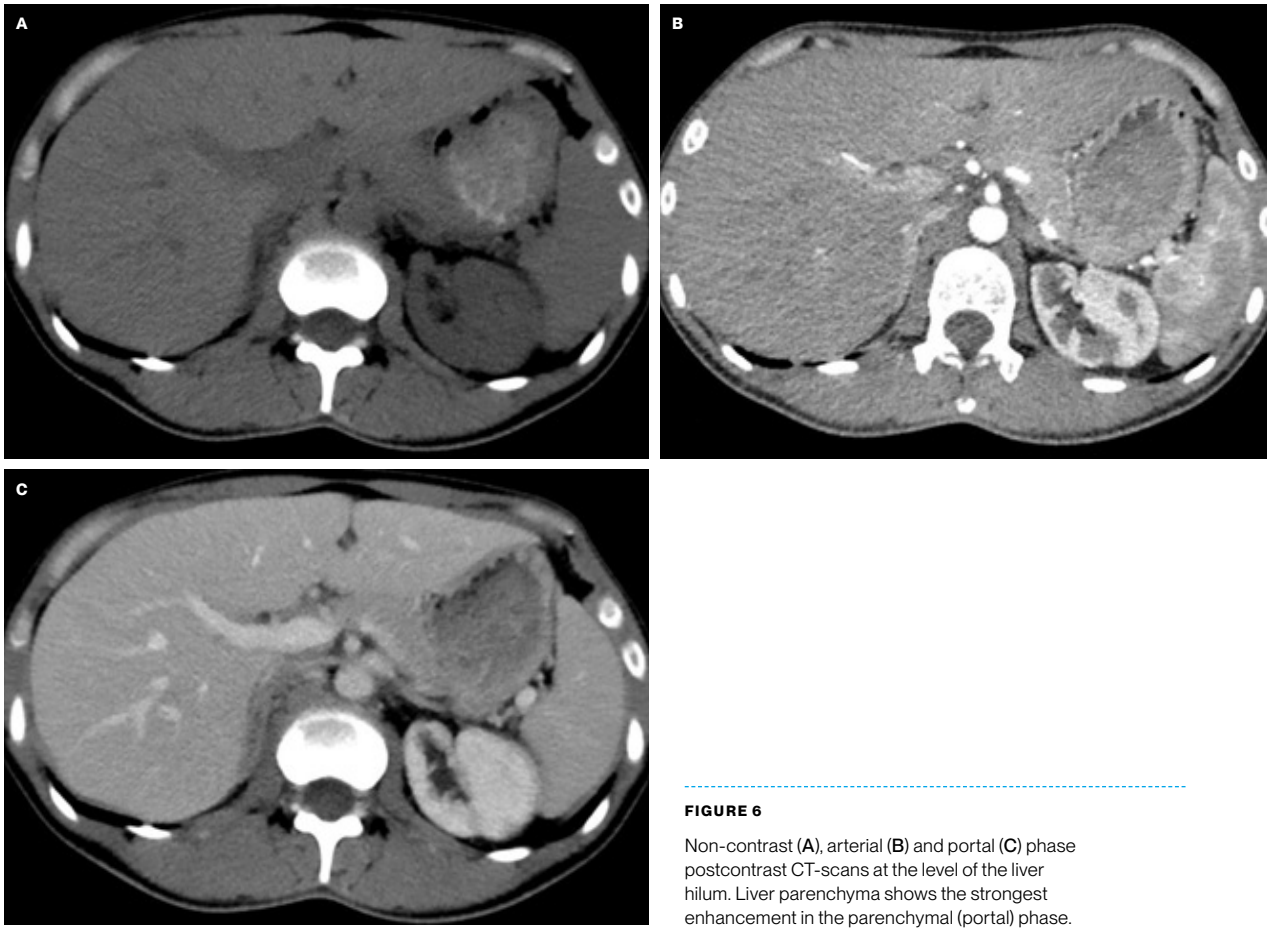


FIGURE 6

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.

Liver Imaging

CHAPTER OUTLINE:

/ Biliary Excretion

<!> ATTENTION

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 (**hepatobiliary 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.

<∞> REFERENCE

Inchingolo R et al, Eur Radiol 2014, DOI 10.1007/s00330-014-3500-7

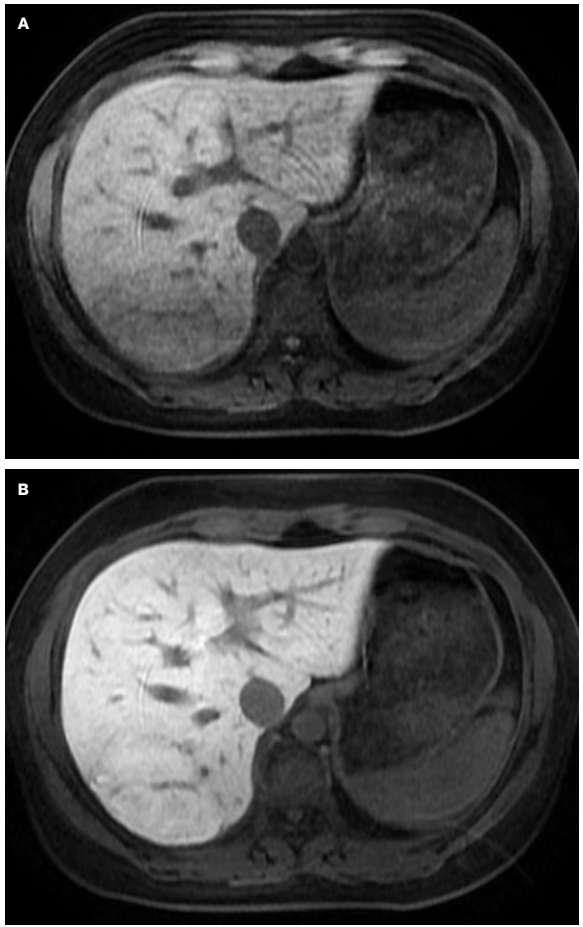


FIGURE 7

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 eBook chapter on Contrast Media!

/ Liver Imaging

CHAPTER OUTLINE:

/ Sinusoids

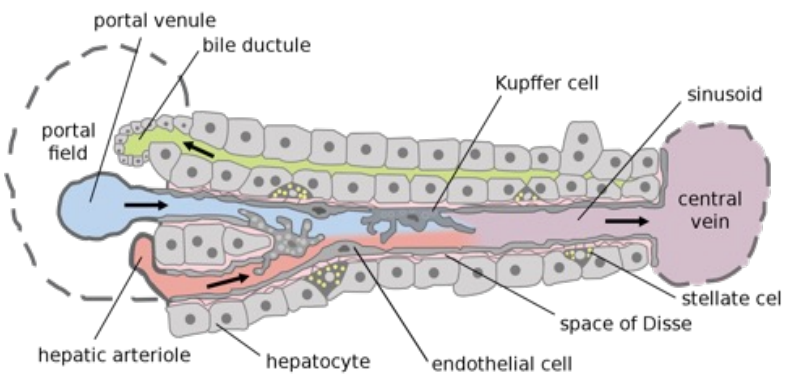
Special liver capillaries called sinusoids (common end-branches of the portal venous and the hepatic arterial circulation) serve for mixing the oxygen-rich hepatic arterial blood with the nutrient-rich portal vein blood.

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 no enhancement is seen.

FIGURE 8

Schematic illustration of the liver sinusoid (see explanation in the text). Figure based on the research article by Frevert U, Engelmann S, Zougbédé 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



CHAPTER OUTLINE:

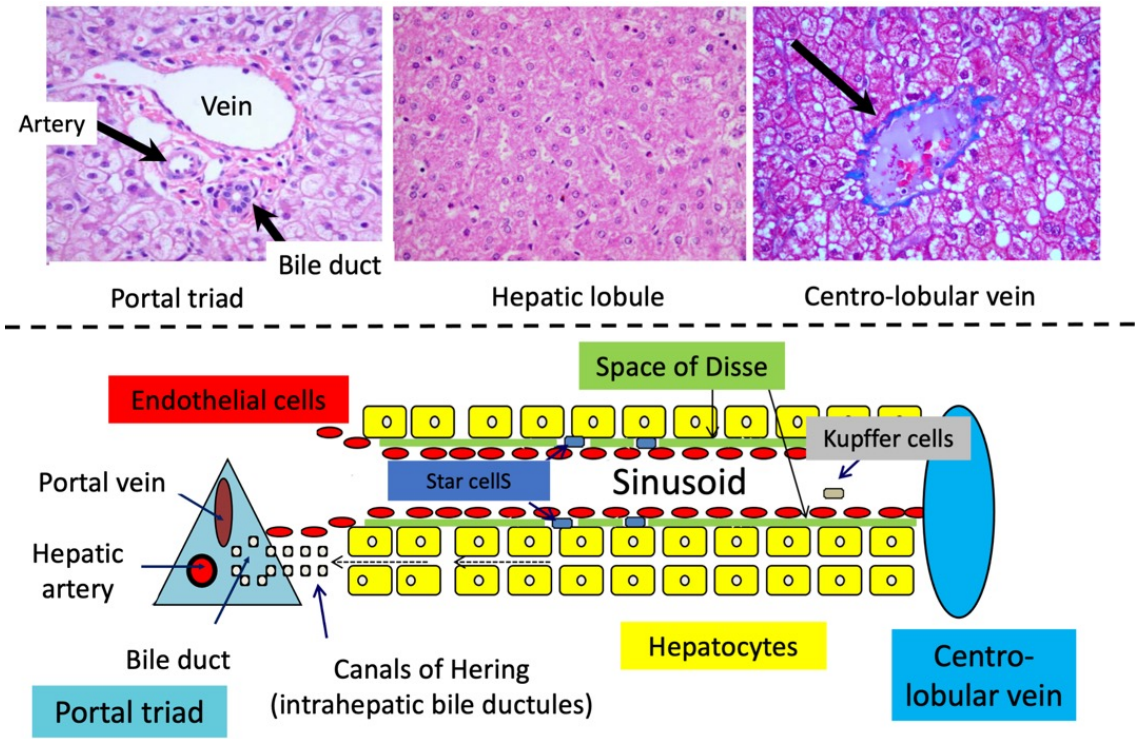


FIGURE 9

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.

CHAPTER OUTLINE:

Strengths, Weaknesses and Role of Imaging Modalities

CHAPTER OUTLINE:

/ X-Ray Examinations

<!> ATTENTION

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.

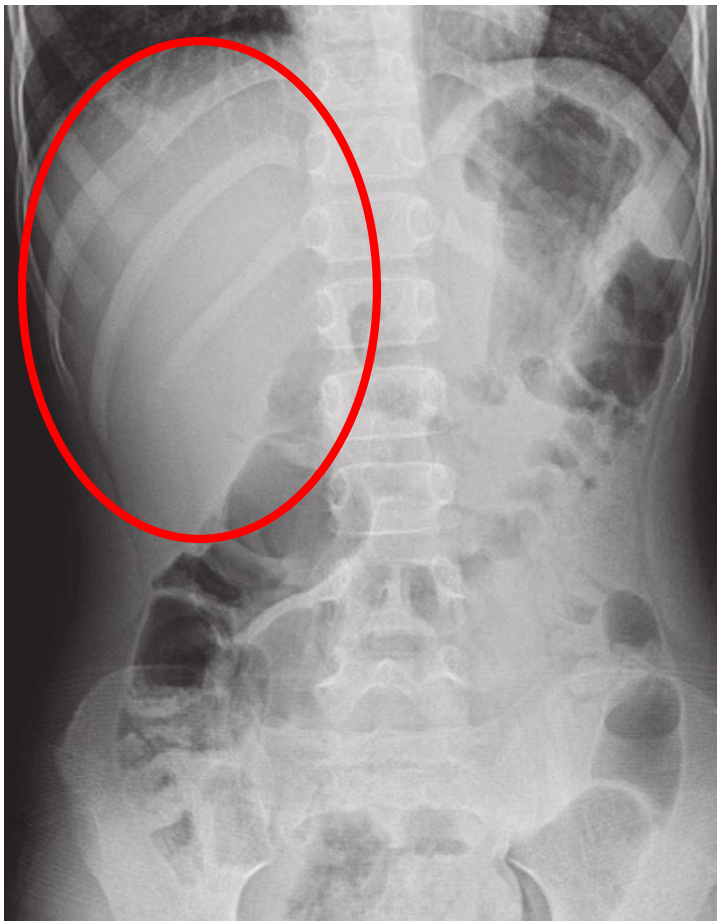


FIGURE 10

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

CHAPTER OUTLINE:

/ Ultrasound

<!> ATTENTION

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).

<!> ATTENTION

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.

<∞> REFERENCES

Aparna Srinivasa Babu et al, RadioGraphics 2016; 36:1987–2006
Burrowes DP et al, RadioGraphics 2017; 37:1388–1400

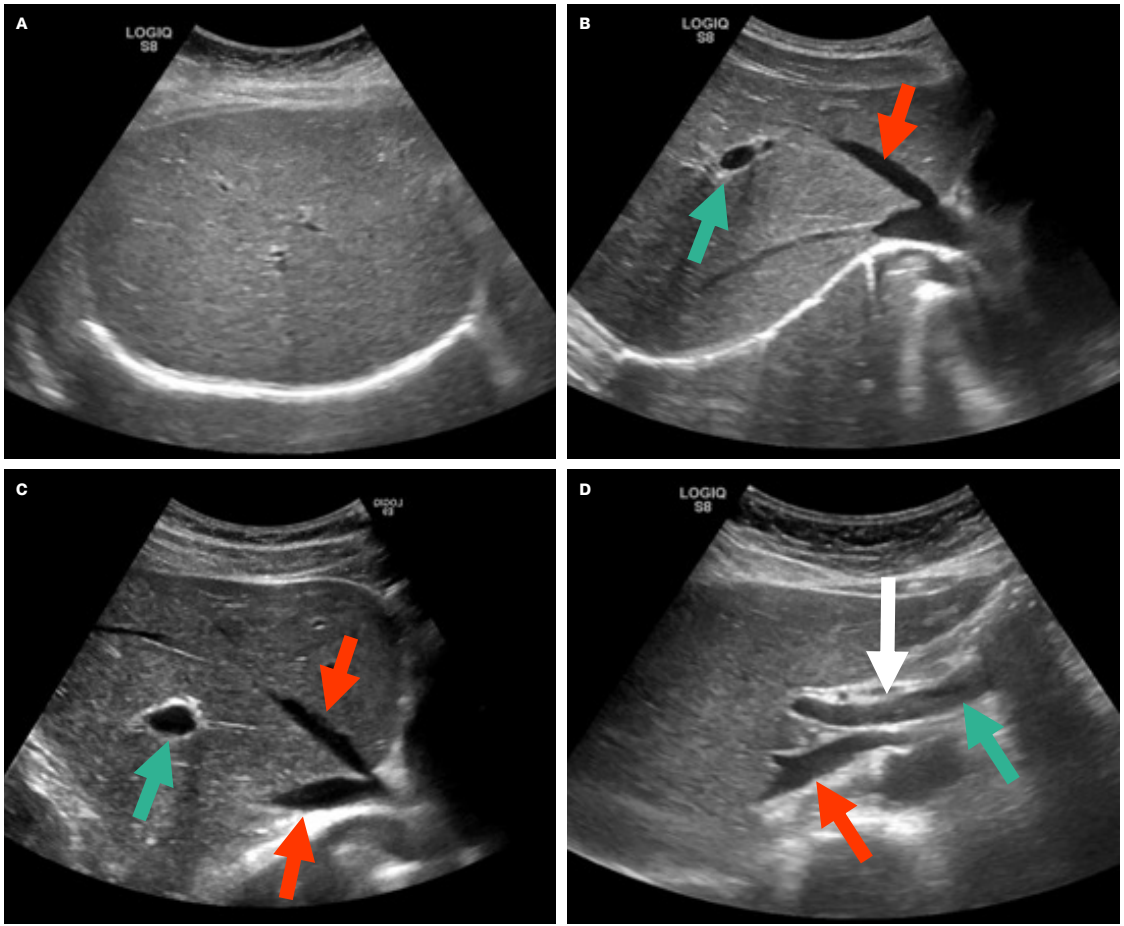


FIGURE 11

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.

Liver Imaging

CHAPTER OUTLINE:

/ 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**).

<!> ATTENTION

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.

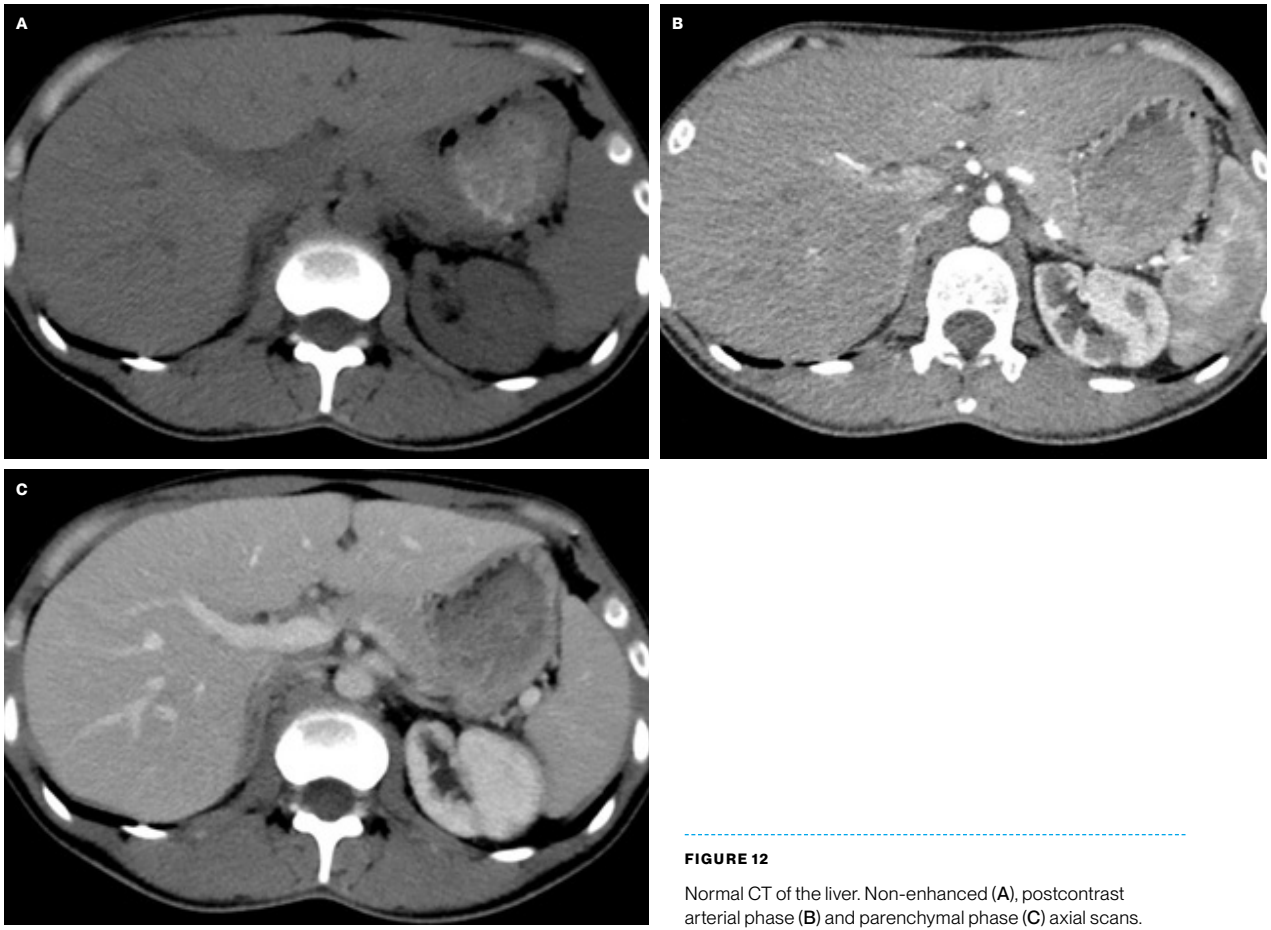


FIGURE 12

Normal CT of the liver. Non-enhanced (**A**), postcontrast arterial phase (**B**) and parenchymal phase (**C**) axial scans.

Liver Imaging

CHAPTER OUTLINE:

/ 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.

<!> ATTENTION

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.

CHAPTER OUTLINE:

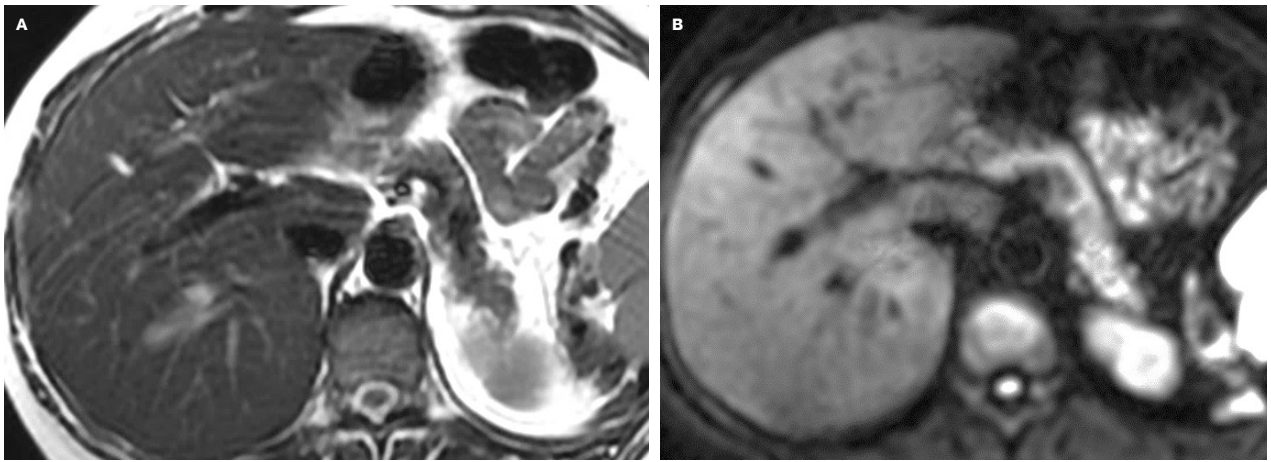


FIGURE 13

Normal MRI of the liver with T2-weighted (**A**) and diffusion-weighted (**B**) sequences.

Liver Imaging

CHAPTER OUTLINE:

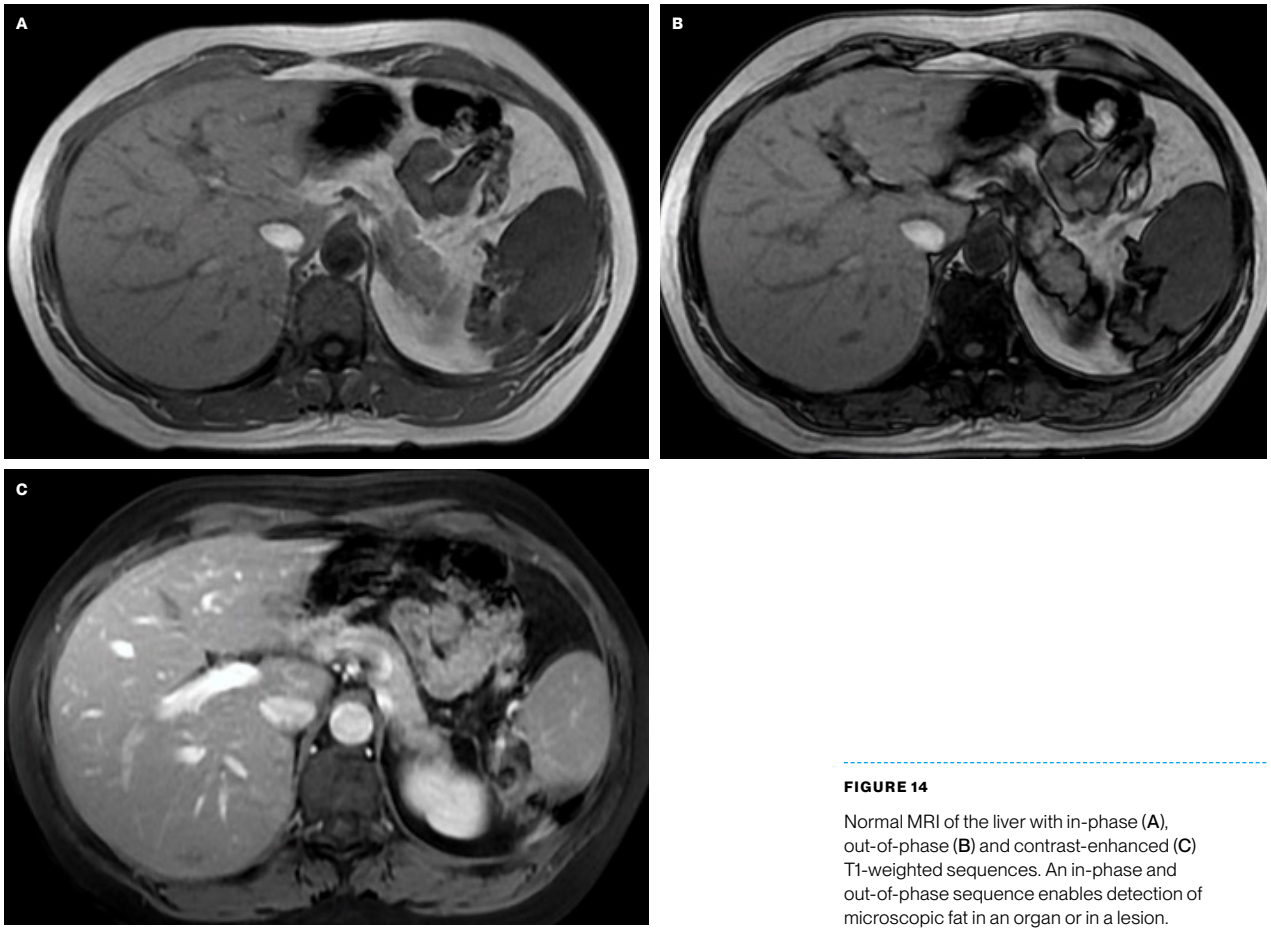


FIGURE 14

Normal MRI 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.

Liver Imaging

CHAPTER OUTLINE:

/ Interventional Procedures

<!> ATTENTION

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 to surgery for the therapy of smaller solitary lesions.

<∞> REFERENCE

Kim Ys et al, RadioGraphics 2011; 31:377–390

/ Interventional Procedures

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

<!> ATTENTION

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 embolisation 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)

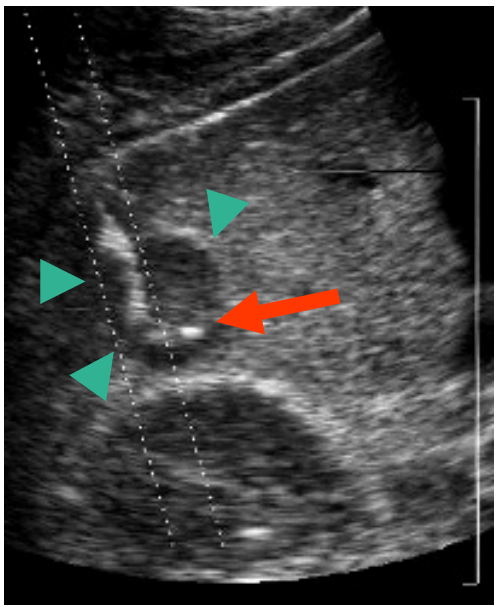


FIGURE 15

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

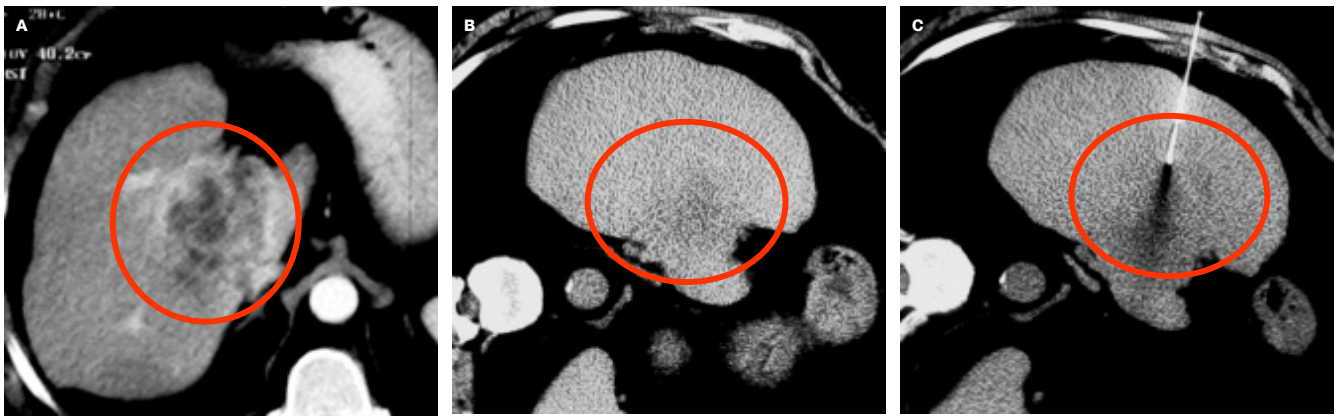


FIGURE 16

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.

Liver Imaging

CHAPTER OUTLINE:

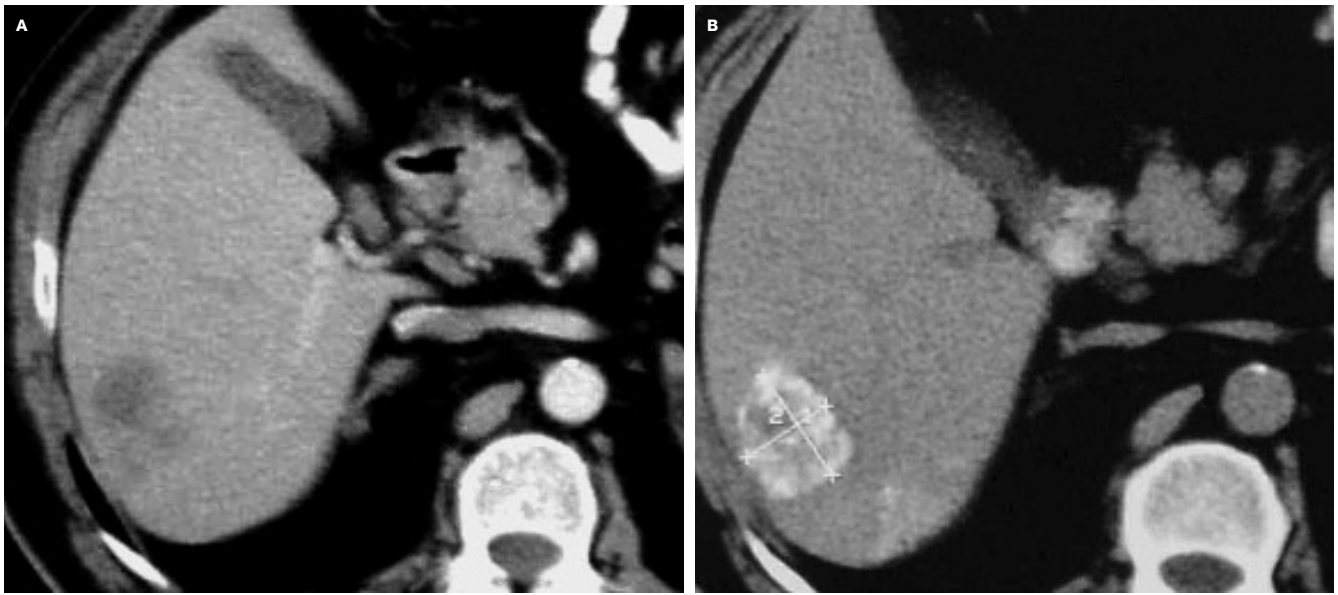


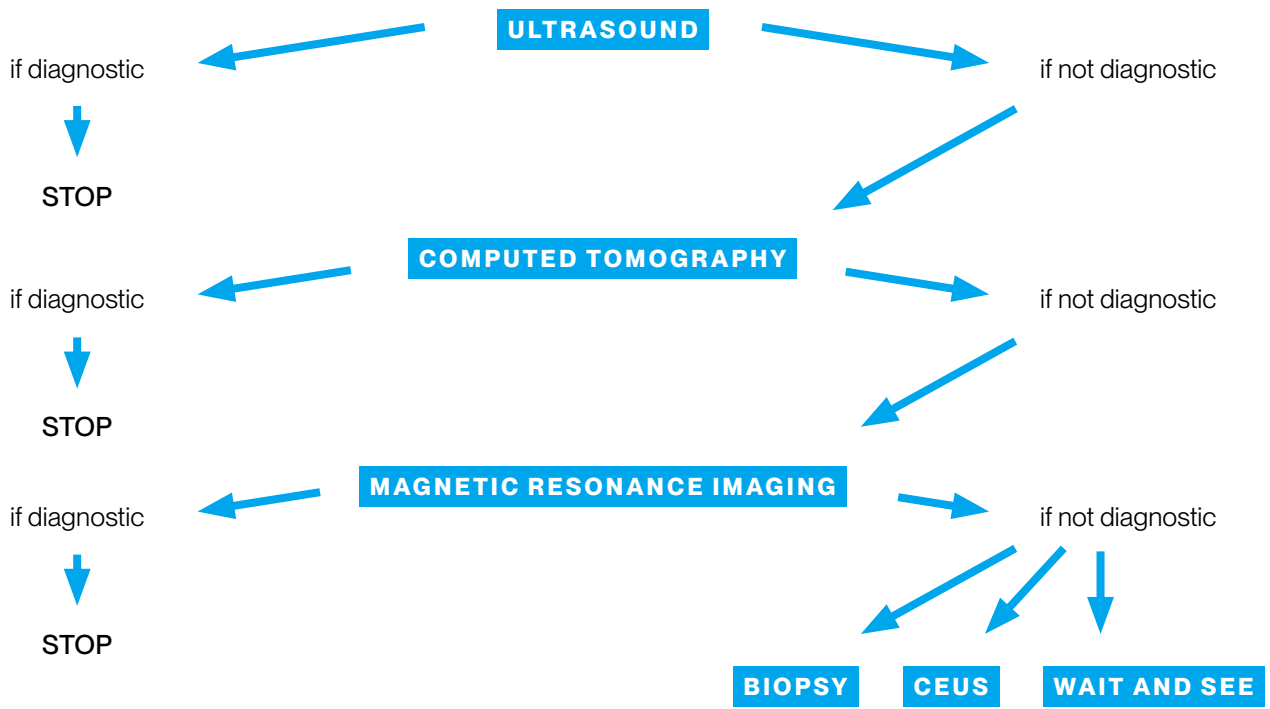
FIGURE 17

CT-scan taken before (**A**) and after (**B**) transarterial chemoembolisation (TACE) of a liver mass: the hyperdense embolising material (Lipiodol UltraFluid) accumulates in the small vessels of the lesion (**B**).

Liver Imaging

CHAPTER OUTLINE:

/ Simplified Diagnostic Algorithm (Focal Lesion Detection / Characterisation)



Main Indications to Liver Imaging by Pathology

CHAPTER OUTLINE:

/ 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.

<!> ATTENTION

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.

<∞> REFERENCES

Roloff am et al, Abdom Radiol (2016) 41:1293–1299
Gotra A, Insights Imaging (2017) 8:377–392

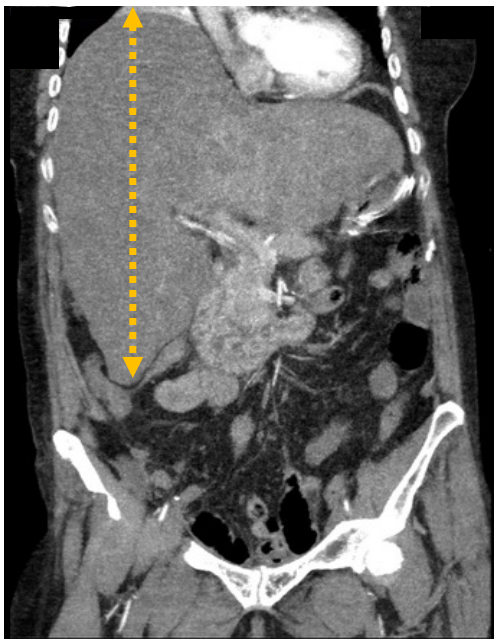


FIGURE 18

Coronal CT reformatted image shows a significantly enlarged liver.

CHAPTER OUTLINE:

/ 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.

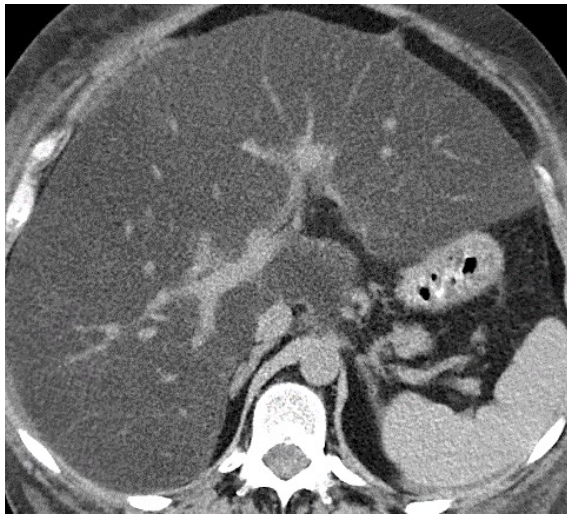


FIGURE 19

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.

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 eBook 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**).

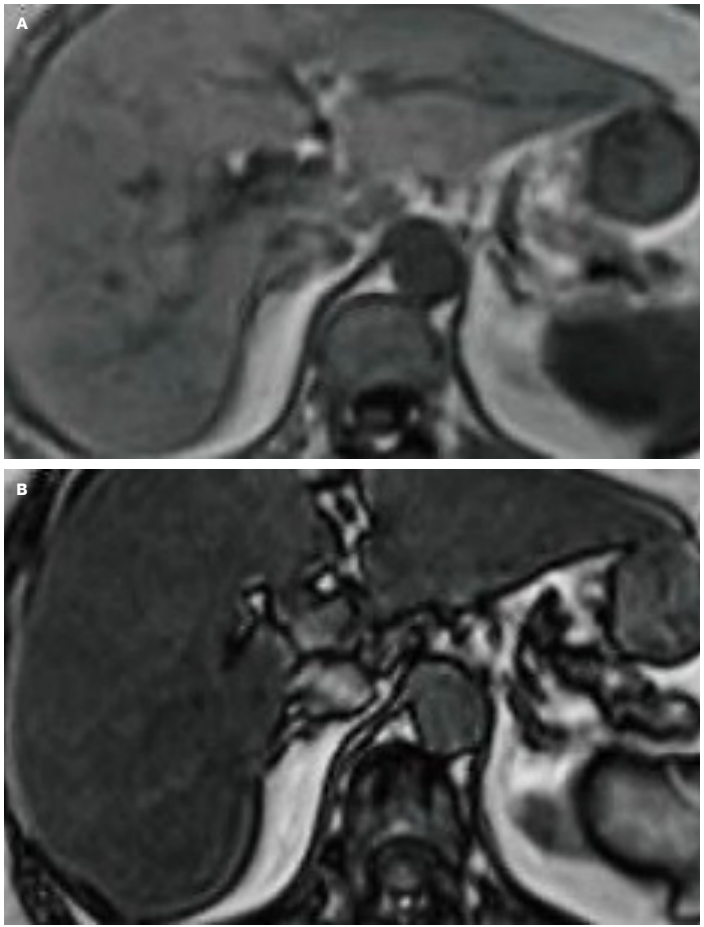


FIGURE 20

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.

Liver Imaging

CHAPTER OUTLINE:

/ 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).

<!> ATTENTION

CT and especially MRI play an 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 transjugular intrahepatic portosystemic shunt.

CHAPTER OUTLINE:

Liver Imaging

CHAPTER OUTLINE:

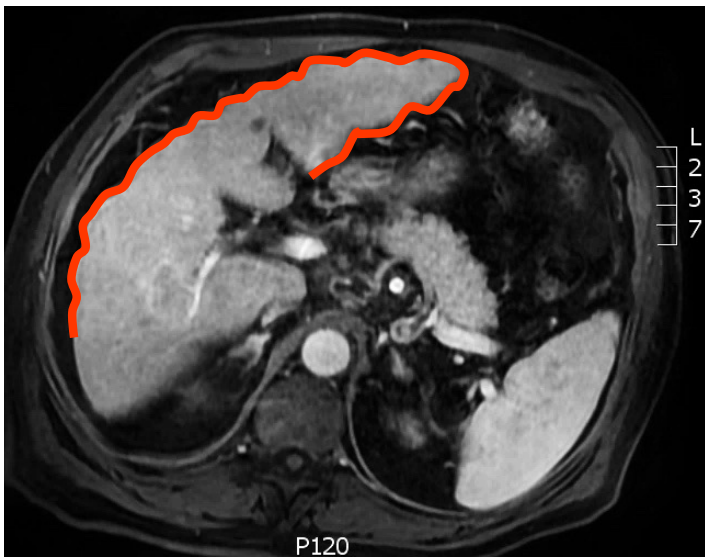


FIGURE 21

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

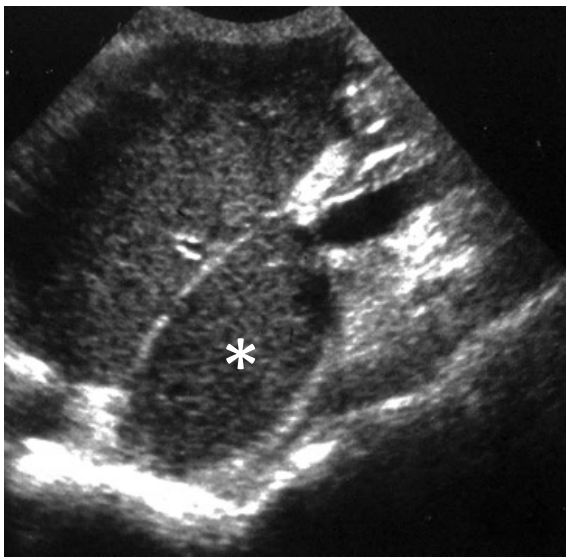


FIGURE 22

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

/ Focal Liver Disease

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

- Hepatocellular Carcinoma (HCC)
- Hepatoblastoma
- Fibrolamellar HCC
- Cholangiocellular Carcinoma (CC)
- Bile duct cystadenocarcinoma
- Angiosarcoma
- Malignant epitheloid haemangioendothelioma
- Undifferentiated sarcoma
- Rhabdomyosarcoma
- Kaposi sarcoma
- Metastasis
- Lymphoma

/ 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 surrounding 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.

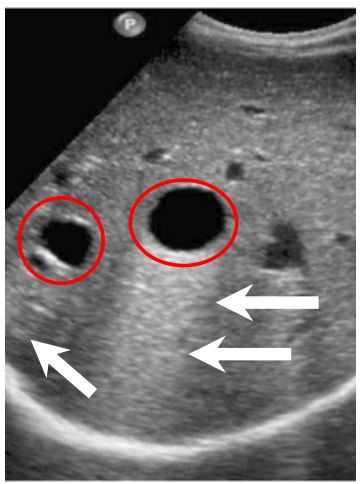


FIGURE 23

Ultrasound image demonstrates two simple cysts with typical posterior "echo enhancement" (**arrows**).

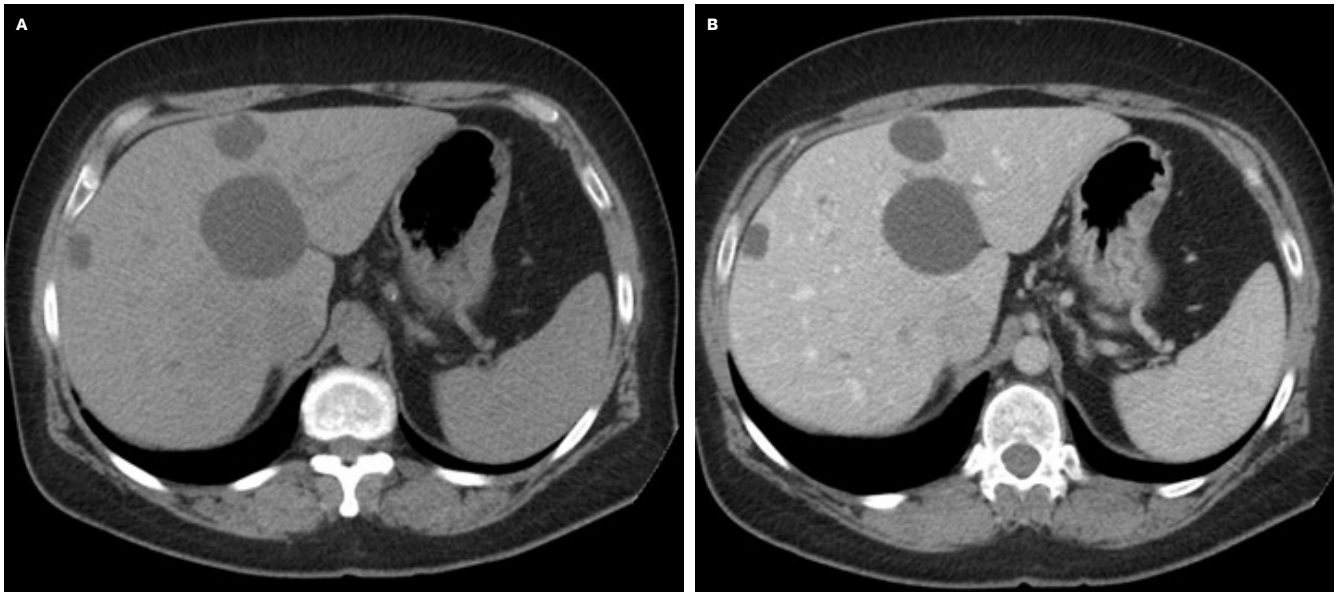


FIGURE 24

Non-enhanced (**A**) and contrast-enhanced (**B**) CT scans demonstrate multiple benign cysts (water density, well-defined, no enhancement).

Liver Imaging

CHAPTER OUTLINE:

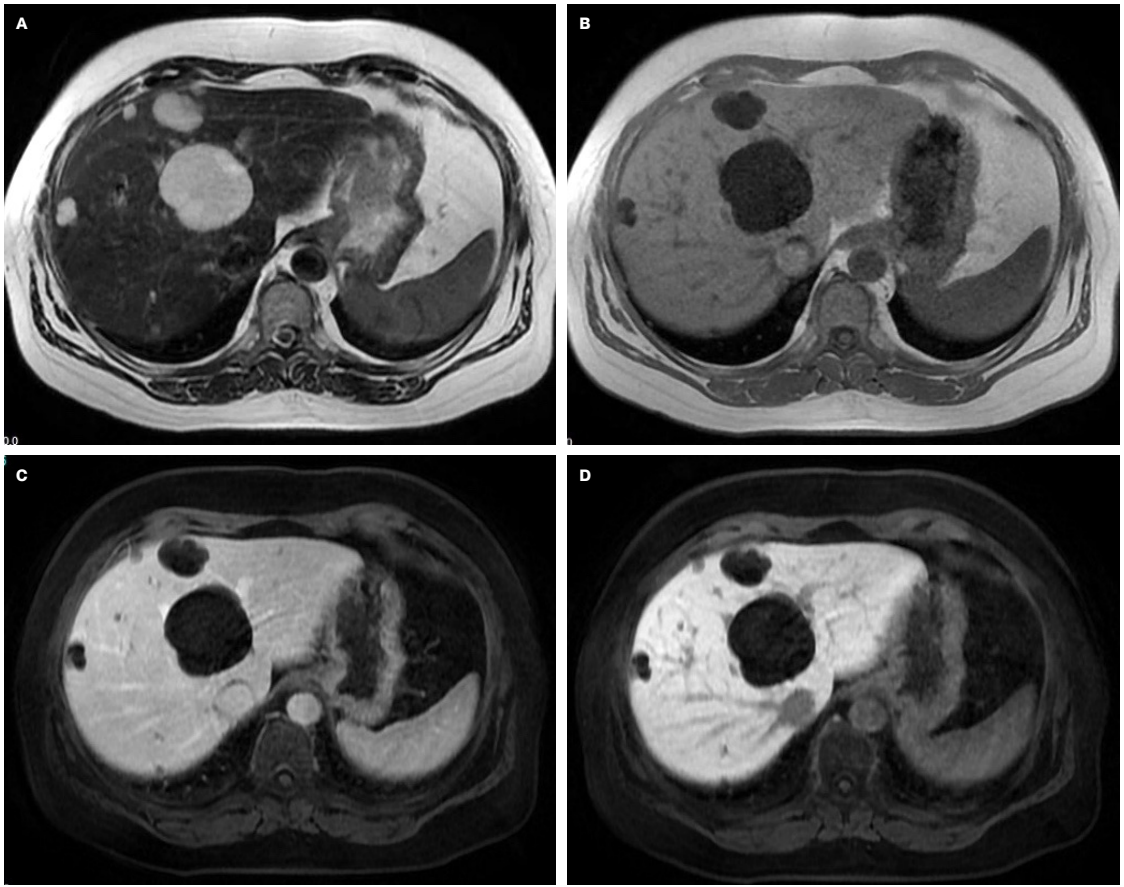


FIGURE 25

Same patient as in Fig. 24. T2-weighted (**A**), T1-weighted (**B**), postcontrast parenchymal phase (**C**) and hepatobiliary phase (**D**) 3D GRE fat-supressed MRI shows multiple benign cysts (water signal intensity, no enhancement))

Liver Imaging

CHAPTER OUTLINE:

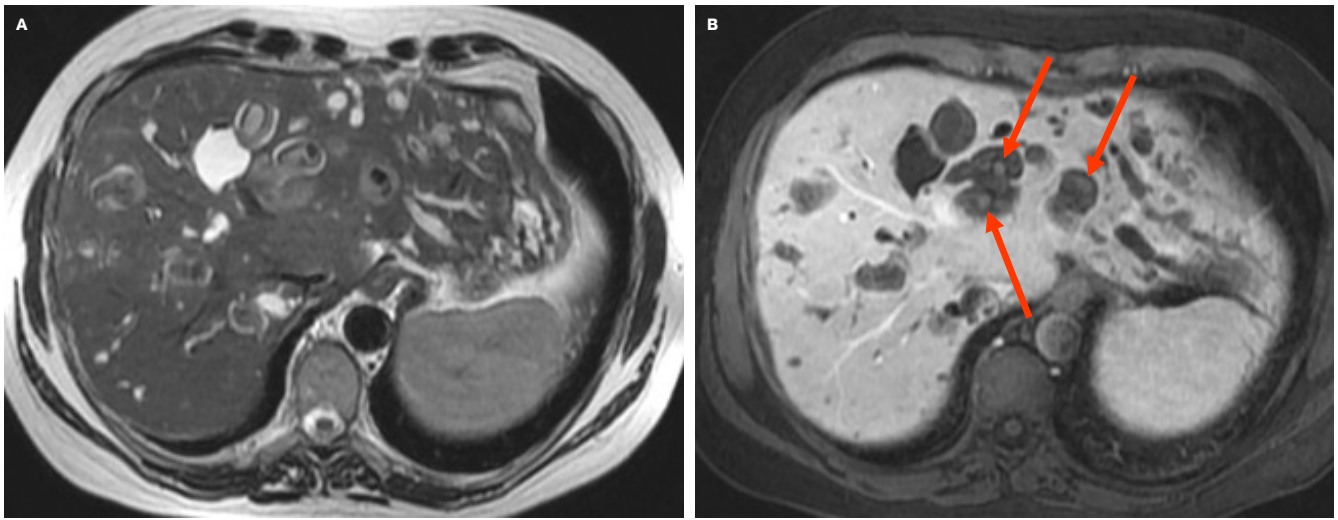


FIGURE 26

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.

Liver Imaging

CHAPTER OUTLINE:

- **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.

<!> ATTENTION

- **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.

CHAPTER OUTLINE:

/ 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.

<!> ATTENTION

/ 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
- / adenomas

/ Solid Benign – Haemangioma

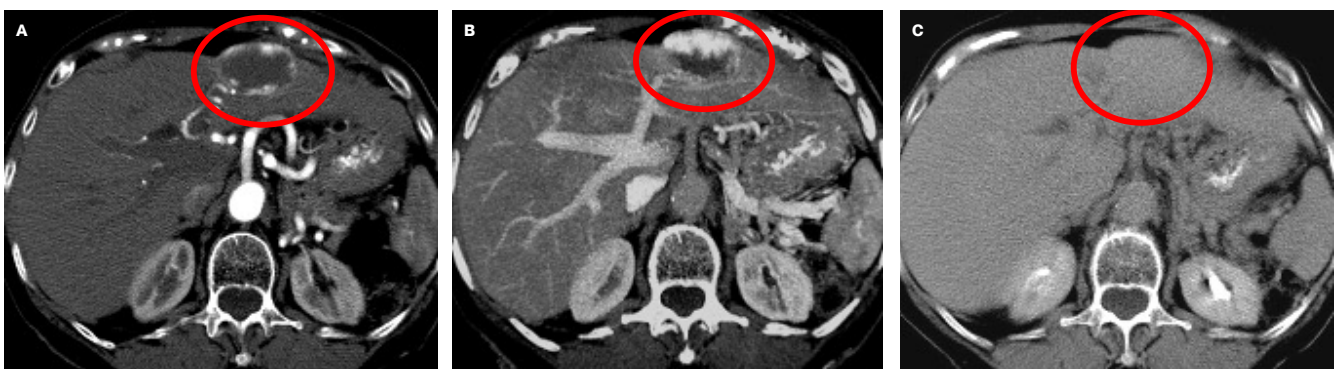
/ The most frequent solid focal lesion of the liver is **haemangioma** (**Figs. 27 and 28**). At US, it typically appears as a well-defined, rounded hyperechoic area. **Cavernous haemangioma** demonstrates a characteristic enhancement pattern at US, CT and MRI: the initial peripheral, irregular contrast 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.

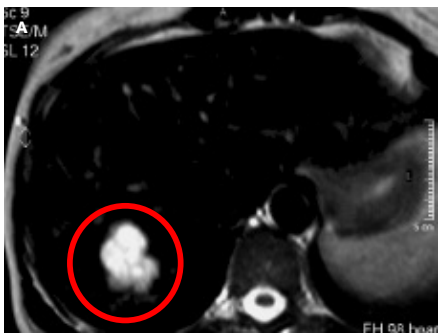
Capillary haemangioma is typically small and shows fast and intensive central enhancement.

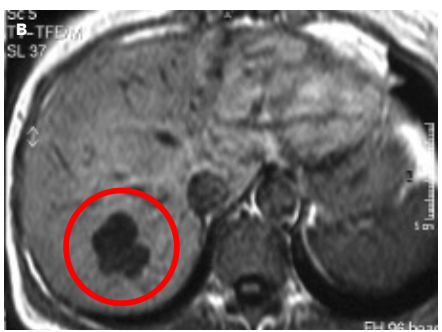
>=< FURTHER KNOWLEDGE

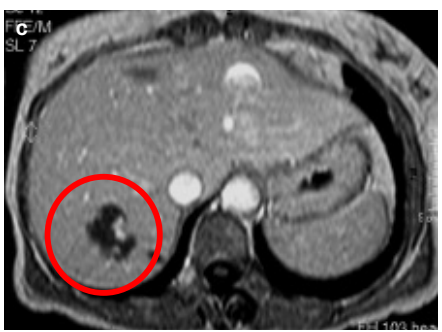
FIGURE 27

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.









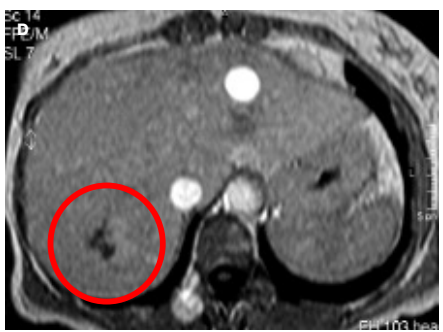


FIGURE 28

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).

Liver Imaging

CHAPTER OUTLINE:

/ 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.

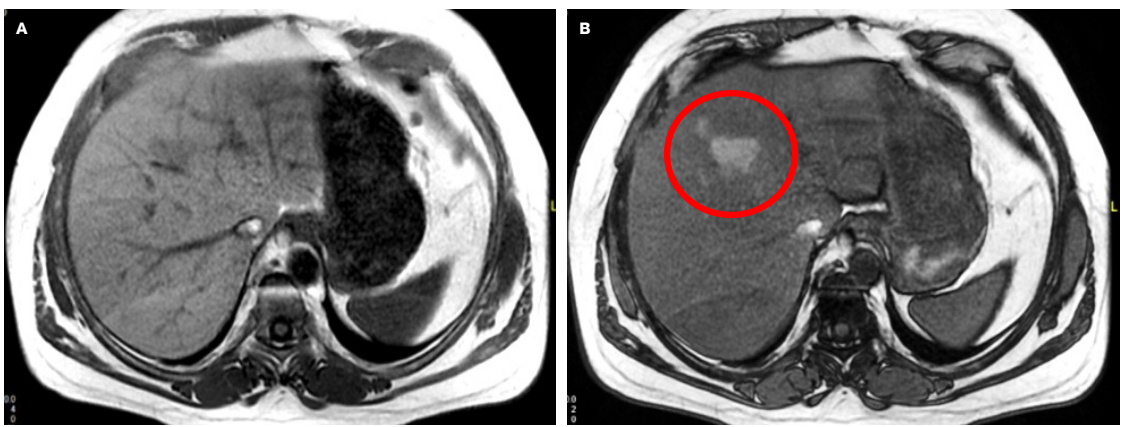


FIGURE 29

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.

Liver Imaging

CHAPTER OUTLINE:

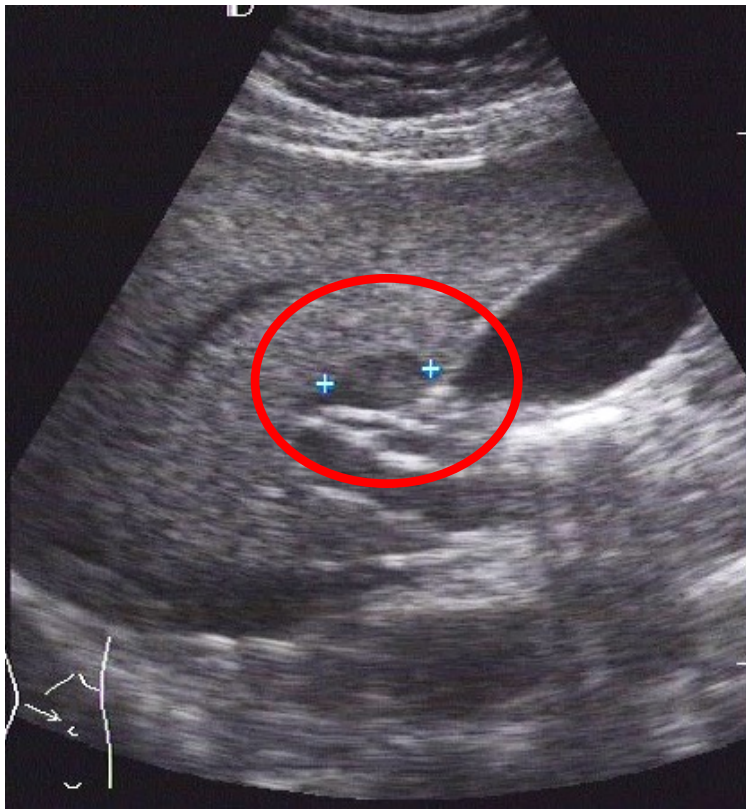


FIGURE 30

US image shows small hypoechoic area within the homogeneously hyperreflective liver, consistent with focal sparing within diffuse steatosis.

/ 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 to 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.

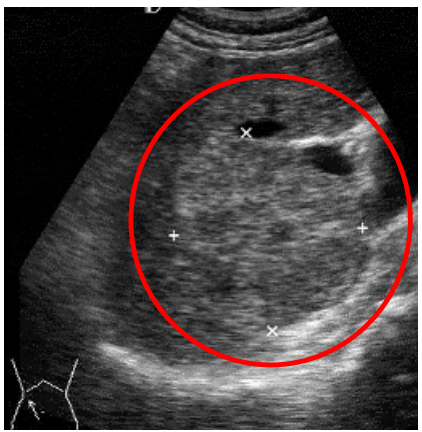


FIGURE 31

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

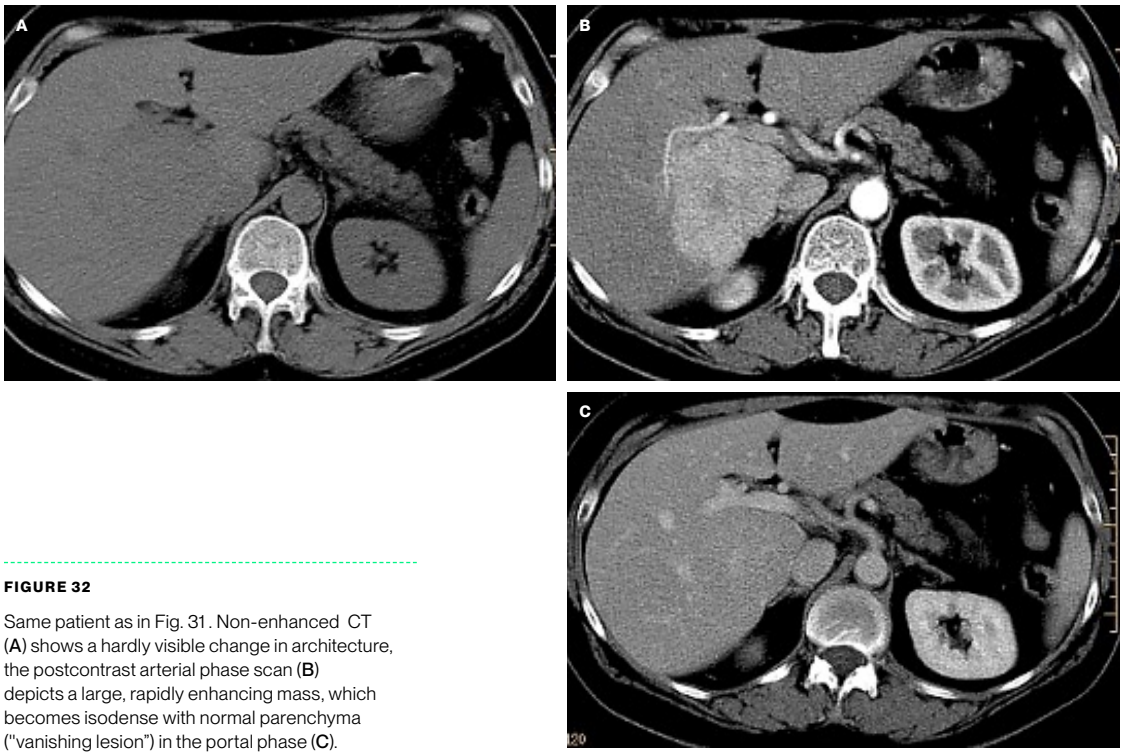


FIGURE 32

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**).

CHAPTER OUTLINE:

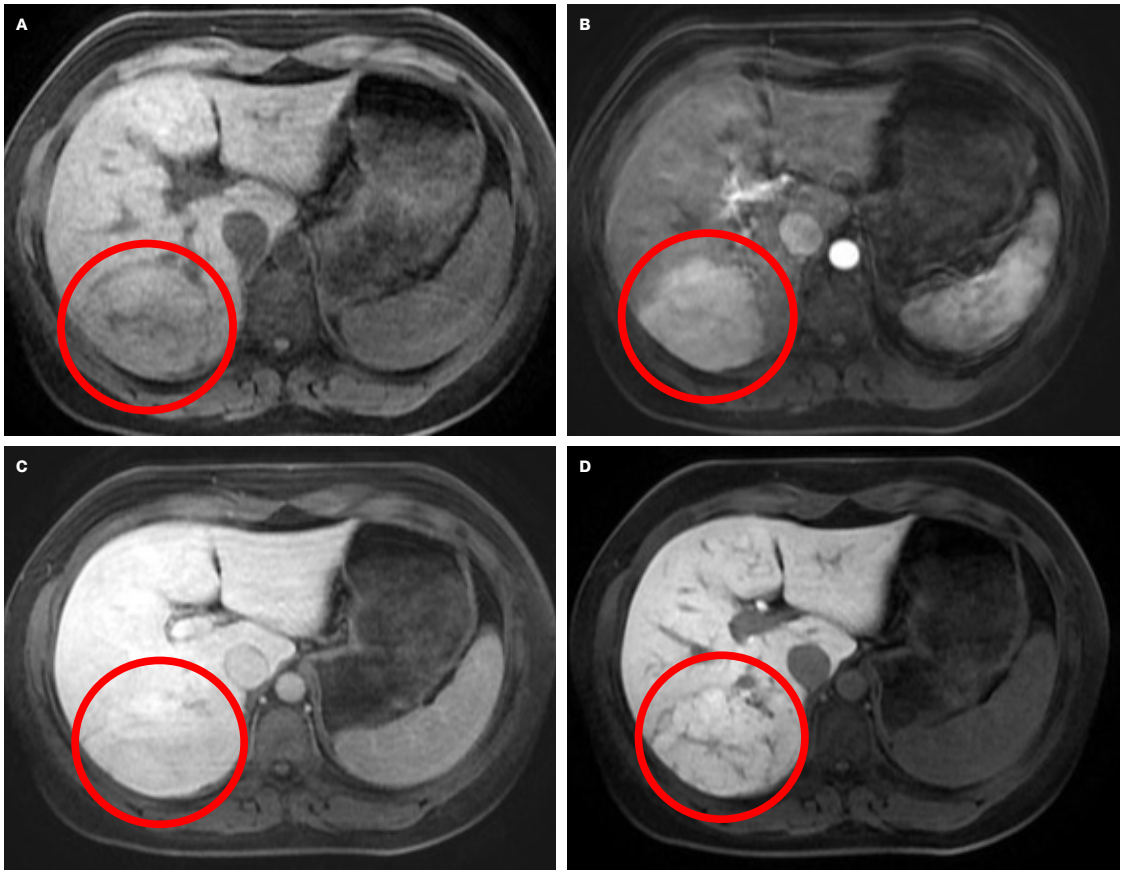


FIGURE 33

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.

CHAPTER OUTLINE:

/ 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.

<!> ATTENTION **>▪< FURTHER KNOWLEDGE**

/ 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.

<!> ATTENTION

>▪< FURTHER KNOWLEDGE

/ 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.

<∞> REFERENCE

Fraum TJ et al, Radiology 2018; 286:158–172

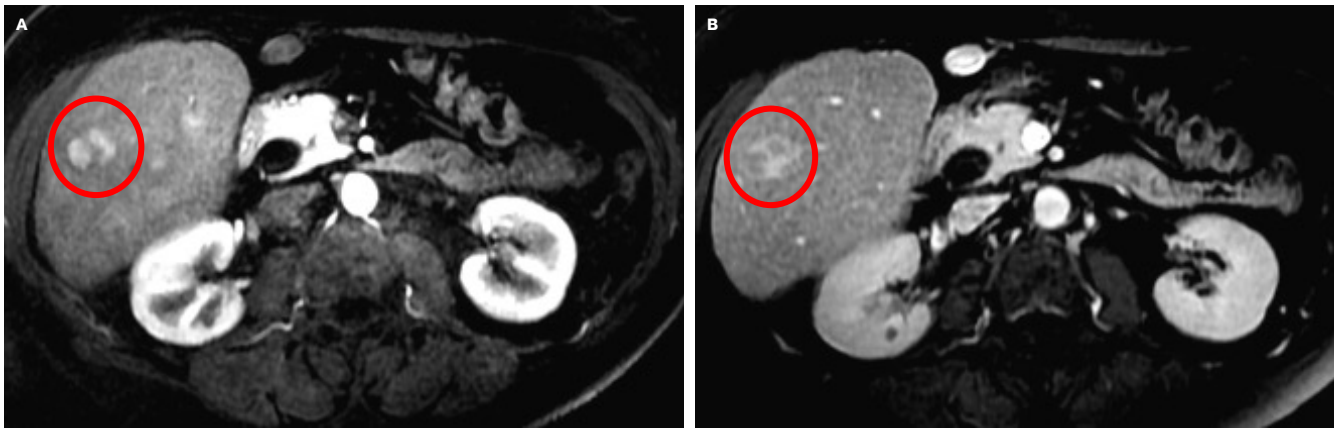


FIGURE 34

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).

CHAPTER OUTLINE:

/ Primary Malignant - HCC

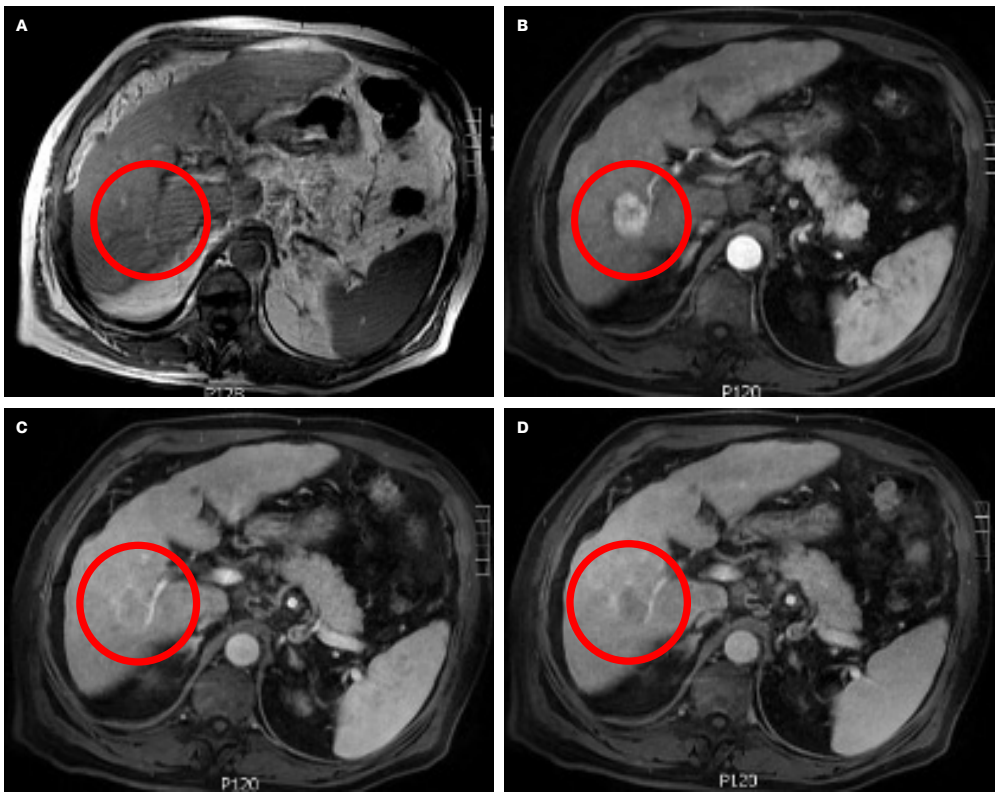


FIGURE 35

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).

/ 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**).

/ Liver manifestations of **malignant lymphomas** are rare. Lymphomas are typically large, sometimes confluent, hypoechoic, hypodense lesions with minimal enhancement.

>=< FURTHER KNOWLEDGE

<!> ATTENTION

/ 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).

/ Secondary Malignant – Metastasis

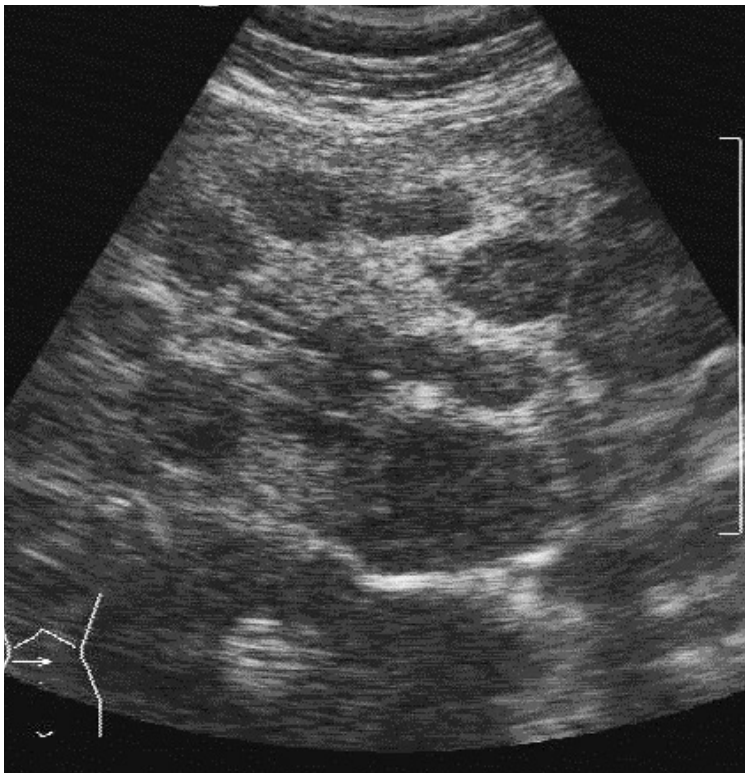


FIGURE 36

Ultrasound examination reveals multiple well-defined round-shaped/oval hypoechoic metastatic lesions in the liver.

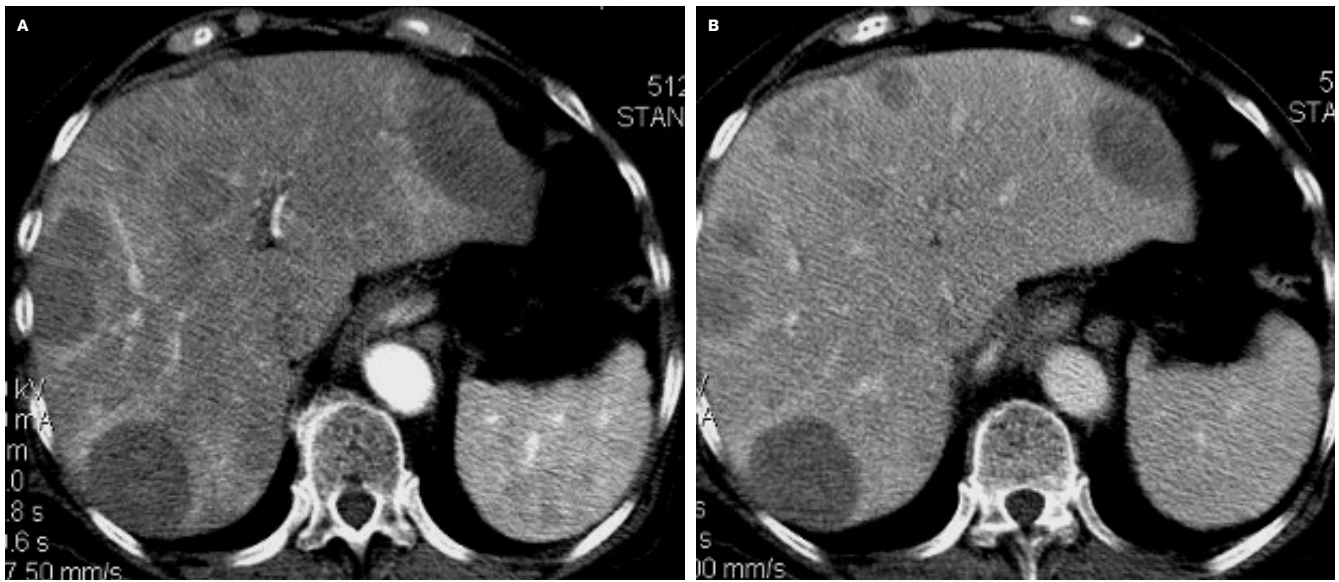


FIGURE 37

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.

CHAPTER OUTLINE:

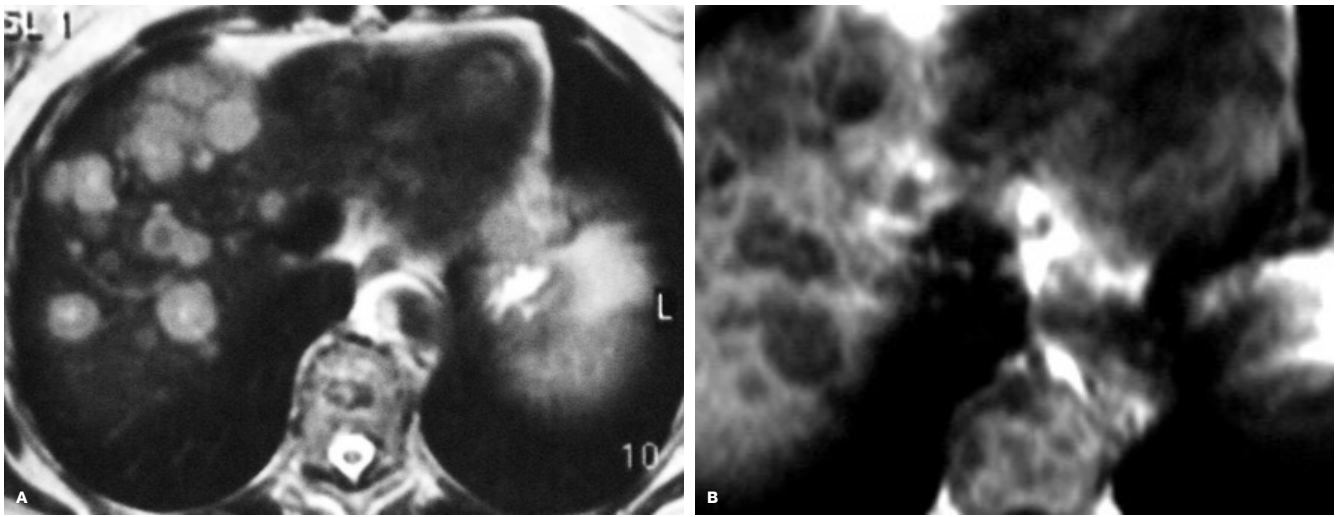


FIGURE 38

T2-weighted (**A**) and T1-weighted (**B**) MRI scans show multiple round-shaped metastases in the liver.

Liver Imaging

CHAPTER OUTLINE:

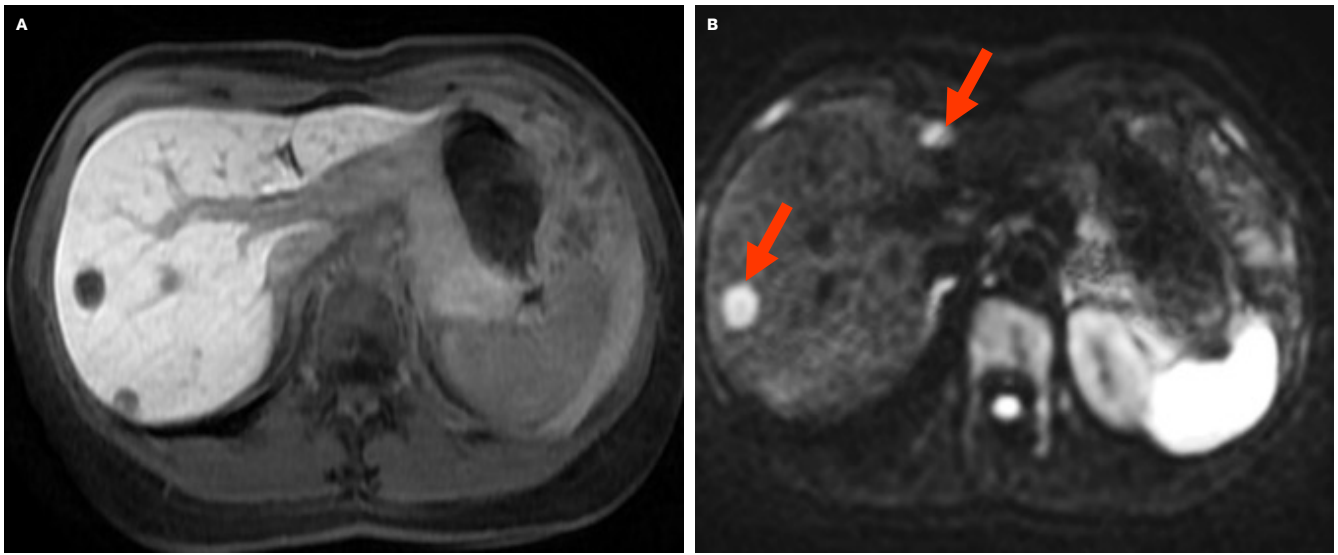


FIGURE 39

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**).

Liver Imaging

CHAPTER OUTLINE:

/ 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 technoiques 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.

/ References

1. Koh Dow-Mu, Ba-Ssalamah A, Brancatelli G et al: Consensus report from the 9th International Forum for Liver Magnetic Resonance Imaging: applications of gadoxetic acid-enhanced imaging. European Radiology 31, 5615–5628 (2021)

2. Ner E, Bali MA, Ba-Ssalamah A et al, ESGAR consensus statement on liver MR imaging and clinical use of liver-specific contrast agents. European Radiology volume 26, pages921–931 (2016)

3. Paulatto, L., Dioguardi Burgio, M., Sartoris, R. et al. Colorectal liver metastases: radiopathological correlation. Insights Imaging 11, 99 (2020).

4. Chenin, M., Paisant, A., Lebigot, J. et al. Cystic liver lesions: a pictorial review. Insights Imaging 13, 116 (2022).

5. Karaosmanoglu, A.D., Uysal, A., Karcaaltincaba, M. et al. Non-neoplastic hepatopancreatobiliary lesions simulating malignancy: can we differentiate?. Insights Imaging 11, 21 (2020).

6. Tan, G.X.V., Miranda, R. & Sutherland, T. Causes of hepatic capsular retraction: a pictorial essay. Insights Imaging 7, 831–840 (2016)

7. Claire E. Brookmeyer C, Bhatt S, Fishman EK et al, Multimodality Imaging after Liver Transplant: Top 10 Important Complications RadioGraphics 42 (2022)

8. Cunha GM, Fowler KJ, Roudenko A, et al: How to Use LI-RADS to Report Liver CT and MRI Observations. RadioGraphics 41 (2021)

/ Liver Imaging

CHAPTER OUTLINE:

Test Your Knowledge

CHAPTER OUTLINE:

/ Test Your Knowledge

<?> QUESTION

1

Which of the following statements is correct ?

(Several correct answers are possible)

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

/ Test Your Knowledge

<?> ANSWER

1 **Which of the following statements is correct ?**
(Several correct answers are possible)

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

/ Test Your Knowledge

<?> QUESTION

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

The liver has

- ☐ a single blood supply and a common venous drainage system
- ☐ a dual blood supply and a common venous drainage system
- ☐ a single blood supply and a dual venous drainage system
- ☐ a dual blood supply and a dual venous drainage system

/ Test Your Knowledge

<?> ANSWER

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

The liver has

- ☐ a single blood supply and a common venous drainage system
- ■ a dual blood supply and a common venous drainage system
- ☐ a single blood supply and a dual venous drainage system
- ☐ a dual blood supply and a dual venous drainage system

/ Test Your Knowledge

<?> QUESTION

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

(Multiple correct answers are possible)

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

/ Test Your Knowledge

<?> QUESTION

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

(Multiple correct answers are possible)

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

/ Test Your Knowledge

<?> QUESTION

4 Which of the following statements regarding invasive, image – guided procedures is correct ?

(Multiple correct answers are possible)

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

/ Test Your Knowledge

<?> ANSWER

4 Which of the following statements regarding invasive, image – guided procedures is correct ?

(Multiple correct answers are possible)

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

/ Test Your Knowledge

<?> QUESTION

5 Which of the following statements is correct ?

The most frequent malignant hepatic nodules are due to

- ☐ Hepatocellular carcinoma
- ☐ Lymphoma
- ☐ Haematogenous metastases
- ☐ Cholangiocarcinoma

/ Test Your Knowledge

<?> ANSWER

5 Which of the following statements is correct ?

The most frequent malignant hepatic nodules are due to

- ☐ Hepatocellular carcinoma
- ☐ Lymphoma
- ■ Haematogenous metastases
- ☐ Cholangiocarcinoma

/ Test Your Knowledge

<?> QUESTION

6 **Among the following, which is the most frequent hepatic benign lesion ?**

- ☐ Hepatocellular adenoma
- ☐ Haemangioma
- ☐ Focal nodular hyperplasia
- ☐ Peliosis

/ Test Your Knowledge

<?> ANSWER

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

- ☐ Hepatocellular adenoma
- ■ Haemangioma
- ☐ Focal nodular hyperplasia
- ☐ Peliosis

/ Test Your Knowledge

<?> QUESTION

7 Among the following, which statement is correct ?

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

- ☐ in the arterial phase
- ☐ in the portal venous phase
- ☐ in the late (parenchymal) phase
- ☐ on unenhanced images, due to a central calcification

/ Test Your Knowledge

<?> ANSWER

7 Among the following, which statement is correct ?

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

- ■ in the arterial phase
- ☐ in the portal venous phase
- ☐ in the late (parenchymal) phase
- ☐ on unenhanced images, due to a central calcification

/ Test Your Knowledge

<?> QUESTION

8

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:

- ☐ A fine, granular appearance of the parenchyma
- ☐ Decreased organ size
- ☐ Irregular liver contours
- ☐ Enlarged caudate lobe caudate

/ Test Your Knowledge

<?> ANSWER

8 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:

- A fine, granular appearance of the parenchyma
- Decreased organ size
- Irregular liver contours
- Enlarged caudate lobe caudate

/ Test Your Knowledge

<?> QUESTION

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

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

/ Test Your Knowledge

<?> ANSWER

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

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

/ Test Your Knowledge

<?> QUESTION

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

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

/ Test Your Knowledge

<?> ANSWER

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

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