

Localisation of focal liver lesions to specific hepatic segments — comparison of multiphase spiral CT and MR imaging

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[Received 2 October 2002; Revised 30 October 2002; Accepted 30 October 2002]

The purpose of this study was an evaluation of the ability of the multiphase spiral CT and MR imaging to localise focal liver lesions referring to specific hepatic segments.

The authors studied prospectively 26 focal liver lesions in 26 patients who had undergone spiral CT and MRI before surgery. Multiphase spiral CT included non-contrast scans, hepatic arterial-dominant phase, portal venous — dominant phase and equilibrium phase. MRI was performed in all cases. The following sequences were performed: SE and TSE T1- and T2-weighted images, STIR and dynamic T1-weighted FFE study after i.v. administration of gadolinium (Gd-DTPA).

The CT and MR scans were prospectively and independently reviewed by three radiologists for visualisation of hepatic and portal veins and segmental localisation of hepatic lesions.

The authors used the right and left main portal veins along with transverse fissura, hepatic veins and gallbladder fossa as landmarks for the tumour localisation to specific hepatic segments.

The primary segmental locations of the lesions were correctly determined with CT in 22 of 26 focal liver lesions (85%) and with MR imaging in 24 of 26 lesions (92%). The full extent of lesions was correctly described with sCT in 19 of 26 focal lesions and with MR in 21 of 26 tumours.

MRI and CT were helpful preoperative tools for determining the segmental location of focal liver lesions and for planning the surgical approach.

key words: liver anatomy, neoplasms, radiological methods, comparative study

INTRODUCTION

The normal anatomy of the hepatic and portal veins has been described extensively in the literature. These descriptions have been based on anatomic dissections, post mortem venograms and corrosion cast studies of liver specimens [7, 10, 16], similarly to an-

atomic descriptions of the veins as depicted by surgery [2, 6], sonography [6, 12], CT [15, 17, 18] and MR imaging [1, 11]. Modern radiological techniques help to correctly select the group of patients, in whom surgery is indicated. The treatment of liver tumours depends on the intrahepatic and extrahepatic extent

of the disease and the function of the underlying liver. For malignant liver neoplasms, resection with negative pathologic margins is the mainstay of treatment [1, 20]. In clinical practice, accurate preoperative tumour location assessment within a liver segment is important in planning the surgical approach [14, 20]. Determining the number of lesions and segmental location of hepatic tumours enhances the ability to do complex anatomic resections, including resection of hepatic segments [3, 21]. The precise visualisation of intrahepatic venous and portal structures has to coexist with good visualisation of hepatic tumours and provide a better tool in differential diagnosis of focal liver lesion.

The presented study evaluated the utility of non-invasive imaging methods -multiphasic spiral CT and MR imaging in topographic localization of focal liver lesions.

MATERIAL AND METHODS

During an 18-month period from 1st April 1999 to 30th September 2000, 96 consecutive patients with focal liver lesion were prospectively studied. All patients were suspected to have hepatic tumour after ultrasonography. From this population, 26 patients (16 men, 10 women) with a single lesion confirmed surgically were included in this study.

Patients were from 22 to 79 years old (mean age 61). Hepatocellular carcinoma (HCC) was recognised in 16 patients and focal nodular hyperplasia (FNH) in 3 cases. Six patients had hepatic metastases of colorectal cancer and one patient — hydatid cyst.

All patients underwent laparotomy performed within 2–8 weeks from imaging examinations. Twelve patients had hemihepatectomies, two persons underwent open biopsy and the others had segmentectomies or bisegmentectomies. Two patients had previously undergone hepatic surgery (partial resection); one because of HCC, the other because of metastases.

The CT and MR scans were prospectively and independently reviewed by three radiologists for visualisation of hepatic and portal veins and segmental localisation of hepatic lesions.

The segmental anatomy used in this study was that described by Couinaud [6] and modified by Bismuth [2].

The division between the right and left lobes of the liver was defined by a plane through the major fissure, gallbladder, the middle hepatic vein and IVC. If the major fissure could not be seen on CT and MR scans through the gallbladder, we used the neck of

the gallbladder as a crude marker for the border between the right and left lobes.

A coronal plane through the right hepatic vein and the IVC separated segments 6 and 7 posteriorly from 5 and 8 anteriorly. The right hepatic vein ran midway between the right portal vein branches. When the right hepatic vein was not visualised on CT and MR images obtained through the bifurcation of right portal vein into anterior and posterior divisions, we used a coronal plane through the midpoint between the portal vein branches and the IVC as the segmental boundary. A transverse plane at the level of the right portal bifurcation indicated the border between segments 5/6 caudally and 8/7 cranially.

Segment 4 was bounded by middle hepatic and left hepatic veins. The middle hepatic vein divided the right lobe and the medial segment (4). The left hepatic vein separated the left medial (4) and lateral (2 and 3) segments. When on CT and MR images the left hepatic vein was not visible, the ligamentum teres and the falciform ligament acted like a border between the left medial and left lateral segments of left lobe. The lateral segment is further subdivided by a transverse plane at the level of the left portal branch into superior and inferior division.

When a lesion was found adjacent to a segmental boundary, it was localised to one segment only. If the tumour was visualised on both sides of the boundary, the lesion was localised to two segments or more.

MR study was performed on a 0.5 T MR system (Gyroscan, Philips). The protocol included: T1-weighted SE (TR/TE 500/10, thk/gap 6/0.6 mm) in the axial plane with and without contrast enhancement, T2-weighted TSE (2500/100 and 2500/175, 6/0.6 mm) in the axial and coronal planes and SPIR/TSE (1800/80, 6/0.6) T2-weighted (2500/100, 6/0.6 mm) in the axial plane and dynamic T1-weighted TFE (15/4.7, th 10 mm). Image matrix size was 256 × 256. Respiratory compensation and spatial presaturation were used to decrease motion artefacts. Dynamic MR imaging was obtained immediately after rapid hand injection of Gd-DTPA in dosage of 0.15 mmol/cc followed by saline solution flush of 25 ml through an 18 G-venous catheter positioned in an antecubital vein. The axial dynamic contrast T1-weighted TFE images were performed in the same location of the hepatic tumours during the first 210 s (over a period of 210 s) after beginning of contrast administration. Images were selected in each phase on basis of the enhancement of normal structures: hepatic artery and aorta in the arterial dominant phase — usually 30-second delay, portal vein in the portal-venous dominant phase (usu-

ally 60-second delay) and parenchyma in equilibrium phase (usually 180-second delay).

CT study was performed on a HiSpeed Advantage scanner (General Electric Medical System). The first phase was non-contrast scans followed by i.v. contrast-enhanced imaging in the hepatic arterial dominant phase (second phase) at 20–25 s after starting intravenous administration of 120 ml of iodinated contrast material at a rate of 4 ml/sec through an 20 G venous catheter positioned in an antecubital vein using a power injector (Medrad). The third phase was the portal-venous dominant phase at 55–60 s and the last equilibrium phase was performed at 180 s after starting contrast injection. The CT section thickness was 5 mm, images interval — 5 mm and pitch — 1.5. Images were obtained with the standard liver window settings (width, 150 HU; level, 50 HU). Helical CT scans were obtained at 210 mA and 120 kV.

The MR study was limited to the liver and the lower abdomen was not evaluated.

In the CT study, the lower abdomen was examined in delayed phase with a 7-mm section thickness.

RESULTS

The right, middle and left hepatic veins 5 cm from their confluence and main portal branches were identified by MR images in all patients (100%).

In CT images the most detailed visualisation of the hepatic veins was obtained in the portal-venous dominant phase (PVP). The right, middle and left hepatic veins were identified in CT study 5 cm from their confluence as follows: right — 26 of 26 patients, middle — 24 of 26 patients and left — 25 of 26 patients (Table 1). In CT study the hepatic veins were seen 15 mm from their confluence in all cases.

The right portal branch was clearly visible on CT scans in 23 of 26 patients. In 3 patients with severe portal hypertension and thrombosis, the right branch of portal vein was not sufficiently seen in any phase of spiral CT scans. In these cases the right branch of portal vein was clearly seen on T2-weighted MR images (TSE and SPIR) and sufficiently visible in T1-weighted MR images without contrast enhancement (Fig. 1A, B). In CT study, the left portal branch was clearly visible in all cases, except one patient because of tumoral vascular structures invasion and vein replacement. This invasion of the left portal branch was clearly visualised in MR dynamic study after i.v. contrast administration.

The primary segmental location of liver lesions was correctly identified with spiral CT in 22 of 26

Table 1. The visualisation of hepatic veins and portal branches in CT and MR study

Name of vein	The number of identified cases in MR study	The number of identified cases in CT study
Right hepatic vein	26 of 26 (100%)	26 of 26 (100%)
Middle hepatic vein	26 of 26 (100%)	24 of 26 (92%)
Left hepatic vein	26 of 26 (100%)	25 of 26 (96%)
Right portal branches	26 of 26 (100%)	23 of 26 (88%)
Left portal branches	26 of 26 (100%)	25 of 26 (96%)

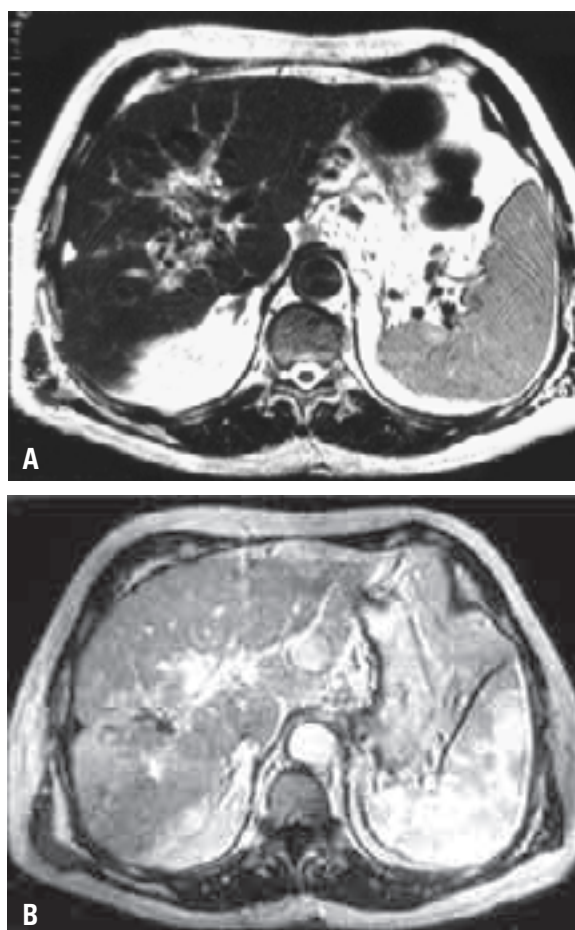


Figure 1. MR images of 69-year-old man with cirrhosis and several portal hypertensions. Transverse TSE T2-weighted MR image (A) clearly shows thrombosis of the right branch of portal vein and poorly presents the subcapsular HCC localised to two segments (7 and 8) of right lobe. Transvers PVP T1-weighted MR image (B) presents enhancement of tumour in segments 7 and 8.

patients and with MR in 24 of 26 patients (Fig. 2A, B, 3A–D). The CT images and surgical descriptions completely concurred with the segmental location and extent of the lesions for 19 of 26 hepatic tumours. In another 3 of 26 focal liver lesions, the sCT

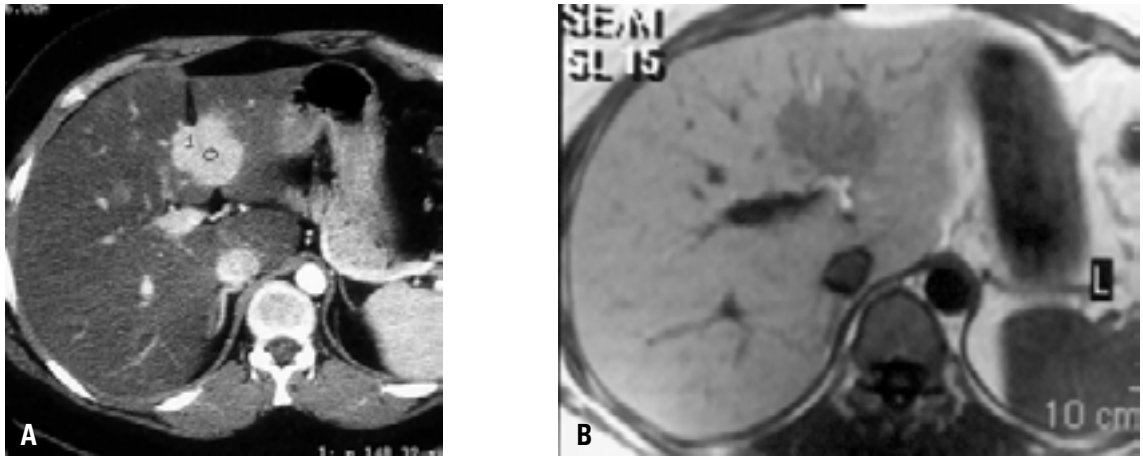


Figure 2. CT and MR images of 36-year-old woman with clearly visible FNH in segments 3 and 4 of left lobe. Transverse PVP CT scan (A) presents intensive homogeneous enhancement of lesion in segments 3 and 4. SE T1-weighted MR image (B) on the same plane shows hypointense mass localised to two segments (3 and 4).

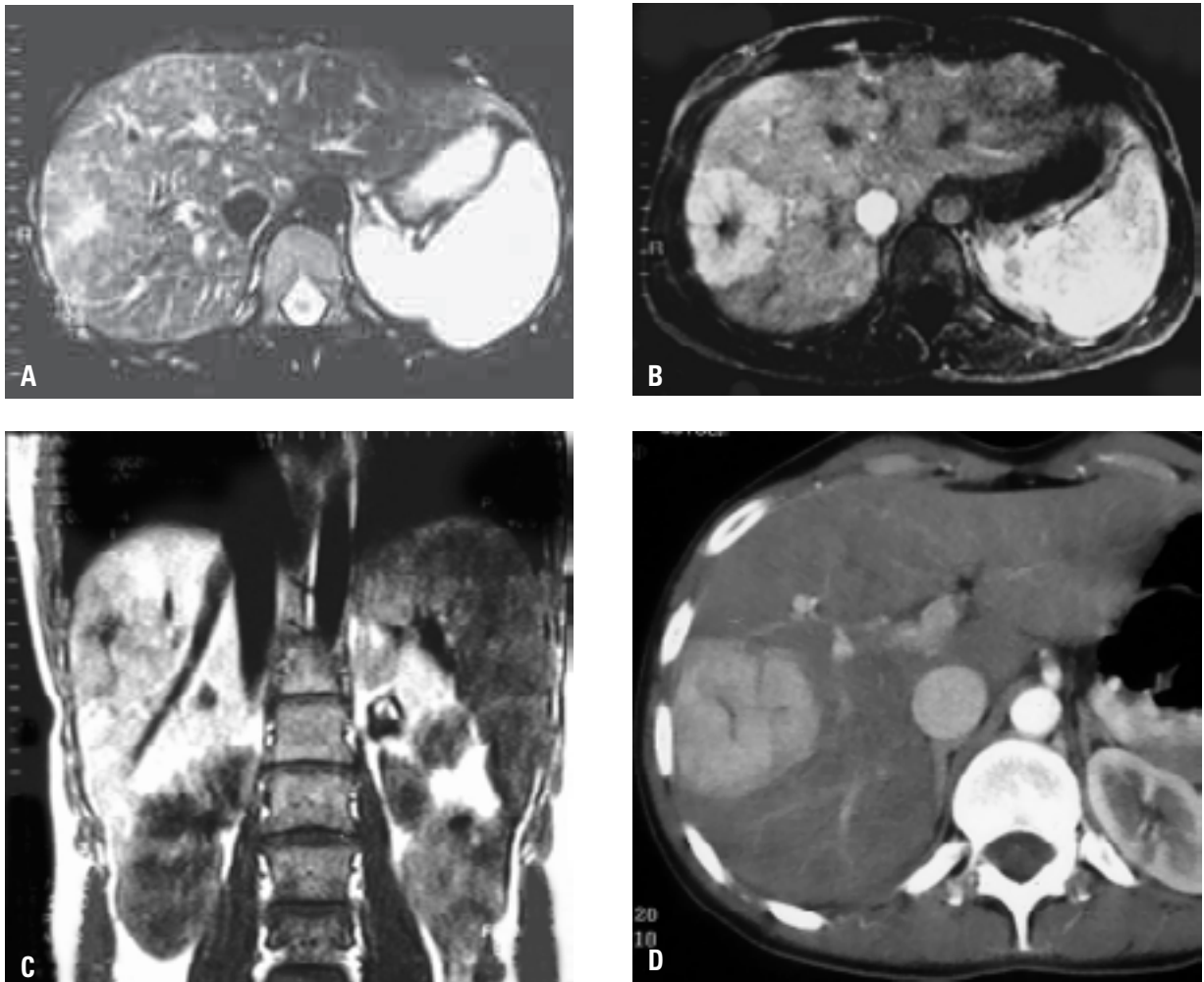


Figure 3. MR images of 22-year-old woman with FNH correctly localised to segments 8 and 7 of right lobe. The sCT and surgical description agreed with the primary location of this lesion in segment 8, but disagreed on the extent of it. Transverse TSE T2-weighted MR image (A) shows lobulated iso-intense mass with hyperintense central scar typical for FNH visible in segments 8 and partially in 7. Transverse PVP SE T1-weighted MR image (B) presents intensive homogeneous enhancement of this lesion. Coronal SE T1-weighted image (C) shows the tumour in segments. Transverse CT (D) scan of the same patient clearly shows a primary location of this tumour in segment 8.

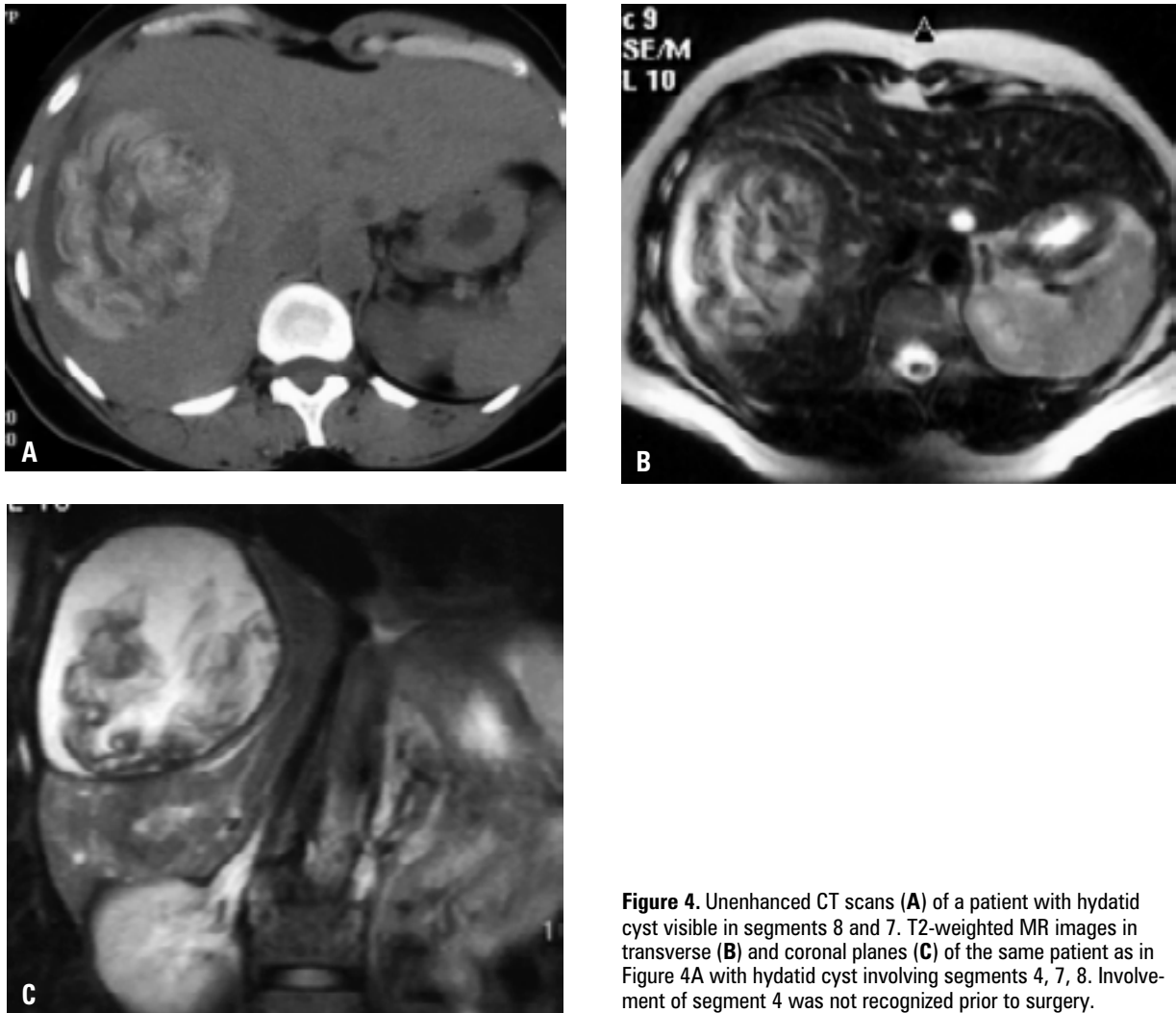


Figure 4. Unenhanced CT scans (A) of a patient with hydatid cyst visible in segments 8 and 7. T2-weighted MR images in transverse (B) and coronal planes (C) of the same patient as in Figure 4A with hydatid cyst involving segments 4, 7, 8. Involvement of segment 4 was not recognized prior to surgery.

and surgical description agreed with the primary location but disagreed on the extent of lesion (Fig. 4A–C). The full extent of the lesions was correctly evaluated with MR in 21 of 26 cases.

The spiral CT and MR images were incorrectly evaluated as to the segment location in one lesion, it was located in segment 1 and was described with radiological methods to be in segment 3 (Fig. 5A, B). Two metastases from colorectal cancer in one patient were noted during surgery and were not identified by MR and CT studies. These lesions (with diameter 12 and 15 mm) were located in segment 3 and were not visible at reanalysis.

DISCUSSION

In 1897 Cantlie [4] first described the main anatomic division of the liver by showing that it was not divided along the line of the falciform ligament but along a main plane (Cantlie's line) extending from the gallbladder fossa to the vena cava. Couinaud [6]

refined the functional anatomy of the liver and demonstrated that the liver was divided into four sectors and eight segments. In this nomenclature [2, 18], the liver is divided by vertical and oblique planes or scissura defined by the three main hepatic veins and a transverse plane or transverse scissure following a line drawn through the right and left portal branches. Thus, the four traditional segments (right anterior, right posterior, left medial and left lateral) have been replaced by sectors (right posterior, right anterior, left anterior, left posterior) and these sectors are divided into segments by the transverse scissure. The eight segments are numbered clockwise in a frontal plane. Each segment is an independent functional unit supplied by a single portal triad.

The portal vein provides about three quarters of the volume of blood supplied to the liver. After receiving the coronary and pyloric veins, the portal vein passage cranially in the hepatoduodenal ligament. In this structure, the portal vein lies dorsally to the



Figure 5. CT and MR images of 31-years-old woman with cirrhosis after partial resection of segment 4 because of HCC. Transverse PVP CT image (A) shows a hypodense lesion in the enlarged left lobe nearly left portal branch. T1-weighted MR image of the same patient (B) in transverse plane presents a hypointense lesion not enhanced after contrast injection in PVP. Transverse T2-weighted MR image (C) of the same patient shows this lesion nearly left portal branch. The segment location of this lesion was incorrectly described with radiological methods (in segment 3) and it was located in segment 1.

hepatic artery and bile ducts. The portal vein divides into right and left branches before entering the liver parenchyma. The right portal vein bifurcates into anterior and posterior branches with further division into superior and inferior branches. The left portal vein divides into medial and lateral branches, which supply the medial and lateral segments of the left lobe. Each branch provides anterior and posterior divisions.

Typically, there are three major hepatic veins (the right, left and middle). The right hepatic vein forms the boundary between the posterior and anterior portions of the right hepatic lobe, while the middle hepatic vein, together with the long axis of the gallbladder, forms a plane separating the right and left hepatic lobes. The caudate lobe of the liver is drained by several branches of the right and left portal vein and by the main caudate vein and minor hepatic veins directly into the vena cava [5]. These veins are quite small and often cannot be identified [8, 12].

Couinaud's nomenclature [5] provides critical information as to the potential resection planes. Surgeons need to know the number of lesions, their size, segmental location, extent and potential invasion to major vascular structures [3, 18, 19]. Recent advances in hepatic surgery have made possible anatomic (also called typical) resections along these planes while minimising morbidity and blood loss [10, 14].

Liver anatomy nomenclature is an invaluable asset for both radiologists and surgeons, allowing them to define the location of tumours and their relationship with major vascular structures, and making it possible to remove a tumour with clear tissue margins and preserve enough liver to sustain life [3, 11, 12].

Previous studies have demonstrated the ability of CT, US and MR to identify the portal and hepatic venous anatomy [8, 9, 11–15, 17, 19].

The gross radiological anatomy of the liver has been well described and the development of new imaging techniques, such as spiral CT, MR, sonography, has made identification and evaluation of the vascular structures significantly easier [8, 13, 15, 17]. Preoperative abdominal sonography provides a clear delineation of segmental anatomy, but the low sensitivity of this method in detection and differentiation of hepatic tumours makes this imaging insufficient [9, 12].

Pagani [15] first correlated hepatic vascular anatomy demonstrated in CT while planning a surgical approach. Mukai et al. [13] compared CT and MR imaging to determine the feasibility of hepatic resection. The study group and the results of their work are similar to ours. They were able to predict the surgical outcome in 21 of 25 cases by CT and 24 of 25 cases in MR imaging.

Arterioportography during CT study (CTAP) has an increased role in the preoperative management of patients with hepatic tumours because of the high sensitivity of this method for detection of focal liver lesion and tumour localisation [14, 19]. Nelson and co-authors [14] studied 36 hepatic masses in 20 patients who underwent CTAP and subsequent hepatic tumour resection. CTAP findings and surgical description agreed with the primary segmental location in 33 of 36 lesions but disagreed on the extent in 11 of 36 tumours. Further review of the CTAP scans of these 11 lesions revealed that the extent of the lesions were more correctly described at surgery in 6 tumours and at CTAP in 4 cases.

Soyer et al. [19] verified the ability of 3D-reconstruction and 2D CTAP study in determining the segmental location of hepatic metastases. The accuracy in determining the segmental location of hepatic metastases was 78% for 2D CTAP and 94% for 3D CTAP.

Jung et al. [11] discussed the role of non-invasive imaging to localise focal liver lesion to specific hepatic segments. In his study, the CT provided the most information for determining the segmental location. 21 lesions of 24 were correctly described with CT, and 17 of 24 cases concurred with MR findings.

We concluded that MRI and spiral CT were helpful preoperative tools for determining the segmental location of focal liver lesions and for planning the surgical approach. MR imaging is a more useful method for the localisation of hepatic tumors to the specific liver segment, particularly among patients with several portal hypertensions.

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