

INTRODUCTION

Liver tumors either benign or malignant including primary liver cancers and metastases are among the most common tumors in the world. Accurate detection of these tumors is of utmost clinical importance before treatment by resection or radio-frequency ablation as a potential curative treatment. Palliative interventions such as chemoembolization also require exact lesion localization. Accurate detection is necessary to ensure correct staging, to prevent tumors from being falsely rated as inoperable and patients with inoperable tumors from being scheduled for surgical procedures (*Huppertz et al., 2004*).

Relatively noninvasive modalities used to image the liver include ultrasonography (US), computed tomography (CT), and magnetic resonance (MR) imaging; more invasive modalities include CT with portography, and intraoperative US. Among the noninvasive techniques, MR imaging with dual liver-specific contrast agent has been shown to have higher ability for lesion detection and characterization than other modalities (*Huppertz et al., 2004*).

Several categories of contrast agents are currently available for magnetic resonance imaging of the liver. They improve lesion detection and characterization by increasing lesion liver contrast. These agents include reticuloendothelial system specific agents, hepatocyte-selective agents, and combined perfusion and hepatocyte-selective agents (*Karabulut and Elmas, 2006*).

Gadolinium ethoxybenzyl diethylenetriamine-pentaacetic acid (Gd-EOB-DTPA) is a new liver specific contrast agent. A bolus injection of this agent enables tumor vascularity to be evaluated in a manner similar to Gadolinium diethyltriaminepentaacetic acid (Gd-DTPA). Moreover, this contrast agent accumulates in normally functioning hepatocytes in the delayed phase thus, the liver parenchyma is enhanced; on the other hand, tumors appear as hypointense lesions because do not possess normally functioning hepatocytes (*Saito et al, 2005*). Therefore, it has been demonstrated to increase the detection of focal liver lesions and to provide differential diagnostic information (*Huppertz et al, 2004*).

AIM OF THE WORK

The aim of the present study is to point out the value of the dual liver specific contrast agent (Gd-EOB-DTPA) in detection and characterization of different hepatic focal lesions.

ANATOMICAL CONSIDERATION

Gross Anatomy of the Liver:

The liver is formed by eight independent functional units, each with specific vascular and biliary connections. The anatomy of the liver can be detailed based on the external appearance of the organ or based on its vascular and biliary architecture (vascular or functional anatomy) (*Bismuth 1982; Bismuth et al., 1982*).

The anatomy of the liver according to its external appearance identifies a superior or diaphragmatic surface and an inferior or ventral surface. On the superior aspect the falciform ligament separates the gland into a larger right lobe and a smaller left lobe (Fig. 1). The inferior surface is more varied: the round ligament continues into with the umbilical portion of the left portal vein (Fig. 2).

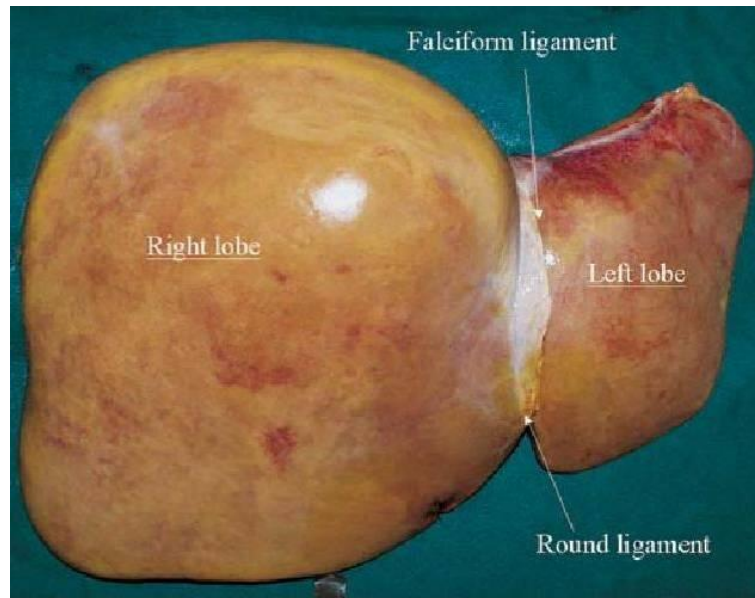


Fig. (1): Superior (Diaphragmatic surface of the liver) Quoted from (MAJNO et al., 2002).

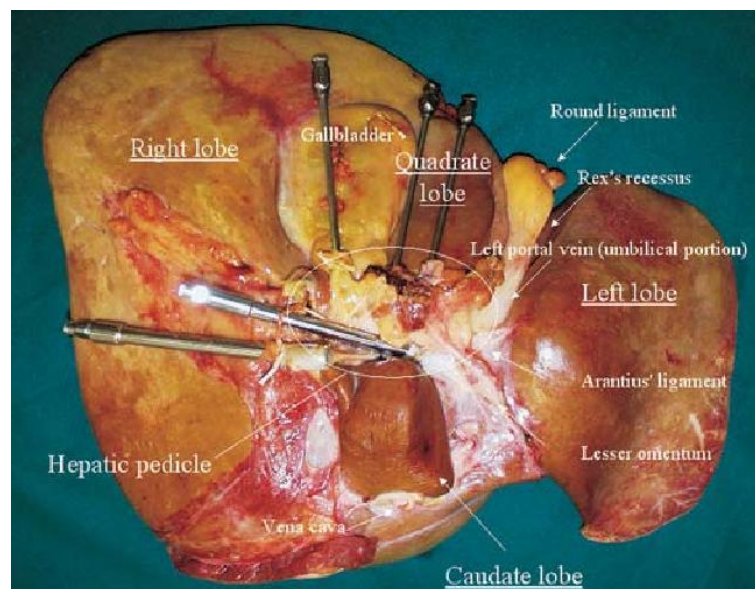


Fig. (2): Inferior (Visceral surface of the liver) Quoted from (MAJNO et al., 2002).

The hepatic pedicle” containing the portal vein, the hepatic artery and the bile duct spreads out, near the liver, in a space called the ”porta hepatis or hepatic hilum” (defined by the bifurcation of the portal vein) and divides into a shorter right pedicle and a longer left pedicle. The left pedicle runs almost horizontal and separates a quadrate lobe anteriorly and a caudate lobe posteriorly. Further on the left, the left hepatic pedicle arches up as an umbilical portion to join the round ligament. The lesser omentum extends from the left border of the hepatic pedicle, along the left hepatic pedicle, abandons the umbilical portion to follow Arantius’ ligament up to the vena cava and the diaphragm. It separates the left lobe anteriorly from the caudate lobe posteriorly. In 10%-20% of the cases an accessory hepatic artery (left hepatic artery) originating from the left gastric artery runs into the lesser omentum to join the left hepatic pedicle. Arantius’ ligament is the remnant of Arantius’ duct, or ”ductus venosum”, that in the fetal circulation connects the left portal vein to the caval system, and that runs from the angle between the transverse portion and the umbilical portion of the left portal vein to the confluence of the left and middle hepatic veins. The right hepatic pedicle is in contact with the gallbladder that defines the right border of the quadrate lobe. Posteriorly the right hepatic pedicle is separated from the vena cava by a rim of liver tissue that

corresponds to the right portion of the caudate lobe (*Majno et al., 2002*).

A simplified scheme of the liver segments assumes that the blood enters the liver from the portal vein (the arteries and the bile ducts follow the branches of the portal vein, so only the portal anatomy will be described hence forth) and is collected by three hepatic veins (left, middle and right) inserting into the inferior vena cava (Fig. 3). The main portal vein divides into two branches, right and left, defining a right liver and a left liver. The middle hepatic vein drains the liver from the main bifurcation. On the right, the right portal vein divides into two second order sectorial branches defining a right anterior sector and a right posterior sector, separated by the right hepatic vein. The third-order division of the (sectorial) portal branches will separate each sector into two segments. On the left, although sectors can be recognized on embryological grounds, it is simpler to remember that the portal vein describes an arch towards the round ligament, and that the concavity of this arch embraces one segment (limited on the right by the middle hepatic vein), and the convexity of the arch two segments, separated by the left hepatic vein (*Bismuth et al., 1982*).

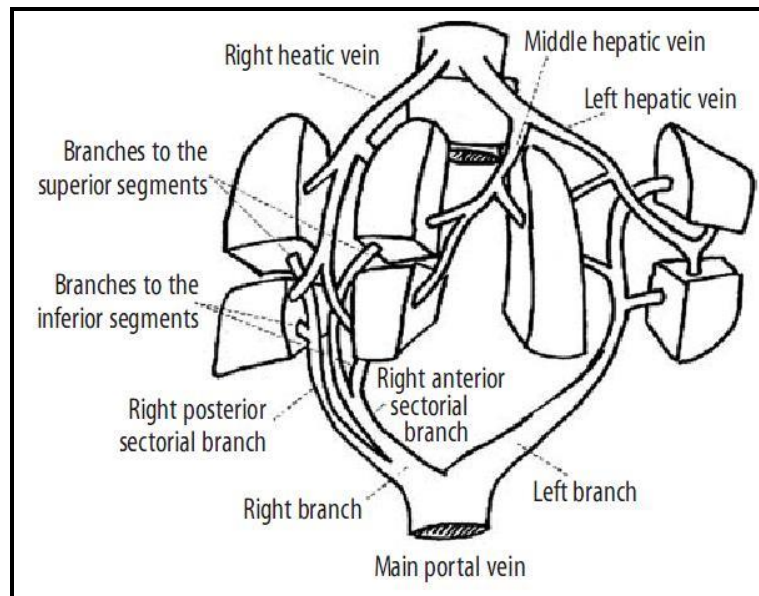


Fig. (3): Simplified scheme of liver segments. Quoted from *(Bismuth et al., 1982)*.

A last segment is constituted by the liver tissue that lies between the posterior aspect of the portal bifurcation and the vena cava. This segment extends from the left (where it has a recognizable external identity in the form of the caudate lobe) to the right, around the vena cava, up to the confluence of the hepatic veins. This segment is fed by a series of smaller portal branches originating from the portal bifurcation before the takeoff of the right and left portal branches, and its parenchyma is drained by a variable number of separate hepatic veins directly into the vena cava. The plane of separation between the right and the left liver can be approximated as a plane going from the gallbladder fossa to the vena cava in which runs the middle

hepatic vein. Couinaud named the eight segments of the liver from the centre (segment 1) clockwise when a cast of the liver vessels is seen from in front (*Bismuth et al., 1982*).

The correspondence between the descriptive anatomy and the functional anatomy

Only few landmarks on the external surface of the liver correspond to the functional (vascular) anatomy, and the eye of the surgeon is blind to the inner architecture of the liver. These landmarks are limited to the round ligament inserting into the umbilical portion of the left portal vein, the left portion of segment 1 (Spigel's lobe) separated from the left liver by the lesser omentum inserting along Arantius' ligament, and the gallbladder fossa, separating segment 4 from segment 5, therefore the right from the left liver. Also, in the rim of tissue between the portal vein and the vena cava, a notch on the surface separates a left portion of segment 1 (supplied mainly by the left half of the portal bifurcation) from a right portion, supplied by the corresponding part of the portal bifurcation. The importance of the division of segment 1 into two parts is questionable, although the notch offers a landmark to start right liver resections (*Kogure et al., 2000*).

Anatomical Landmarks and Nomenclature

The segmental anatomy described by Couinaud and modified by Bismuth is based on the three-dimensional concept that all hepatic segments except for the caudate lobe are defined by three vertical scissurae and a single transverse scissura. The middle hepatic vein (corresponding to the main scissura) divides the liver into right and left hemilivers. The right hemiliver is divided by the right hepatic vein into anterior and posterior sectors. The left hemiliver is divided by the left hepatic vein into medial and lateral sectors. There are four sectors (right anterior, right posterior, left medial, and left lateral). Each of these is divided into superior and inferior segments by a transverse line drawn through the right and left portal branches, the so-called transverse scissura. The eight segments are numbered clockwise in frontal view and counterclockwise from the inferior vena cava on a caudal to cranial view (*Fasel et al., 1998; Fischer et al., 2002; Strunk et al., 2003*).

Using cross-sectional imaging, the following anatomic landmarks are used to divide the liver into segments: hepatic veins, portal system, gallbladder fossa, falciform/round ligament, and ligamentum venosum. The falciform ligament contains at its base the obliterated umbilical vein (ligamentum teres or round ligament) and

separates the right from the left liver lobe. It is seen between the umbilical portion of the left portal vein and the outer surface of the liver. The ligamentum venosum carries the obliterated ductus venosus, which until birth shunts blood from the umbilical vein to the inferior vena cava and therefore runs from the umbilical portion of the left portal vein to the confluence of the left and middle hepatic veins (*Majno et al., 2002*).

MR anatomy of the liver

Computed tomography and MR are traditionally considered as cross-sectional axial imaging modalities, and the concept of three vertical planes that divide the liver into four sectors and of a transverse scissura that further subdivides the sectors into two segments each, is applied to localize liver lesions (*Couinaud 1957; Bismuth 1982; Soyer et al., 1994*).

The hepatic veins separate the following segments: the left hepatic vein separates segment 2 from segment 4; the middle hepatic vein separates segment 4 from segments 5 and 8; and the right hepatic vein separates the anteriorly situated segments 5 and 8 from the more posteriorly situated segments 6 and 7. The main portal vein divides into right and left branches. The right portal vein has an anterior branch that lies centrally within the

anterior segment of the right lobe and a posterior branch that lies centrally within the posterior segment of the right lobe. As the portal vein divides into the sectorial and the segmental branches very close to the hepatic hilum, the plane where the segmental branches originate can be approximated to the plane passing by the main portal bifurcation: in each sector the inferior segments (5 and 6) will lie caudal to the portal bifurcation, and the superior segments (7 and 8) will be cranial to it. Therefore in the right anterior sector segment 5 will be below and segment 8 above, and in the posterior sector segment 6 below and segment 7 above. The left portal vein initially courses anterior to the caudate lobe and describes a smooth arch from the main bifurcation to the round ligament. All liver tissue consisting of the concavity of the arch and the middle hepatic vein will be segment 4. On the convexity of the arch, on the left side (the left lobe of the descriptive anatomy) the distal part of the left hepatic vein will separate segment 2 (posteriorly and superiorly) from segment 3 (more anteriorly and inferiorly).

Anatomical landmarks, represented by hepatic and portal veins, can be represented on CT only after contrast media injection. These vessels are in fact hardly visible on baseline scans and during the arterial phase of a liver CT scan. A precise match between arterial phase and portal-

venous phase images is needed to assign the correct segment, also considering that some lesions are best depicted during the arterial phase (Fig. 4).

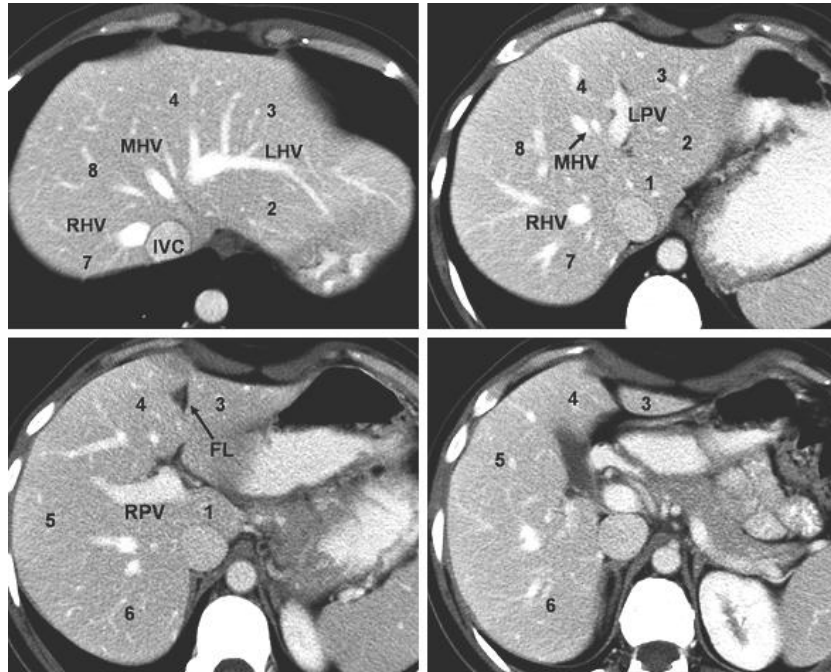


Fig. (4): CT segmental anatomy of the liver Quoted from (*Soyer et al., 1994*).

Magnetic resonance imaging has some inherent advantages in its segmental lesion localization, due to the natural high contrast between vessels and liver parenchyma also in the plain images (Fig. 5). After injection of paramagnetic contrast media the segmental delineation is almost the same as that described for portal-venous phase CT (Fig. 6).

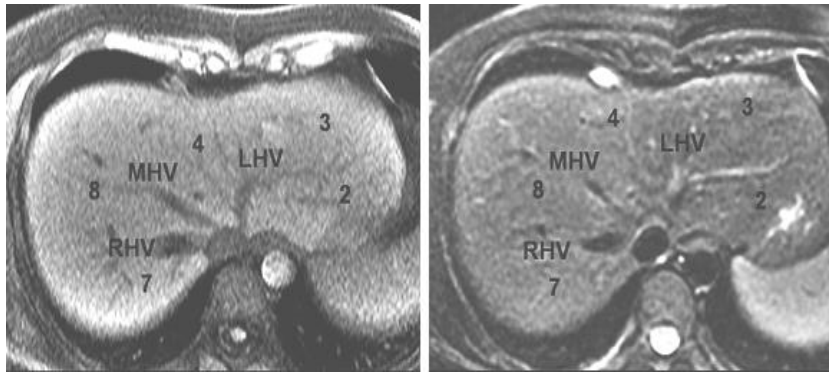


Fig. (5): Plain MR. segmental anatomy of the liver Quoted from *(Crocetti et al., 2005)*.

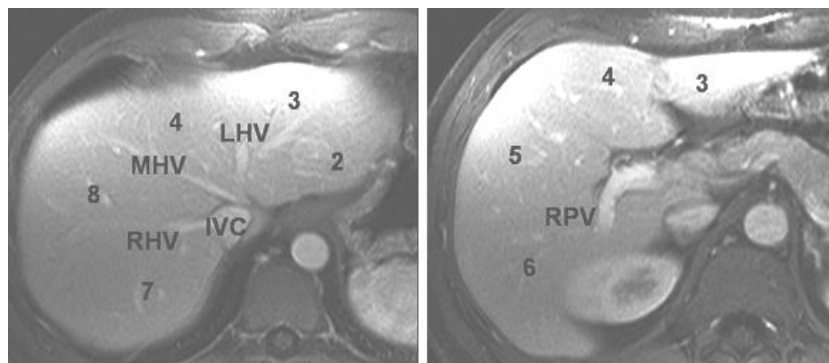


Fig. (6): MR postcontrast. Segmental anatomy of the liver Quoted from *(Crocetti et al., 2005)*.

Recent advances in MR imaging allow fast sequences (true-FISP, FIESTA) to be performed which are less sensitive to motion artifacts and in which blood has high signal intensity also in the absence of contrast material (Fig. 7) *(Nitz, 2002)*.

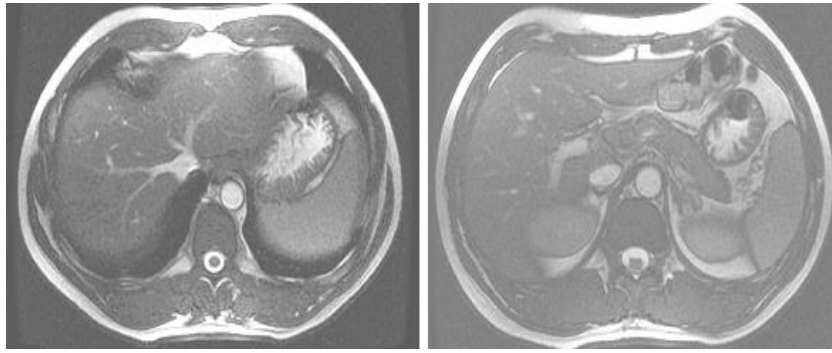


Fig. (7): MR post-contrast (true-FISP, FIESTA) segmental anatomy of the liver Quoted from (*Nitz, 2002*).

An additional point that has to be taken into consideration is that in the scheme previously described the hepatic veins are considered almost as flat structures running in planes, while in reality they are like branches of a tree, the vena cava. Because of the cross-sectionality of CT and MR, all these anatomical landmarks are not contained in a single image and a meticulous evaluation of the overlapping transverse slices in an interactive cine mode at a workstation allows the appreciation of the individual vascular anatomy. Multiplanar and three-dimensional reconstructions are not necessarily needed to provide insight into the segmental anatomy, but may often better convey to the surgeon the complex relationship between lesions and individual vascular anatomy (*van Leeuwen et al., 1994a; van Leeuwen 1994b*).

Blood supply of the liver