Dynamic and Multi-phase Contrast-Enhanced CT Scan

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Piero Boraschi, Gaia Tarantini, Federica Pacciardi, and Francescamaria Donati

Key Concepts

- Imaging of liver disease represents the diagnostic tool useful for guiding and confirming the clinical suspicion
- Multiphasic CT has a central role in the diagnosis of liver diseases
- CT scanning protocol should be optimized in order to answer to a specific clinical question
- For the diagnosis of liver diseases, it is essential to know what are the most common CT imaging features
- CT imaging usually allows to differentiate the most common benign and malignant liver diseases

42.1 Introduction

Imaging actually plays a pivotal role in the diagnosis of liver diseases. Ultrasound (US), Computed Tomography (CT), and MR imaging (MRI) are daily used in the management of patients with liver abnormalities. Although contrast-enhanced US (CEUS) and MRI with hepato-biliary contrast media and diffusion-weighted sequences are increasingly used in the evaluation of hepatic diseases, CT remains the workhorse in this field [7, 20].

Over the last years substantial developments have been mapped out. In fact, with the advent of the spiral technology and multi-slice CT, there has been an exponential use of this technique. It may provide a large number of acquisition parameters and reconstruction modes. Furthermore multiphasic and multiplanar capabilities of multislice CT represent the added power of this modality [7].

P. Boraschi (✉) · G. Tarantini · F. Pacciardi · F. Donati
Department of Diagnostic Imaging, Pisa University Hospital, Pisa, Italy
e-mail: p.boraschi@do.med.unipi.it

CT plays a very important role in the diagnosis, staging, preoperative planning and follow-up of patients with hepatic diseases.

CT is associated with higher radiation exposure than conventional radiography so, for each patient, exposure to ionizing radiation must be justifiable on the basis of the likely benefit.

The liver scanning protocol usually provides for a non-enhanced scan followed by enhanced acquisitions (acquired at different time-points after the intravenous administration of the iodine-based contrast medium) [7].

42.2 CT Technology Developments

Since the introduction of CT in a clinical scenario in 1974, this modality underwent a progressive and rapid improvement in terms of both acquisition time and spatial resolution. CT provided sequential acquisition of axial slices until the advent of spiral technology at the end of 1980s. So, CT evolved from two-dimensional to three-dimensional technique. A further revolution happened when multi-slice or multi-detector CT (MDCT) was appeared on medical scene in 1992 ("dual slice" scanner) and in 1998 ("four slice" scanner). From then the number of detectors has progressively increased: from 8-, 16-, 32-slices in the early 2000s until to 64-, 128-, 256-, 320-, 512-, etc. slices in the last years. This continuous technological evolution caused a progressive reduction in acquisition time and an ever better spatial resolution. With MDCT technology larger volume coverage can be obtained within one breath-hold time of the patient. Due to the increased number and reduced thickness of slices generated by MDCT, images should be evaluated by the radiologist on a dedicated workstation. This offers the opportunity to create reconstructed images with different algorithms (Multiplanar Reformation, Maximum Intensity Projection, Volume Rendering), that are particularly useful for the surgical planning. In this way diagnostic capability of the radiologist is also strengthened [11, 20].

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On the other hand, with MDCT there was a significant increase in radiation dose. For this reason various strategies to reduce dose have been employed modifying scanning parameters—such as tube potential (kV) and tube current (mA)—or personalizing protocols for individual patients or specific clinical questions. Moreover, for multiphasic CT examinations there are new ways to reduce radiation exposure such as adaptive statistical iterative reconstruction (ASiR); it helps reducing patient dose while maintaining image quality [7, 20].

Further advances were obtained with the more recent introduction of Dual-energy CT. It is based on the appearance of different substances (calcium, iodine and so on) at two separates energy sets. It can generate virtual unenhanced images allowing a reduction in radiation dose. It also helps to distinguish iodine, calcium and acid uric crystal from soft tissues. This technique proved to be useful in the evaluation of hypervascular liver lesions, such as hepatocellular carcinoma especially after treatment.

42.3 Hounsfield Units

Hounsfield units (HUs) are a unit without dimension universally used in CT to express CT numbers in a standardised form. HUs derive from a linear transformation of the measured attenuation coefficients. The mathematical transformation is based on the arbitrary definitions of air and water: radio density of distilled water at standard temperature and pressure (STP) is 0 HU, while radio density of air at STP is −1000 HUs. HUs are measured and utilised in a variety of clinical applications by the radiologists. For example the cysts demonstrate a content with attenuation values similar to water, approximately from 0 to +20 HUs. On the other hand, bone and all types of calcification show strong positive values of HUs (bone ranging from +400 to +3000) [7].

42.4 Liver Scanning Protocol

The use of iodinated contrast medium (ICM) is essential for diagnosis of liver diseases. Current guidelines recommend the use of a minimal dose of ICM necessary to obtain adequate images for diagnosis. Theoretically, a complete liver examination should include a non-enhanced acquisition followed by contrast-enhanced multi-phasic scans [11].

Non-enhanced acquisition is useful in detecting different component of liver lesions with high attenuation (calcifications, bleed, glycogen, iron, etc.) and with low attenuation (cystic lesions, fat, oedema, necrosis, air and so on). It is also useful for evaluating contrast-enhancement of hepatic lesions compared to hepatic parenchyma [7].

The use of contrast-enhanced CT with ICM has significantly improved the accuracy of imaging diagnosis. The rapid development of CT technologies has led to an increase in worldwide usage of ICM. With the contrast-enhanced CT it is possible to localize a lesion increasing the contrast between the lesion and the surrounding hepatic parenchyma [7, 20].

The CT protocols must be established on the basis of the clinical question and of the diagnostic suspicion.

An hepatic mass will be hypodense, isodense or hyperdense in relation to the surrounding hepatic tissue in a specific phase of enhancement. Hypodense is defined when the density of the lesion is lower than that of surrounding hepatic parenchyma; isodense when the density is equal or very similar, and hyperdense when the density is higher than that of hepatic parenchyma. So, it is important to understand the principal CT phases to answer the clinical question or to deepen a radiological finding [2, 13].

Important parameters are: volume and iodine concentration of the ICM, the injection rate (3–5 mL/s) and the scanning delay from the intravenous injection of ICM [13].

Individual variations (body weight, heart rate, circulation time) can influence the time window, so we can use contrast agent bolus timing methods (bolus tracking or bolus test) in order to correct for differences them. Iodine dose should be increased with increasing body weight (BW) of individual patient. This can be assessed by multiplying the body weight with a constant amount of contrast per kg of BW keeping the iodine flow rate constant.

The rate of iodine injection and timing of contrast bolus primarily influence hepatic arterial enhancement; instead, venous phase enhancement is conditioned by total administered dose of iodine.

Following the main enhanced CT phases are reported:

- **Early arterial phase** starting 15–20 s post intravenous administration of ICM or immediately after bolus tracking;
- **Late arterial phase** starting 35–40 s post intravenous administration of ICM or 15–20 s after bolus tracking;
- **Portal-venous phase** is performed 70–80 s post intravenous administration of ICM or 50–60 s after bolus tracking;
- **Delayed/equilibrium phase** is performed 180–300 s after ICM injection or 160–280 s after bolus tracking;
- **Ultra-delayed phase** starting after 5–10 min after ICM injection.

However, in the daily clinical activity, all the six phases (non-enhanced, early arterial, late arterial, portal-venous phase, delayed/equilibrium and ultra-delayed) are not performed in each patient, first of all for radiation exposure and uselessness in diagnosis.

In the early arterial phase the contrast is prevalently confined in the arteries and has not well enhanced the liver. The early arterial phase allows to explore the arterial anatomy of

the patient and shows possible arterial anatomical variants that are information helpful for the surgeons. This phase is useful for patients who are candidates for liver transplantation, for complex hepatobiliary surgery, for trans-catheter arterial chemo or radio-embolization [7, 13].

With the late arterial phase all anatomical structures and lesions that have arterial supply enhance; in particular, all hypervascular lesions such as hepatocellular carcinoma (HCC), hypervascular liver metastasis, hemangioma (typical peripheral enhancement starting in this phase), adenoma and focal nodular hyperplasia are typically hyperdense. However, the usefulness of performing the early arterial phase and the late arterial phase is debated in the diagnosis of HCC; some authors report that the difference in sensitivity between the late arterial phase and the double arterial phase is not statistically significant in detecting HCC [15].

In the portal-venous phase there is the maximal difference in attenuation between the lesion and the enhanced surrounding liver parenchyma. With this phase most of primary and secondary malignant liver lesions are identified. They appear as hypodense lesions compared to the liver parenchyma. In fact, malignant tumours are vascularised by arterial system instead of liver parenchyma, predominantly ensured by portal venous system [13].

The delayed/equilibrium phase is characterized by a reduction in attenuation between lesions and liver parenchyma. So, it is helpful in detecting and diagnosing liver lesions with prevalent fibrous component, such as cholangiocarcinoma, cavernous hemangioma and diffuse liver fibrosis. These disease entities show a prolonged contrast enhancement due to their fibrous tissue, appearing hyperdense compared to liver parenchyma. For these entities it may be important to obtain an ultra-delayed phase in order to highlight the progressive enhancement of the lesion and improve the diagnostic confidence [7, 13].

42.5 Benign Focal Liver Lesions

42.5.1 Hepatic Cystic Lesions

Simple hepatic cysts represent one of the commonest lesions involving the liver. They are developmental lesions without communication with the biliary tree, generally unilocular. They are benign entities, without malignant potential. They can be isolated or multiple. They are more often diagnosed in women and are usually asymptomatic. Their size is variable from few millimeters to several centimeters. They tend to grow in number and size with age. Rarely, due to regressive phenomena, they may decrease in volume [14, 20].

On non-enhanced CT scan the hepatic cysts appear as round or ovoid and have well-defined margins, with no evident wall. They demonstrate hypoattenuating content with attenuation values similar to water (less than 20 HUs). On enhanced CT scans (arterial, portal-venous, delayed phases), their density doesn't change and their wall doesn't show any enhancement (Fig. 42.1) [14, 20].

Polycystic Liver Disease is a hereditary condition characterised by development of several cysts involving the liver, often found in association with renal polycystic disease. The cysts are generally large and multiple and determine a significant enlargement of the organs involved. Spontaneous intracystic hemorrhage, infection and rupture may occur. On unenhanced CT scan some cysts can be hyperdense because of hemorrhagic content. Their density does not significantly increase after ICM injection [2, 13].

Caroli disease is a rare congenital autosomal recessive disorder. It belongs to group of entities resulting from abnormal development of the ductal plates. The simple type of Caroli disease affects the large bile ducts, instead Caroli syndrome involve both the central intrahepatic bile ducts and the ductal plates of the smaller peripheral bile ducts. It can be diffuse, lobar or segmental. In 95% of the cases there are calculi in the cysts. Pre-contrast CT shows hypoattenuating cystic structures (generally do not exceed 2–3 cm in diameter) that communicate with dilated intrahepatic biliary tree. A sign considered very suggestive of Caroli disease is the "central dot sign"; it consists in small dots within the dilated intrahepatic bile ducts with evident contrast enhancement, representing portal radicles. In 7% of cases it degenerates into cholangiocarcinoma [2].

Peribiliary cysts are multiple retention cysts of peribiliary glands. They appear as multiple cystic formations at the level of the periportal spaces (often at the level of biliary confluence) that do not show communication with the biliary tree. Most of them are found in patients with chronic liver disease and are benign. On CT continuous small cysts are typically identified along the portal veins reflecting the periportal collar (Fig. 42.2) [2].

42.5.2 Benign Hepatic Tumors

Hepatic haemangioma is the most frequent benign hepatic tumour, much more common in women (F:M = 5:1). Usually, it is an incidentally detected lesion since the patient is nearly always asymptomatic. It has a congenital origin and it is prevalently of cavernous subtype. It can be solitary or multiple; it can have dimensions ranging from a few millimetres up to over 10 cm (giant haemangioma) [3, 12].

The imaging features of the typical cavernous haemangioma are the following:

On non-contrast CT scan it is generally hypoattenuating relative to the surrounding liver parenchyma, whereas during

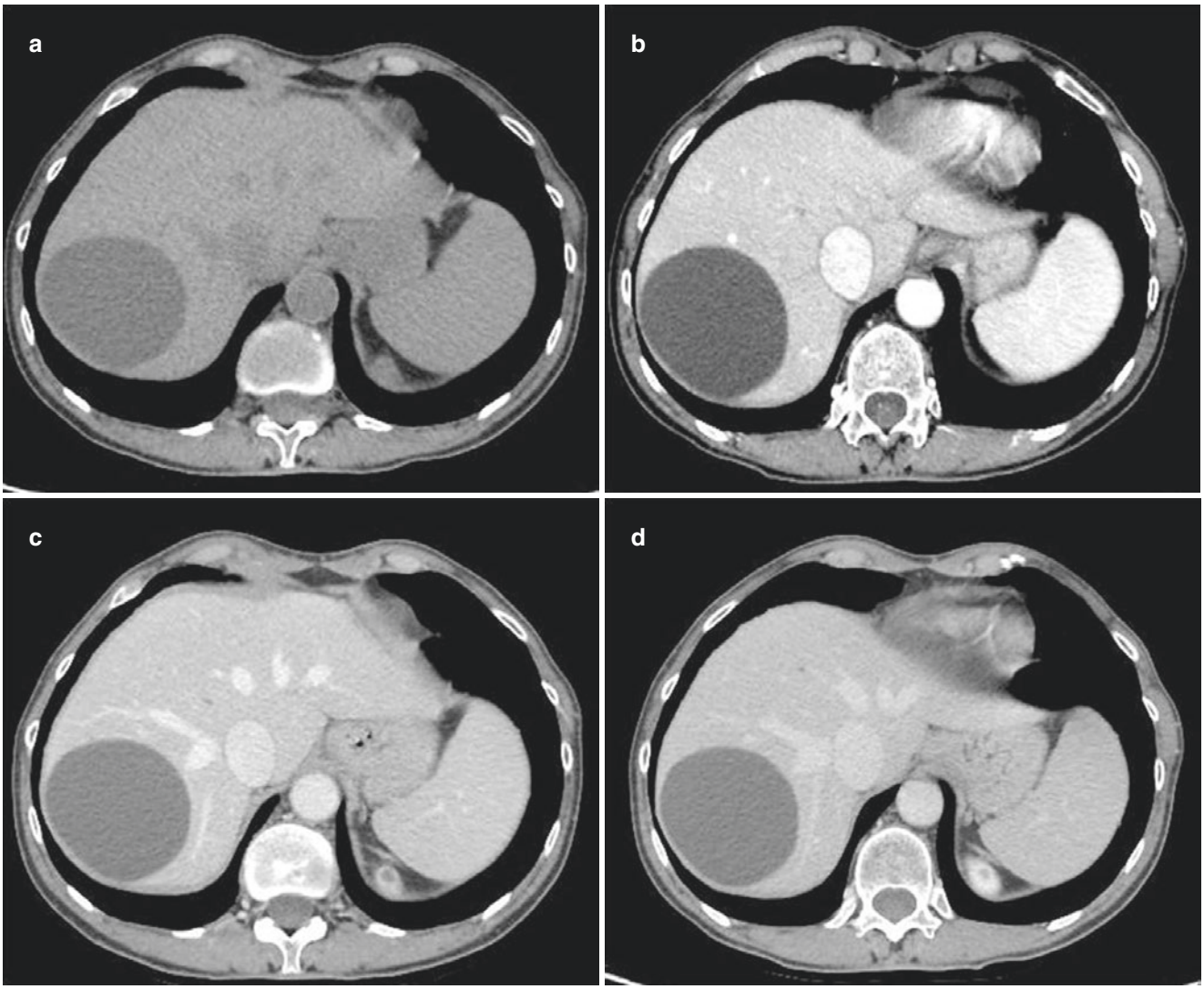

Fig. 42.1 (**a**–**d**) Simple cyst in the right hepatic lobe. CT shows a round-oval lesion in the VII–VIII segment with homogeneous hypoattenuation on unenhanced scan (**a**). The wall is imperceptible and the cyst does not enhance after intravenous administration of ICM on the arterial (**b**), portal-venous (**c**) and delayed (**d**) phases

the arterial phase it shows peripheral globular enhancement with *wreath-like* appearance. On portal-venous phase a progressive centripetal enhancement of the lesion is observed and a complete filling is generally appreciable on delayed/ultradelayed phase (Fig. 42.3).

In the case of the so-called "atypical" haemangioma these peculiar imaging CT features are not so easily recognizable. In the case of giant haemangioma we can have an incomplete filling of the lesion by ICM due to its fibrosis and/or necrotic component or to thrombotic phenomena [12].

Another type of haemangioma is the capillary haemangioma. It is usually iso-/hypodense on unenhanced CT scan. On arterial phase it appears like a fleeting brilliant focus of enhancement (similar to the aortic enhancement in the arterial phase), whereas on the portal-venous and delayed acquisitions it retains the contrast and remains isodense or slightly hyperdense to the surrounding liver parenchyma (Fig. 42.4) [12].

Focal nodular hyperplasia (FNH) is the second most common benign liver lesion after haemangioma and it is usually treated conservatively. It is found mostly in young women. Typically it is an asymptomatic lesion. On unenhanced CT scan it commonly appears isodense or sometimes hypodense respect to the surrounding hepatic parenchyma. A hypoattenuating central scar can be seen in the lesion, especially in larger ones. On arterial phase FNH demonstrates a vivid contrast enhancement except for the central scar which doesn't enhance (it remains hypodense). On the following phases it becomes hypo/isoattenuating respect to the liver. On ultradelayed phase the central scar shows contrast enhancement becoming isodense and not recognizable (Fig. 42.5) [10, 13].

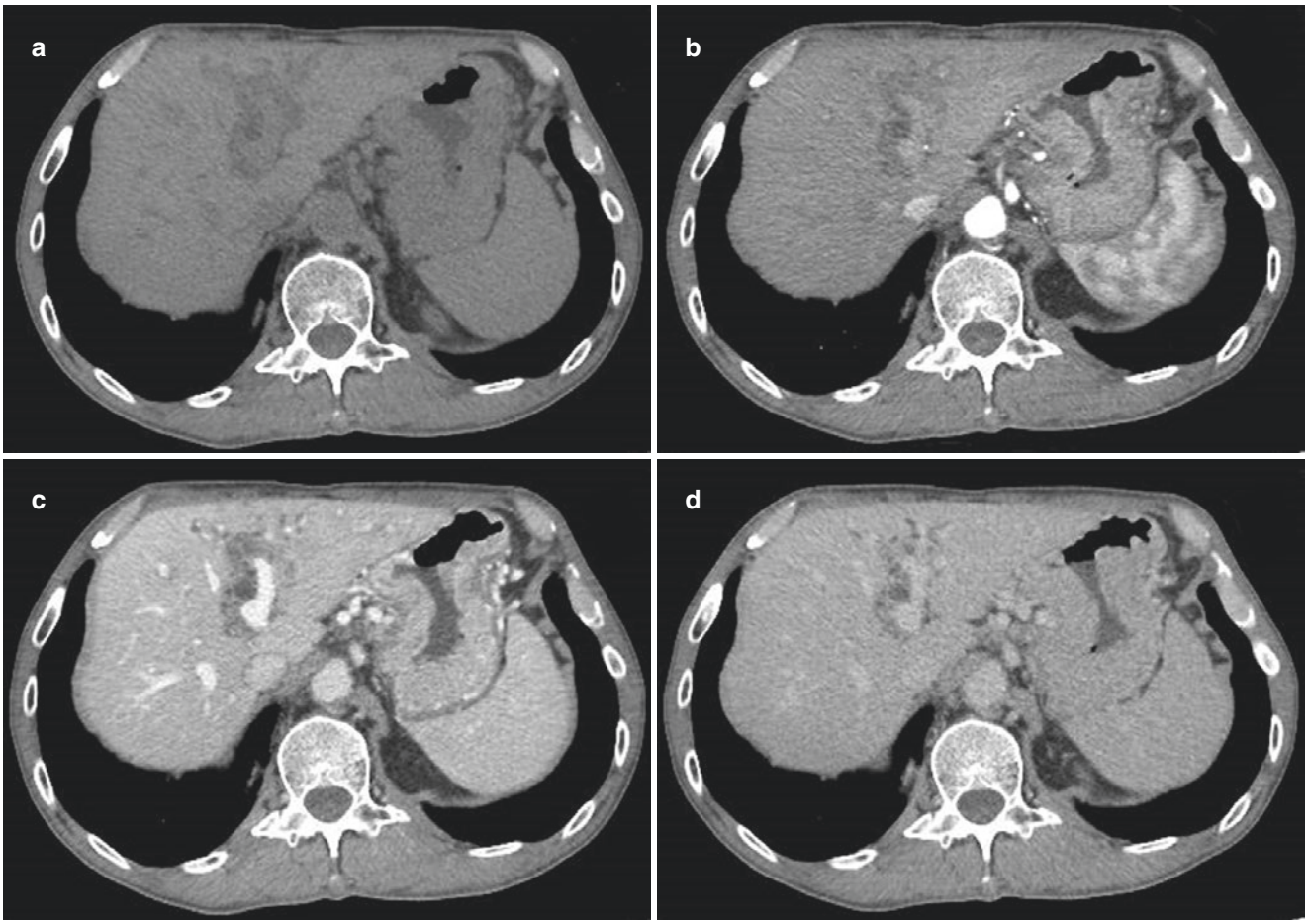

Fig. 42.2 (**a**–**d**) Multiple hepatic peribiliary cysts. Fluid density, well-defined intrahepatic structures are appreciable at the level of the peri-portal spaces around the liver hilum. They appear hypodense on unenhanced CT scan (**a**) with no significant enhancement on the arterial (**b**), portal-venous (**c**) and delayed (**d**) phases

Hepatic adenoma is a rare benign tumour of the liver with a strong prevalence in women, generally hormone-induced (mostly related to prolonged use of oral contraceptives). It can bleed (causing hemoperitoneum) or can rarely degenerate into hepatocarcinoma. It is usually solitary (80%), larger than 5 cm at the time of diagnosis, more frequently located in the right hepatic lobe. The surgical resection can be indicated in specific cases for the risk of hemorrhage and possible malignant transformation. On unenhanced CT scan it may be clearly hypodense due to its fatty component; sometimes it can present hyperdense areas inside for the presence of calcifications and/or hemorrhages. After ICM injection it shows a transient vivid enhancement, with reduction of density on the portal-venous and delayed phases (becoming isodense). The differential diagnosis of this lesion with FNH can be very difficult on multiphasic CT and it is indicated the use of MR imaging with hepato-biliary contrast agents [10, 13].

42.6 Malignant Hepatic Tumours

42.6.1 Hepatocellular Carcinoma (HCC)

HCC is the most common primary malignant hepatic tumour (80–90% of cases) and occurs predominantly in patients with underlying chronic liver disease and cirrhosis. It develops from a regenerative nodule to a carcinoma through a dysplastic phase [9, 10, 13, 20].

The risk of tumour formation is higher in patients with chronic viral hepatitis, but nowadays there is an increased HCC incidence in patients with NAFLD (Non Alcoholic Fatty Liver Disease) associated with metabolic syndrome, diabetes and obesity. Other causes of liver cirrhosis are chronic alcohol abuse and genetic hemochromatosis.

Three main subtypes of HCC are reported:

1. Nodular type (the most common), often characterized by multiple lesions;

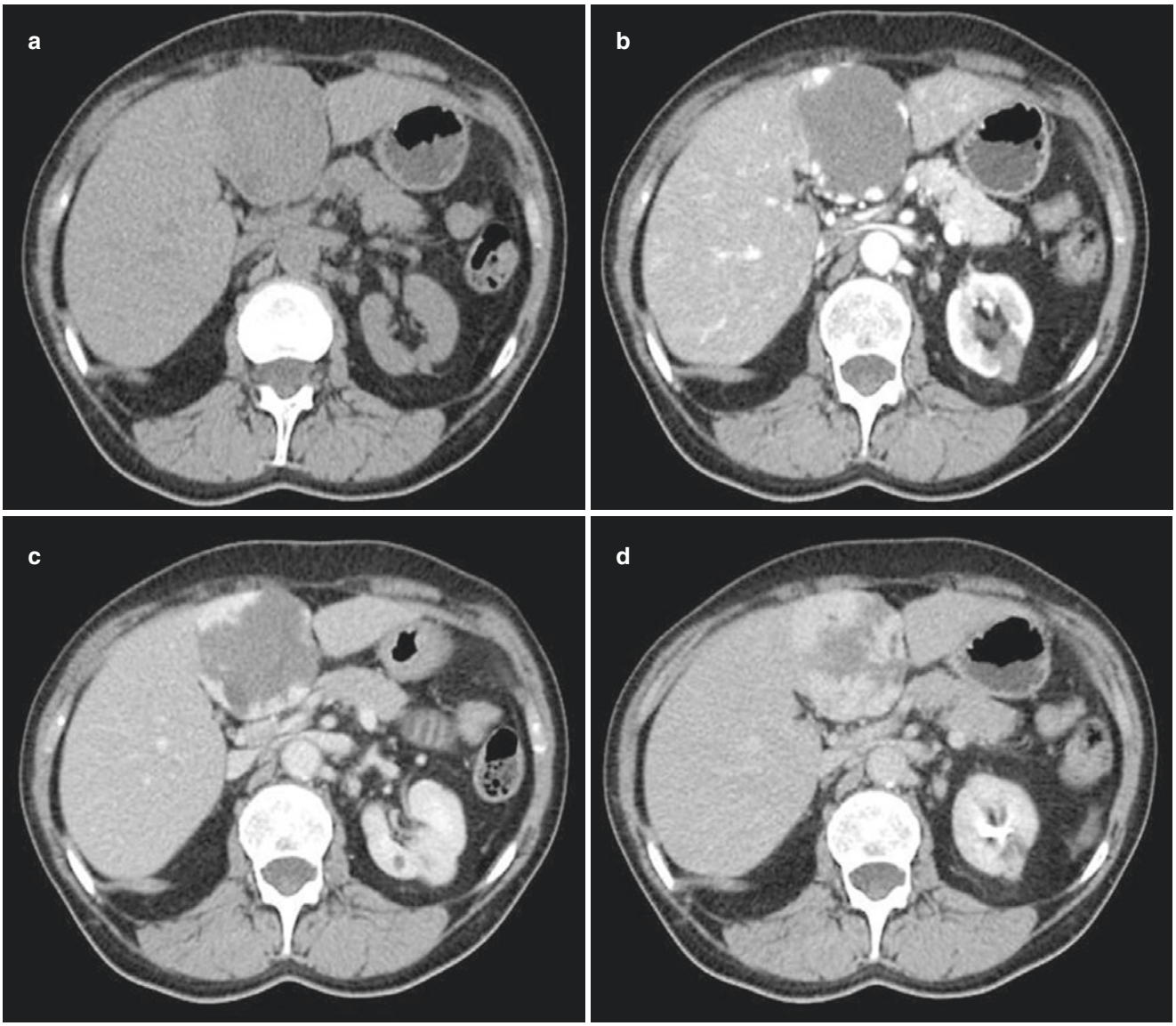

Fig. 42.3 (**a**–**d**) Cavernous haemangioma in the left hepatic lobe. Unenhanced CT scan (**a**) shows a 7-cm-in-size lesion with smooth margins that is slightly hypodense respect to the surrounding parenchyma. On arterial (**b**), portal-venous (**c**) and delayed (**d**) phases the lesion demonstrates a characteristic progressive globular and centripetal enhancement that is isoattenuating to the vessels

2. Macronodulary type (often fibrolamellar type) occurring on healthy liver, usually single or with satellite malignant nodules, and often diagnosed late when they reach large dimensions;
3. Diffuse or infiltrating type, characterized by multiple micronodules (<1 cm) scattered throughout the liver parenchyma with a cirrhotic-like appearance [5, 20].

Furthermore, small satellite HCC nodules can be identified near to the main tumour (representing intrahepatic metastases) and show the same CT appearance of the main lesion.

At the baseline CT scan nodular and macronodular types of HCC are well defined and appear hypodense respect to the surrounding hepatic parenchyma, sometimes with a central necrotic portion or focal adipose degeneration (with negative density values). Hyperdense foci are also present in case of calcifications and/or haemorrhage. On the other hand, the infiltrative type has poorly defined margins. This type is sometimes isodense and is only visible for the dislocation of intrahepatic vessels and/or deformation of the hepatic margins [7, 13, 20].

After ICM administration late arterial, portal-venous and delayed phases are usually acquired. In late arterial phase there is a typical arterial enhancement; so, vital neoplastic tissue (sometimes with a central necrotic hypodense portion) is clearly hyperdense for the rapid wash-in of contrast medium due to arterial neoangiogenesis. Early-stage HCCs might fail to enhance and cannot be distinguished on the arterial phase due to the lack of adequate vascular supply [7, 13].

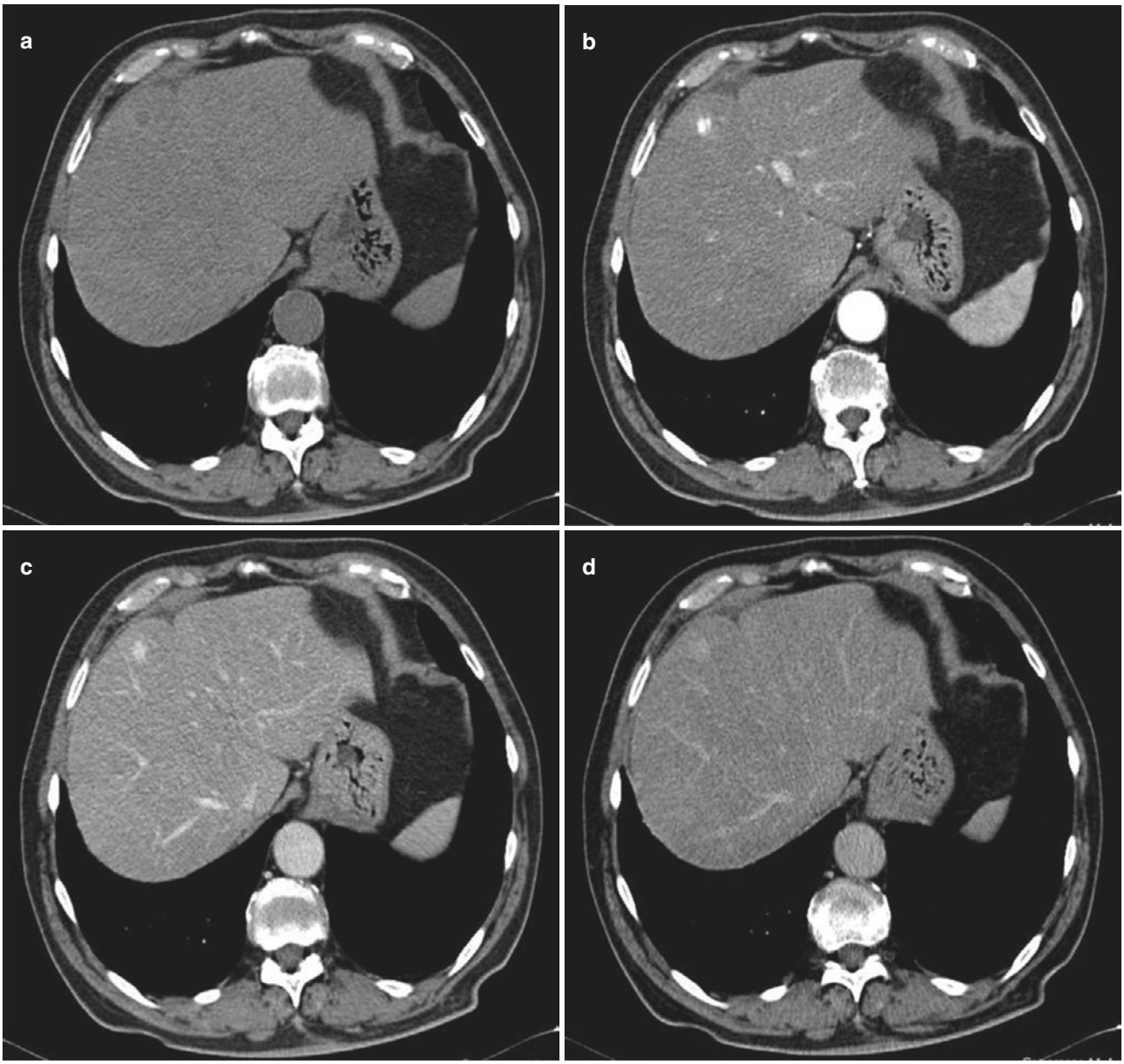

Fig. 42.4 (**a**–**d**) Capillary "flash-filling" haemangioma in the right hepatic lobe. Unenhanced CT scan (**a**) demonstrates a centimetric subcapsular hypodense lesion in the IV segment. On arterial phase (**b**) the lesion shows homogeneous vivid enhancement similar to the aortic one. It maintains slightly hyperdense respect to the surrounding liver parenchyma on portal-venous (**c**) and delayed (**d**) phases, remaining isoattenuating to the vessels ("blood-pool" features of the lesion)

As just mentioned in the text, the early arterial phase is useful to map the arterial anatomy of the patient; the presence of possible anatomical variants is helpful for the surgeon and interventional radiologist.

In the portal-venous and delayed phases HCC is characterized by a rapid contrast wash-out and so it becomes hypodense. Huge tumours can present a peripheral hyperdense fibrous capsule on delayed phases (Fig. 42.6).

The presence of tumour thrombi within the main branches of portal vein is crucial for the staging of HCC and represents a prognostic factor for the therapeutic management. Neoplastic thrombi show the same CT pattern of the main lesion appearing as solid masses with a characteristic wash-in and wash-out [4, 16].

Moreover, CT plays a pivotal role in tumour response assessment after surgery and loco-regional therapy (such as Radiofrequency ablation, TransArterial ChemoEmbolization and Selective Internal Radiation Therapy). Dynamic CT studies are able to detect persistent or residual tumour by identifying a nodular enhancing area within or peripherally

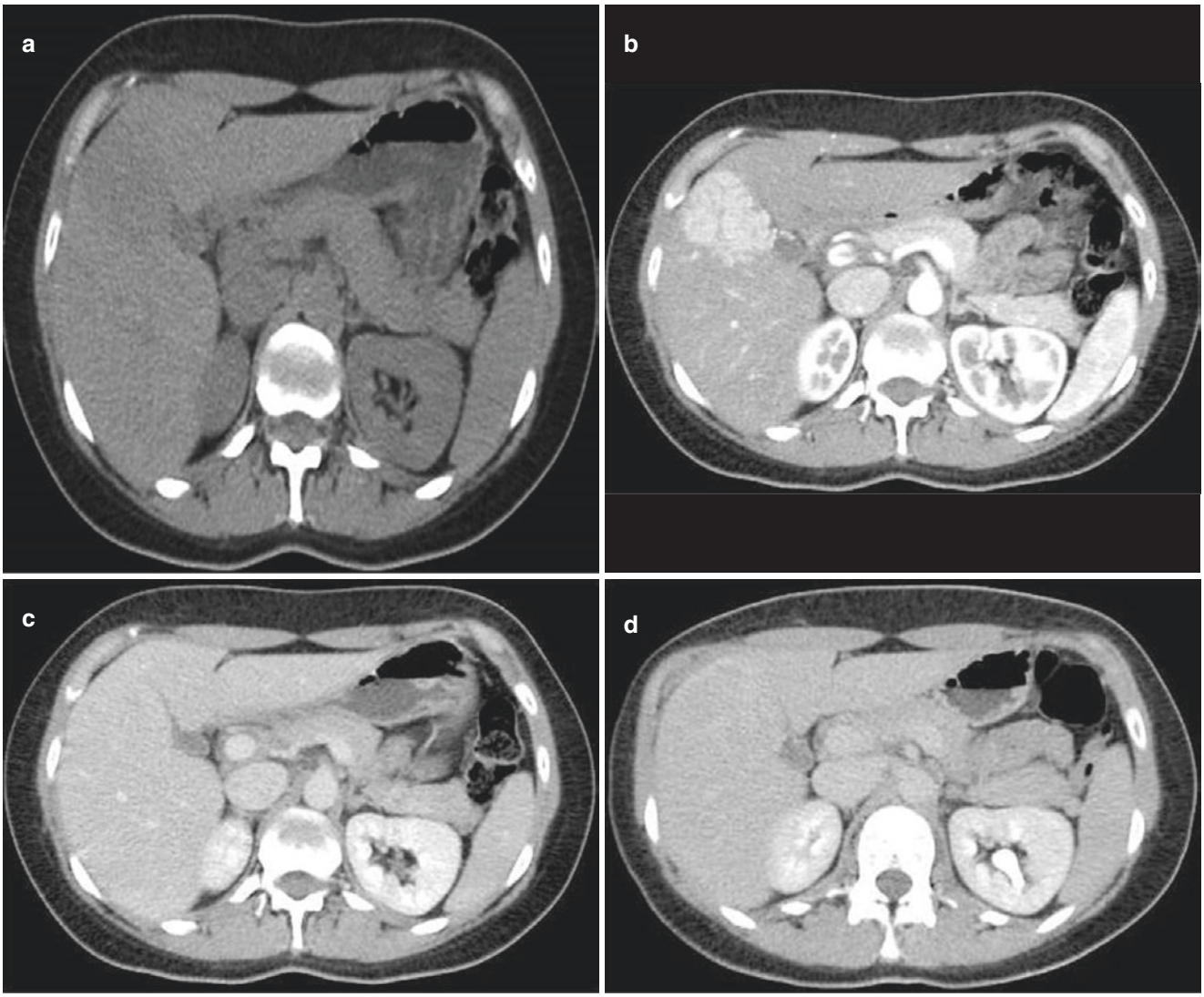

Fig. 42.5 (**a**–**d**) Focal nodular hyperplasia in the right hepatic lobe. A round-oval slightly hypodense area is present in the V segment on unenhanced CT scan (**a**). The lesion is markedly hyperdense except for the central scar which doesn't enhance on arterial phase (**b**). It becomes isodense respect to the surrounding liver parenchyma on portal-venous phase (**c**). The central scar is slightly hyperdense on delayed phase (**d**)

to the treated lesion, with the same pattern of the native HCC. At least, CT is also useful in identifying extrahepatic spread of the disease (lung, adrenal glands, lymph nodes, and bone are the most common sites) [8, 19].

42.6.2 Cholangiocarcinoma

Cholangiocarcinoma is the second most common primary malignant hepatic tumour and originates from the epithelium of the intra and extrahepatic bile ducts. It often develops in people aged 50–60 with chronic calculi of the biliary tract, Carolì disease and primary sclerosing cholangitis [13, 18].

Cholangiocarcinoma can be divided into intra- or extrahepatic form and it includes three types:

1. Mass-forming type, predominantly intrahepatic (originating from small intrahepatic peripheral bile ducts);
2. Periductal-infiltrating type, predominantly intrahepatic, central or hilar (the most common type); it often originates at the confluence of the right, left and common hepatic ducts (Klatskin tumour); obstructive jaundice is the usual clinical manifestation;
3. Intraductal-growing type, intra or extrahepatic; it is characterized by small polypoid projections often confined into the biliary lumen, without infiltration of the hepatic parenchyma; this subtype grows slowly, and has a relatively favourable prognosis [1, 2, 6].

Intrahepatic cholangiocarcinoma seldom includes the hepatocellular-cholangiocellular carcinoma subtype.

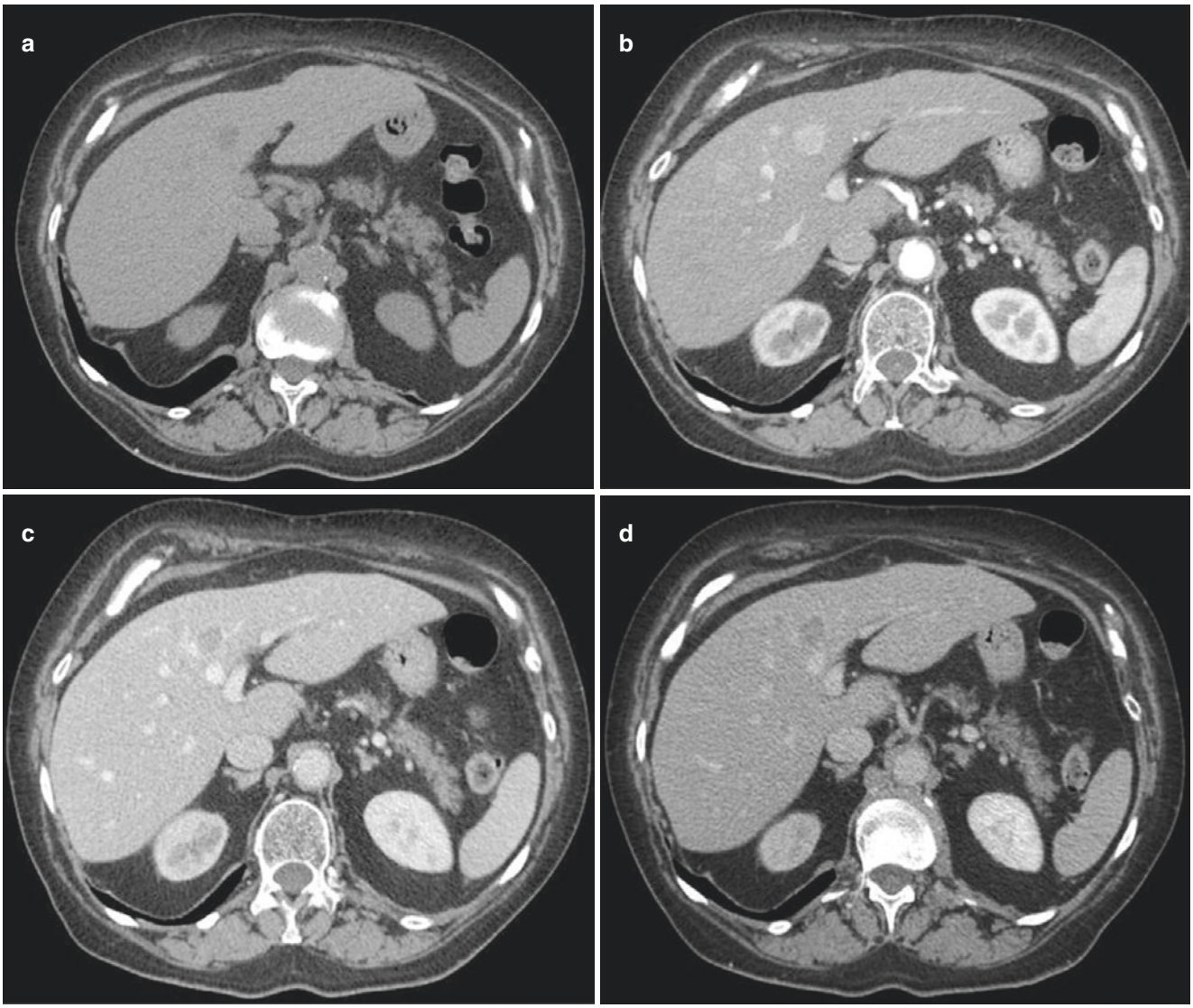

Fig. 42.6 (**a**–**d**) Hepatocellular carcinoma in the right hepatic lobe. Unenhanced CT scan (**a**) shows a 2.5-cm-in-size hypodense lesion in the IV hepatic segment. On late arterial phase (**b**) the lesion appears hyperdense, due to contrast medium wash-in. It becomes clearly hypodense on portal-venous (**c**) and delayed (**d**) phases for typical wash-out of contrast agent. These features are diagnostic for HCC

CT is often helpful for a reliable diagnosis and staging in patients with disease entity. This technique is also very useful for depicting a vascular roadmap in order to establish arterial and venous invasion.

CT protocol for cholangiocarcinoma usually includes a non-enhanced acquisition (in order to detect intraductal lithiasis) and a three-phase acquisition: late arterial (for arterial anatomy evaluation), portal-venous and delayed phases.

Mass-forming type is tenuously hypodense compared to the normal liver parenchyma at non-enhanced CT scan. It shows inhomogeneous enhancement in the arterial and venous phase with a progressive uptake of the contrast medium from the periphery to the centre of the lesion. Signs of vascular encasement and infiltration of the contiguous intrahepatic venous vessels can be present. The lesion typically appears inhomogeneously hyperdense on delayed phases, in particular at the level of central portion. An ultra-delayed phase can be also performed in order to assess a persistent tumour enhancement compared to the surrounding liver parenchyma, due to the significant fibrous component of the tumour (Fig. 42.7) [6, 18].

Biliary tract dilation upstream of the lesion can be reported. In the more advanced stages, lobar or segmental atrophy of the involved hepatic territories with capsular retraction may be present due to the abundant desmoplastic reaction. Hepatic hilar lymphadenopathies and peritoneal nodules are identified whenever lymphatic metastatic diffusion is present [13, 14].

Periductal infiltrating type results in an irregular bile stricture growing along the bile duct (involving mucosa and serosa). It

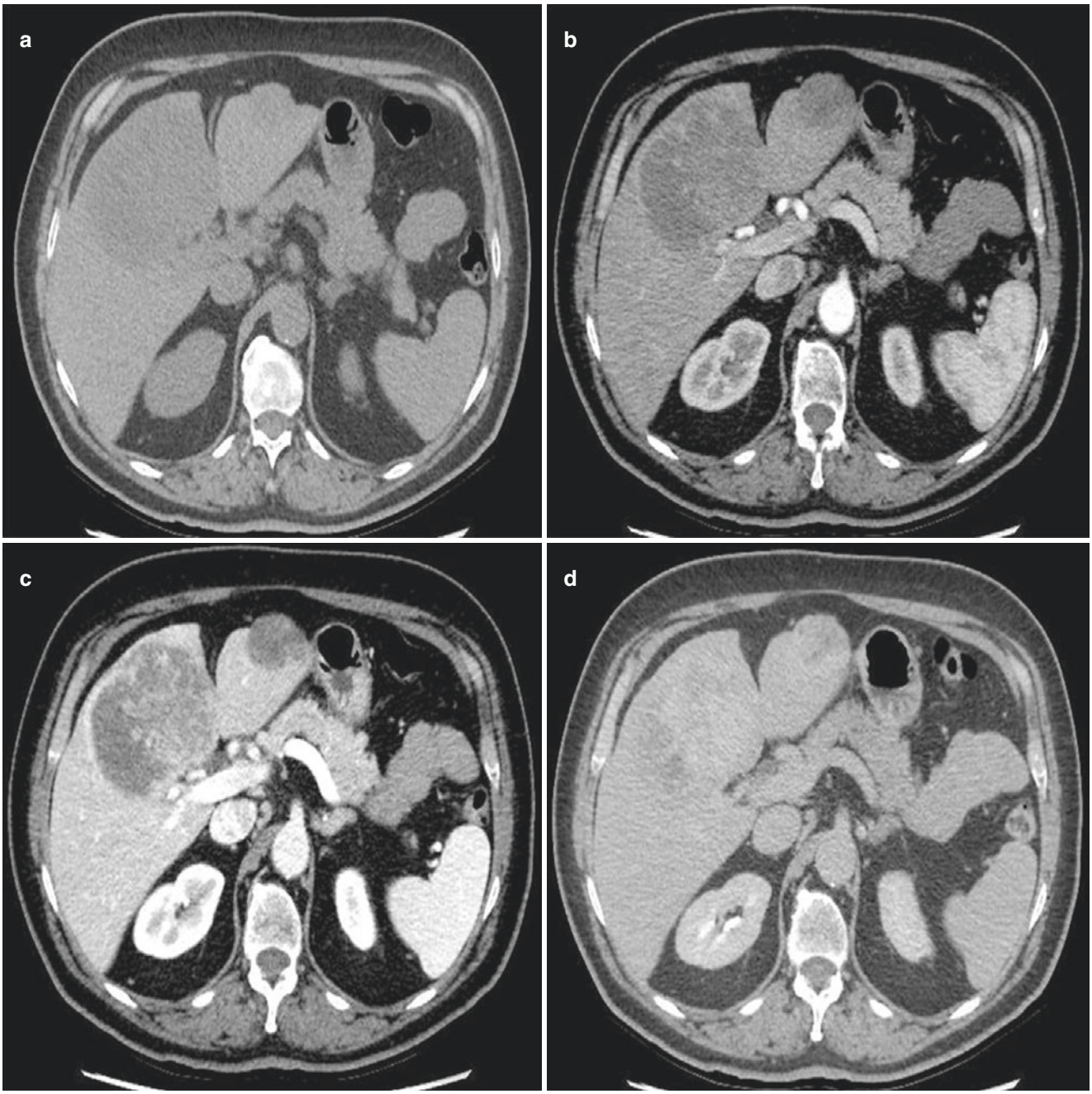

Fig. 42.7 (**a**–**d**) Multifocal peripheral mass-forming cholangiocellular carcinoma. Unenhanced CT scan (**a**) shows a large, heterogeneously hypodense mass with lobulated margins in the IV–V–VIII hepatic segments and another smaller one with analogous CT appearance in the III segment. After ICM administration both lesions well exhibit inhomogeneous progressive enhancement from the late arterial phase (**b**) to the portal-venous (**c**) and delayed (**d**) ones. The lesions result slightly and inhomogenously hyperdense on delayed phase

appears as a concentric thickening of the biliary wall, hyperenhancing in delayed phase, without forming a nodular mass. It is often associated to upstream biliary dilation. Differential diagnosis of these malignant strictures from the benign ones (inflammatory or post-traumatic) is always difficult [2, 6].

Intraductal type includes a variety of imaging features. CT can demonstrate diffuse and marked duct ectasia with or without a grossly visible mass, that appears hypodense on unenhanced CT scan and shows progressive enhancement on the subsequent post-contrastographic phases. These lesions tend to grow within the biliary tract [6].

42.6.3 Hepatic Metastases

Metastatic lesions originate throw a sequential process which favours the survival of a small population of metastatic cells in the context of the primary tumour. Liver is the second

most common site of metastasis in the human body, after lymph nodes, due to its double blood supply: portal vein for intra-abdominal primary tumour and arterial system for extra-abdominal malignancies. Less frequently, there are liver metastases by continuity, via the lymphatic vessels or by intra-peritoneal spread [7].

Most frequently, liver metastases originate from primary carcinoma of the colon, stomach, pancreas, breast and lung. Usually metastatic lesions are multiple with different diameter and bilobar involvement [2].

CT is useful to identify focal liver lesions, their number, localization, and characterization. Furthermore, CT provides information in order to assess surgical or loco-regional treatment [17].

Before ICM administration, CT appearance of hepatic metastases is variable: isodense, hypodense (the most frequent) or hyperdense respect to the surrounding liver parenchyma. Isodense lesions are often visible only for indirect signs such as vascular dislocation or capsular deformation. Metastases appear hyperdense when are detected in diffuse hepatic steatosis or when contain haematic or calcific component inside (such as colorectal or mucinous metastases). After ICM injection, CT features of metastases are dictated by their vascularity because, differently to liver parenchyma, hepatic metastases get their blood supply almost exclusively by the hepatic artery [17].

Also for the detection and characterization of liver metastases late arterial, portal-venous and delayed phases are needed on CT.

Most of hepatic metastases are generally hypovascular because they receive only minimal arterial and portal-venous blood supply due to confluent dense cellularity, fibrosis or necrosis. On late arterial and portal-venous phases these metastases often show a continuous hyperdense peripheral rim enhancement that is the most specific sign for a positive diagnosis of metastasis. As the size of the lesions increases, only its peripheral part continues to be adequately vascularized and hyperdense, while the central part becomes necrotic or replaced by fibrosis. Hypovascular lesions usually originate from gastrointestinal tract adenocarcinomas, lung and breast tumours and are better visualized during the portal-venous phase as hypodense lesions. In the delayed phase peripheral rim may become isodense to surrounding liver parenchyma and the lesion appears smaller than it is in reality (Fig. 42.8) [13, 17].

Hypervascular metastases, frequently found in neuroendocrine tumours of pancreatic or enteric origin, renal cell carcinoma, and thyroid cancer (more rarely in melanoma, sarcomas, and ovarian choriocarcinoma), show a rapid diffuse enhancement during late arterial phase and rapid washout during the portal-venous and delayed phases [7].

Cystic degeneration may be evident in liver metastases from head and neck squamous cell carcinoma and after chemotherapy treatment, mainly with new antiangiogenic drugs.

42.7 Conclusions

In conclusion, CT has a crucial role in the diagnosis, staging, preoperative planning and follow-up of patients with hepatic diseases. CT scanning protocol should be optimized on the basis of the clinical question and of the diagnostic suspicion. For the diagnosis of liver diseases, it is essential to know what are the most common CT imaging features in order to differentiate the most common benign and malignant disease entities.

Self Study

Questions

1. Which statement is true?
   (a) The arterial phase is helpful in detecting and diagnosing liver lesions with prevalent fibrous component.
   (b) In the daily clinical activity, all the six CT phases (non-enhanced, early arterial, late arterial, portal-venous phase, delayed/equilibrium and ultra-delayed) are performed in each patient.
   (c) On the portal-venous phase there is the maximal difference in attenuation between the lesion and the enhanced surrounding liver parenchyma.
   (d) With ultra-delayed phase all anatomical structures and lesions that have arterial supply enhance.
2. Which statement is true?
   The typical cavernous haemangioma after ICM injection:
   (a) On arterial phase it appears like a fleeting brilliant focus of enhancement whereas on the portal-venous and delayed acquisitions it retains the contrast.
   (b) On arterial phase it shows peripheral globular enhancement and on portal-venous phase it shows a progressive centripetal enhancement.
   (c) On arterial phase it shows a transient vivid enhancement, with reduction of density on the portal-venous and delayed phases.
   (d) Its density doesn't change compared to non-enhanced CT scan.

Answers

1. Which statement/statements is/are true?
   (a) The DELAYED/EQUILIBRIUM phase is helpful in detecting and diagnosing liver lesions with prevalent fibrous component. This phase is characterized by a reduction in attenuation between lesions and liver parenchyma.
   (b) In the daily clinical activity, all the six CT phases (non-enhanced, early arterial, late arterial, portal-venous phase, delayed/equilibrium and ultra-

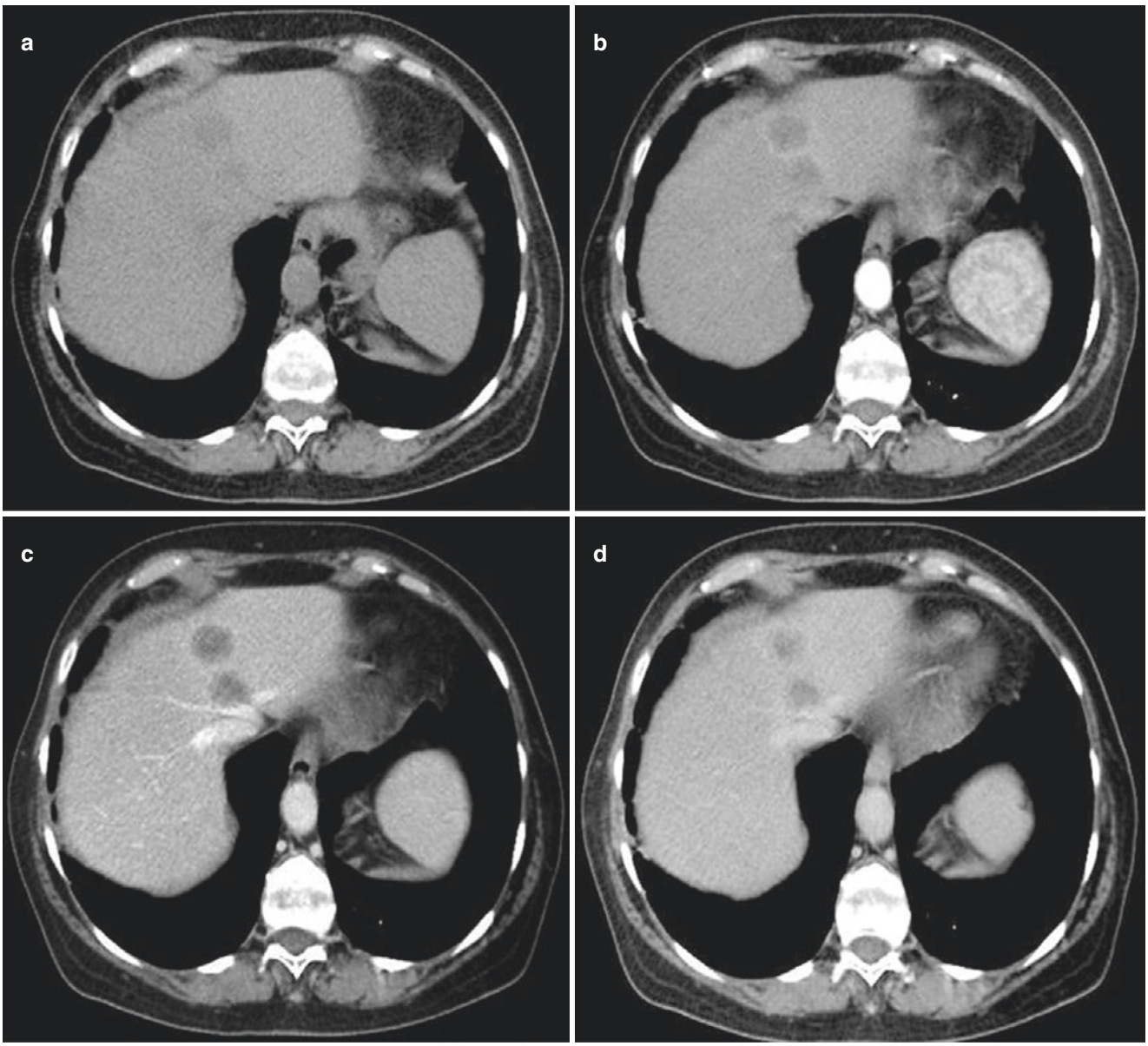

Fig. 42.8 (**a**–**d**) Colorectal cancer liver metastases. Unenhanced CT scan (**a**) shows two hypodense lesions in the IV–II hepatic segments. On arterial (**b**) and portal-venous (**c**) phases these lesions show a typical hyperdense peripheral rim enhancement with a hypodense central portion. On delayed phase (**d**) metastatic lesions appear inhomogeneously hypodense and smaller than the previous ones, with an isodense peripheral rim

delayed) are NOT performed in each patient due to the radiation exposure and due to uselessness in diagnosis.

(c) On the portal-venous phase there is the maximal difference in attenuation between the lesion and the enhanced surrounding liver parenchyma. **CORRECT.** In fact with this phase most of primary and secondary malignant liver lesions are identified. They appear as hypodense lesions compared to the liver parenchyma.

(d) With LATE ARTERIAL phase all anatomical structures and lesions that have arterial supply enhance. In fact all hypervascular lesions are typically hyperdense on late arterial phase.

2. Which statement is true?
   The typical cavernous haemangioma after ICM injection:
   (a) On arterial phase it appears like a fleeting brilliant focus of enhancement whereas on the portal-venous and delayed acquisitions it retains the contrast. This is the appearance of the capillary haemangioma.
   (b) On arterial phase it shows peripheral globular enhancement and on portal-venous phase it shows a progressive centripetal enhancement. **CORRECT**. These are the CT imaging features typical of a cavernous hemangioma.
   (c) On arterial phase it shows a transient vivid enhancement with reduction of density on the portal-venous

and delayed phases. This is the appearance of a hypervascular lesion such as hepatic adenoma.

(d) Its density doesn't change compared to non-enhanced CT scan. This is the appearance of a cystic-like lesion.

References

1. Bartella I, Dufour JF. Clinical diagnosis and staging of intrahepatic cholangiocarcinoma. J Gastrointestin Liver Dis. 2015;24(4):481–9.
2. Bernd H, Ros PR, editors. Abdominal imaging. Berlin: Springer; 2013.
3. Boland GW, editor. Gastrointestinal imaging: the requisites (requisites in radiology). 4th ed. Philadelphia: Elsevier Saunders; 2014.
4. Chan SL, Chong CCN, Chan AWH, et al. Management of hepatocellular carcinoma with portal vein tumor thrombosis: review and update at 2016. World J Gastroenterol. 2016;22(32):7289–300.
5. Choi JY, Lee JM, Sirlin CB. CT and MR imaging diagnosis and staging of hepatocellular carcinoma: Part I. Development, growth, and spread: key pathologic and imaging aspects. Radiology. 2014;272(3):635–54.
6. Chung YE, Kim MJ, Park YN, et al. Varying appearances of cholangiocarcinoma: radiologic-pathologic correlation. Radiographics. 2009;29:683–700.
7. Dal Pozzo G. Compendio di Tomografia Computerizzata e TC multistrato. Torino: UTET Scienze Mediche; 2007.
8. European Association for the Study of the Liver EASL. Clinical practice guidelines: management of hepatocellular carcinoma. J Hepatol. 2018;69(1):182–236.
9. Ganeshan D, Szklaruk J, Kundra V, et al. Imaging features of fibrolamellar hepatocellular carcinoma. Am J Roentgenol. 2014;202(3):544–52.
10. Horton KM, Bluemke DA, Hruban RH, et al. CT and MR imaging of benign hepatic and biliary tumors. Radiographics. 1999;19(2):431–51.
11. Kagawa Y, Okada M, Yagyu Y, et al. Optimal scan timing of hepatic arterial-phase imaging of hypervascular hepatocellular carcinoma determined by multiphasic fast CT imaging technique. Acta Radiol. 2013;54(8):843–50.
12. Klotz T, Montoriol PF, Da Ines D, et al. Hepatic haemangioma: common and uncommon imaging features. Diagn Interv Imaging. 2013;94(9):849–59.
13. Lencioni R, Cioni D, Bartolozzi C, editors. Focal liver lesions - detection, characterisation, ablation. Berlin: Springer; 2005.
14. Levy AD, Mortele KJ, Yeh BM, editors. Gastrointestinal imaging. Oxford: Oxford University Press; 2015.
15. Pozzi Mucelli RM, Como G, Del Frate C, et al. Multidetector CT with double arterial phase and high-iodine-concentration contrast agent in the detection of hepatocellular carcinoma. Radiol Med. 2006;111(2):181–91.
16. Reynolds AR, Furlan A, Fetzer TD, et al. Infiltrative hepatocellular carcinoma: what radiologists need to know. Radiographics. 2015;35:371–86.
17. Sica GT, Ji H, Ros PR. CT and MR imaging of hepatic metastases. Am J Roentgenol. 2000;174:691–8.
18. Sureka B, Bansal K, Arora A. Imaging of perihilar cholangiocarcinoma. Am J Roentgenol. 2015;205(3):W385.
19. Willatt J, Ruma JA, Azar SF, et al. Imaging of hepatocellular carcinoma and image guided therapies - how we do it. Cancer Imaging. 2017;17(1):9.
20. Zech CJ, Bartolozzi C, Baron R, Reiser MF, editors. Multislice CT of the abdomen. Berlin: Springer; 2012.