

Introduction

In the past, invasive contrast material enhanced conventional angiography was the main diagnostic tool in depiction of hepatic vascular anatomy (**Tanikake et al., 2003**).

Recently, multidetector CT (MDCT) with advanced imaging processing is considered a powerful non invasive diagnostic tool (**Saini, 2004**).

MDCT is considered the latest breakthrough in CT technology, by which thin sections could be acquired as a routine basis, in a single breath hold (**Kamel et al., 2004**).

Three-dimensional CT angiography is obtained by imaging processing either by, maximum intensity projection (MIP), surface shaded display (SSD), or volume rendering (VR) (**Tanikake et al., 2003**).

By advanced imaging processing, MDCT angiography could be an accurate non invasive method of depicting hepatic arterial anatomy. Multiplanar volume rendering and maximum intensity projection of multislice CT data allow for evaluation of hepatic parenchyma with early detection of neovascularity and tumor stain and enable better assessment of tumor burden compared with routine axial images (**Kamel et al., 2004**).

According to the degree of vascularity hepatic focal lesions, they are divided into hypervascular and hypovascular hepatic focal lesions (**Fishman, 2004**).

MDCT with advanced imaging processing is capable of differentiating between benign lesions and malignant lesions by visualization of feeding arteries, draining veins, central scars and septations (**Kamel et al., 2006**).

MDCT angiography is not only used in depiction of hepatic arterial anatomy with specific hepatic arterial variants, but also assesses the number of lesions, their size, and segmental location (**Fishman, 2004**).

In addition, MDCT is capable of detection of some features that are not well seen by axial plane including vascular displacement, encasement, invasion, neovascularity, tumor blush and arterio-venous shunting (**Luo et al., 2005**).

A volume display can determine the resectability of the lesion by showing whether it has directly invaded the portal vein, inferior vena cava or even the heart (**Fishman, 2004**).

Also, MDCT with advancing imaging processing is useful in delineating uncommon hypervascular liver lesions that simulate tumors. Familiarity with the appearance of the lesions may reduce the need for additional imaging follow up and histological correlation (**Kamel et al., 2006**).

Aim of Work

The aim of this work to highlight the role of MDCT with advanced imaging processing as non invasive modality, in depiction, characterization and evaluation of hepatic focal lesions.

Anatomy of the Liver

The liver assumes the shape of the cavity it occupies. It has two surfaces, the diaphragmatic surface and the visceral surface. The diaphragmatic surface is smooth and flat posteriorly and has a smooth, rounded upper surface with a large dome for the right hemidiaphragm and a smaller dome for the left hemidiaphragm. A depression between these marks the site of the central tendon and the overlying heart. The diaphragmatic surface ends anteriorly in the inferior border of the liver. This lies at the costal margin laterally to within about 4 cm from the midline, the site of the gallbladder notch. Medial to this, the inferior border ascends less obliquely than the costal margin and lies below it as it crosses the midline to meet the costal margin of the left side at approximately the eighth costal cartilage. The lateral extent of the left lobe is variable: it may extend only to the midline or may surround the stomach or spleen to reach the left lateral abdominal wall (**Ryan et al., 2004**).

In addition to the notch for the gallbladder, the inferior border is marked by a notch for the ligamentum teres. This ligament is the obliterated remnant of the left umbilical vein, which carries blood from the placenta to the fetus. It is also known as the round ligament. It passes, with small paraumbilical veins, from the umbilicus to the inferior border of

the liver in the free edge of a crescentic fold of peritoneum called the falciform ligament (meaning 'sickle-shaped'). This meets the liver just to the right of the midline. The site of attachment of the falciform ligament is used as an anterior marker of the sagittal plane of division of the liver into traditional anatomical left and right lobes. The posteroinferior, or visceral, surface of the liver is marked by an H-shaped arrangement of structures (see figure 1). The crossbar of the H is made by the horizontal hilum of the liver called the porta hepatis. This is the entry site of the right and left hepatic arteries and portal veins, and also the exit of the right and left hepatic ducts. There are also autonomic nerves and lymph vessels. The gallbladder in its bed, together with the IVC in a deep groove or tunnel, forms the right vertical part of the H. These are separated by the caudate process. The left vertical part of the H is formed by the ligamentum teres and the ligamentum venosum. The ligamentum teres runs to its attachment to the left portal vein in the left extremity of the porta hepatis. This is continuous with the fissure for the ligamentum venosum. This is a deep fissure lined by peritoneum, with the obliterated remnant of the ductus venosum (the ligamentum venosum) at its base. The ductus venosum shunts blood from the left umbilical vein to the IVC in the fetus, bypassing the liver. At the upper end of the fissure the ligamentum venosum curves laterally to attach to either the left hepatic vein or the IVC (Ryan et al., 2004).

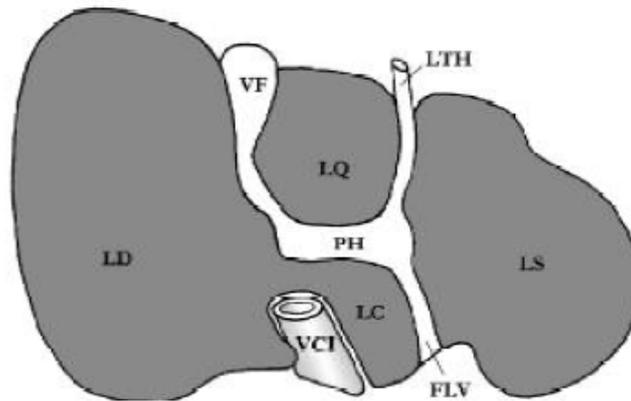


Fig. (1): Visceral surface of the liver. LD – right lobe; LS – left lobe; LQ – quadrate lobe; LC – caudate lobe; VF – gallbladder; LTH – ligamentum teres; PH – porta hepatis; FLV – fissure of ligamentum venosum; VIC – cava vena inferior. Quoted from (Saulius et al., 2006).

Segmental liver anatomy

The liver is comprised of two functionally independent right and left lobes, defined by the arterial distribution. Each is supplied by the right and left portal veins and the right or left hepatic arteries, and each drained by the right or left hepatic duct. The plane of division between these lobes is called the principal plane. There is no external marking of this plane on the anterosuperior surface, but it lies parallel to and about 4 cm to the right of the attachment of the falciform ligament. On the visceral surface the principal plane is defined by the IVC superiorly and the gallbladder bed inferiorly. The hepatic veins do not run with the structures of the portal triad (portal vein, hepatic artery and bile duct) but are intersegmental, draining portions of adjacent segments. The middle hepatic vein lies in the principal plane and drains from both lobes (Ryan et al., 2004).

The caudate lobe is segment I. Segments II and III are the furthest left, divided by the left hepatic vein from segment IV. The left portal vein separates segment II above from segment III below. Segment IV lies between the left hepatic vein and the middle hepatic vein. It is divided into segment IVa above and IVb below by the left portal vein. The right lobe has four segments, divided by the right hepatic vein into anteromedial and posterolateral divisions and by the plane of the right branch of the portal vein into superior and inferior sections. These four segments are numbered in a clockwise fashion from anterior inferomedial: V, VI, VII and VIII (see figure2). The segments may also be named descriptively according to their location, e.g. posterior segment (caudate), right posterior lateral, posterior medial, anterior lateral and anterior medial segments, and left medial superior, medial inferior and lateral segments (see table 1) (Ryan et al., 2004).

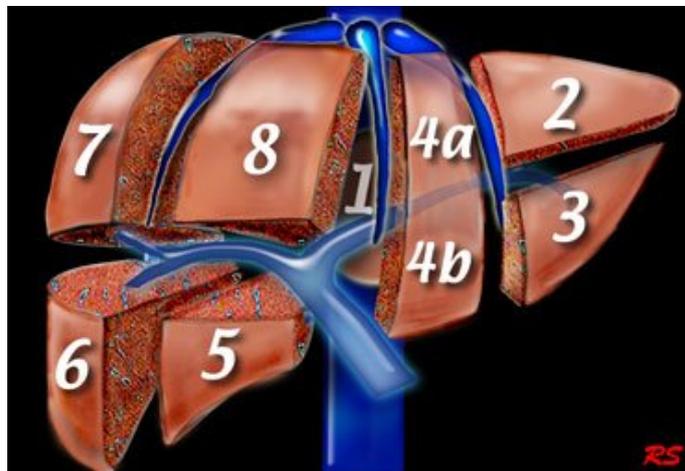


Fig. (2): Segmental anatomy of the liver. Quoted from (Soyer et al., 1994)

Table (1): Surgical anatomical terminology of hepatic segments. Quoted from **(Ryan et al., 2004)**

Right part of liver		Left part of liver		Posterior part of liver	
Right lateral division	Right medial division	Left medial division	Left lateral division	Right caudate	Left caudate
Seg VII (posterior superior)	Seg VIII (anterior superior)	Seg IVa (medial superior)	Seg II (lateral superior)		
Seg VI (posterior inferior)	Seg V (anterior inferior)	Seg IVb (medial inferior)	Seg III (lateral inferior)		

Liver vessels related to surface contours

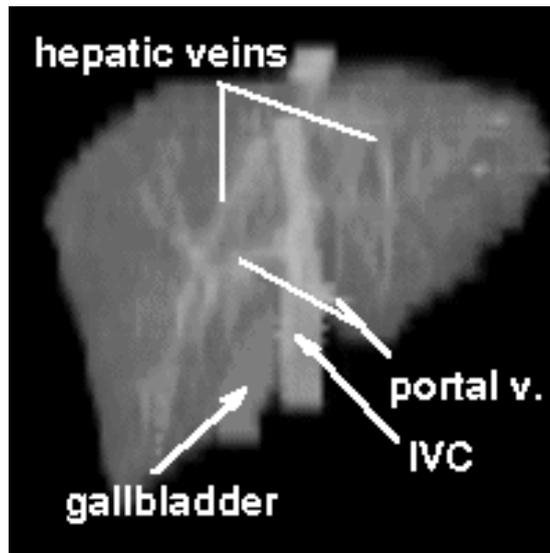


Fig. (3): MIP views of vessels related to surface contours with the gallbladder, IVC, and falciform ligament labeled. Quoted from **(Gazelle et al., 1999)**.

The 3-dimensional maximum intensity projections (MIP) shown above outline the vessels in white while showing the liver parenchyma in grey. This allows us to "see through" the parenchyma and relate surface contours to the underlying vessels. These MIP views show the portal vein entering the liver hilum. The portal veins project into the center of the Couinaud segments. In most cases, the vascular outflow for each segment is provided by the 3 hepatic veins at its periphery; however accessory hepatic veins are common (**Gazelle et al., 1999**).

Plane of the Right Hepatic Vein

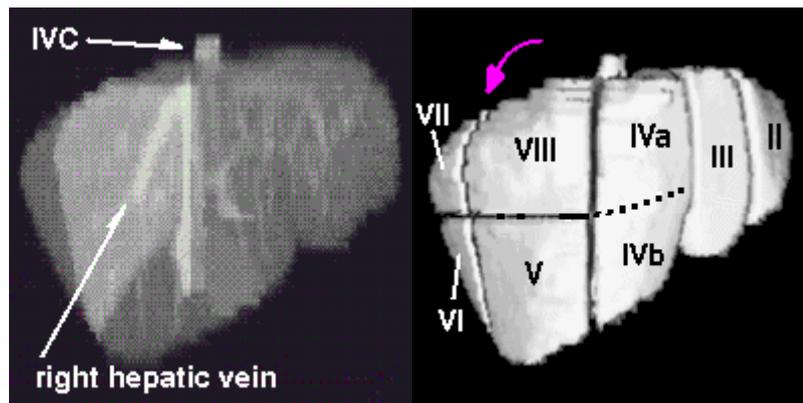


Fig. (4): MIP view of the liver (left panel) showing plane of right hepatic vein as it courses to the IVC. Shaded-Surface projection (right panel) showing, how the plane of the right hepatic vein provides the vertical division of the right liver lobe into anterior and posterior segment groups. Quoted from (**Gazelle et al., 1999**).

The intersegmental plane defined by the right hepatic vein subdivides the right lobe of the liver into anterior (V and VIII) and posterior (VI and VII) divisions. Shown above are a maximum intensity projection and surface projection of the liver indicating the location and significance of the right hepatic vein plane. Both projections are rotated 30 degrees to illustrate the positions of segments VI and VII which actually lie posterior to V and VIII and not lateral to them as they often appear in the literature. As will be explained later, the anterior and posterior divisions are further subdivided by a plane defined by the right portal vein. (Gazelle et al., 1999)

Plane of the Middle Hepatic Vein

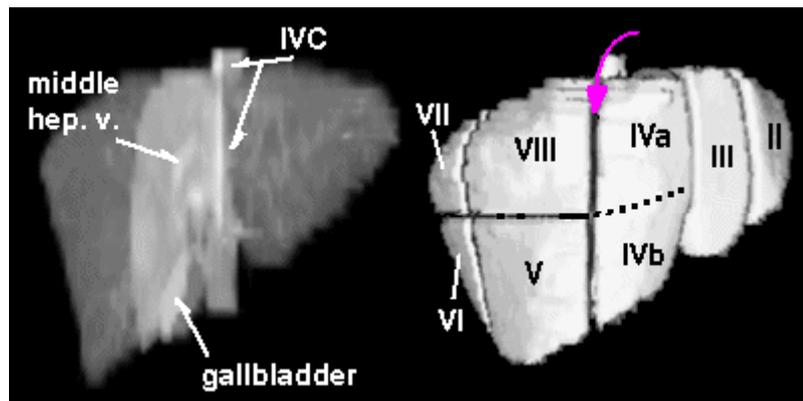


Fig. (5): MIP and shaded surface views showing that the course of the middle hepatic vein falls roughly along a plane extending from the gallbladder fossa and the IVC. This plane divides the right hepatic lobe from the left hepatic lobe. Quoted from (Gazelle et al., 1999)

In both the traditional and the Couinaud classifications, the plane defined by the middle hepatic vein subdivides the liver into the true right and left lobes. A standard right or left lobectomy requires division along the plane of the middle hepatic vein. Segments IVa and IVb lie to the left of the plane while segments V and VIII lie to the right with VIII being superior to V. In Fig.5, the gallbladder is slightly brighter than the rest of the plane. Because the plane of the middle hepatic vein usually intersects the gallbladder fossa, Cantlie's line (the projection on the liver surface of a plane between the gallbladder and IVC) is generally a valid line of division between the right and left lobes. However, it is the vasculature that determines the true boundary (**Gazelle et al., 1999**).

Plane of the Umbilical Fissure

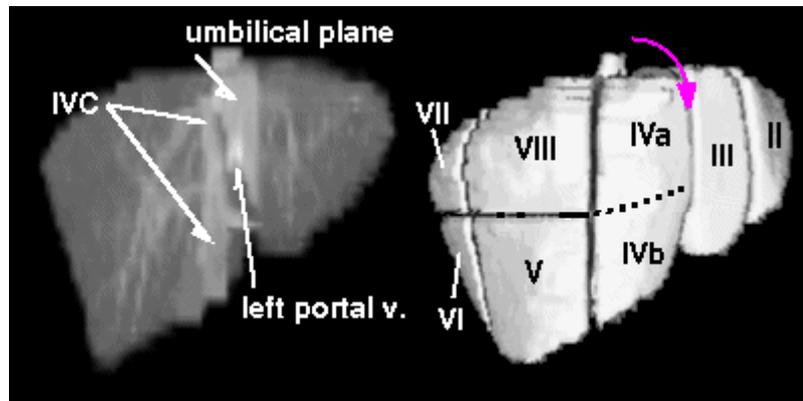


Fig. (6): MIP and shaded-surface views showing that the plane of the umbilical fissure divides the left lobe into medial and lateral portions which need to be further divided to qualify as independent Couinaud segments. Quoted from (**Gazelle et al., 1999**).

The umbilical plane divides the left lobe of the liver into medial (segment IV) and lateral (segments II and III) divisions. This division is the only vertically oriented plane of division that is not defined by the hepatic veins. It can be defined on the surface of the liver by its associated landmarks. It extends from the umbilical fissure anteriorly through the ligamentum venosum along the lateral aspect of the caudate lobe. Structures within the plane of the umbilical fissure include the falciform ligament, ligamentum venosum, and the ligamentum teres. The ligamentum venosum and the ligamentum teres are remnants of the ductus venosus and umbilical vein respectively (Schneck et al., 1994).

Plane of the Left Hepatic Vein

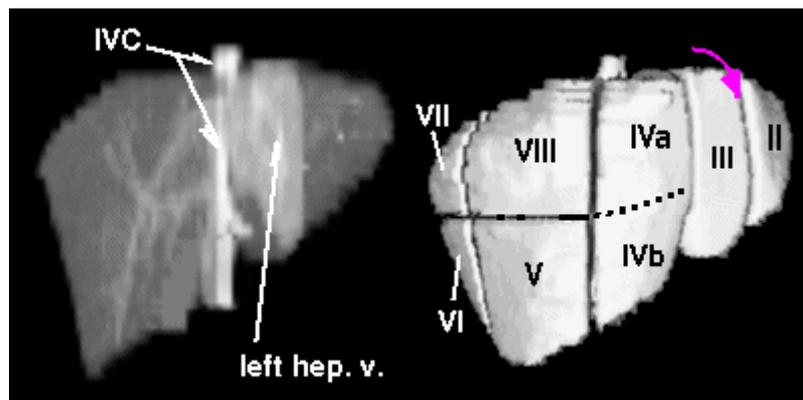


Fig. (7): MIP and shaded-surface views showing that the plane of the left hepatic vein subdivides the lateral portion of the left hepatic lobe. Quoted from (Gazelle et al., 1999).

The significance of the left hepatic vein plane is somewhat controversial. Some authors have shown it to coincide with the umbilical fissure (Soyer et al., 1994).

In reality the left hepatic vein courses to the lateral to the umbilical fissure. Some authors have claimed that the true division between segments II and III is formed by the transverse plane of the left portal vein. Most investigators feel that the plane defined by the left hepatic vein is a true intersegmental boundary and is not the same as the plane of the umbilical fissure. The plane of the left hepatic vein as the boundary between segments II and III. In actual practice, when a lesion occurs within the lateral segment of the left lobe, both Couinaud segments II and III are usually removed based on the plane formed by the umbilical fissure (left lateral segmentectomy). Note that because the plane of the left hepatic vein is oblique, it forms a division between segments III anteriorly and segment II posteriorly (Gazelle et al., 1999).

Plane of the Portal Vein

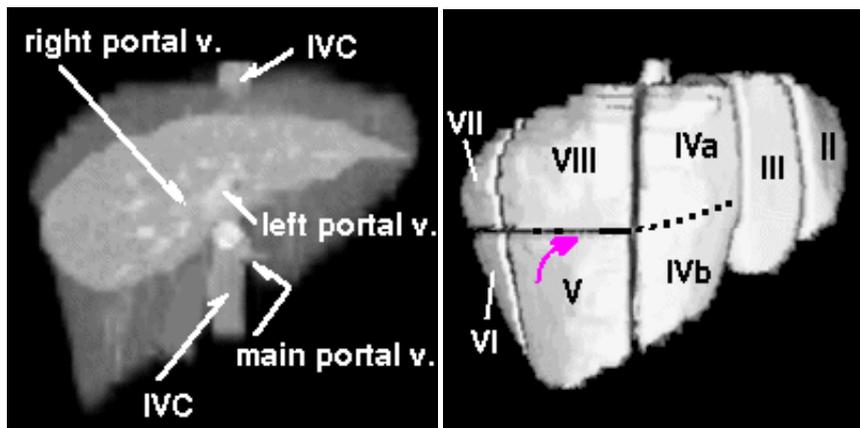


Fig. (8): MIP and shaded surface views showing the plane of the main intrahepatic portal vein. Note this plane (arrow on surface view) is roughly horizontal but in some cases may be angled as shown in the MIP dataset. The dotted line indicates how this plane is sometimes used to divide segment IV into superior (IVa) and inferior (IVb) divisions. Quoted from (Gazelle et al., 1999).

In Couinaud nomenclature, the plane defined by the right branch of the portal vein divides the anterior and posterior divisions of the right liver superiorly and inferiorly, thus dividing the right lobe into 4 segments (V-VIII). The medial segment of the left lobe can also be divided into two segments by the plane of the portal vein (IVa and IVb). (*Soyer et al., 1994*)

Couinaud Segments: the Complete Picture

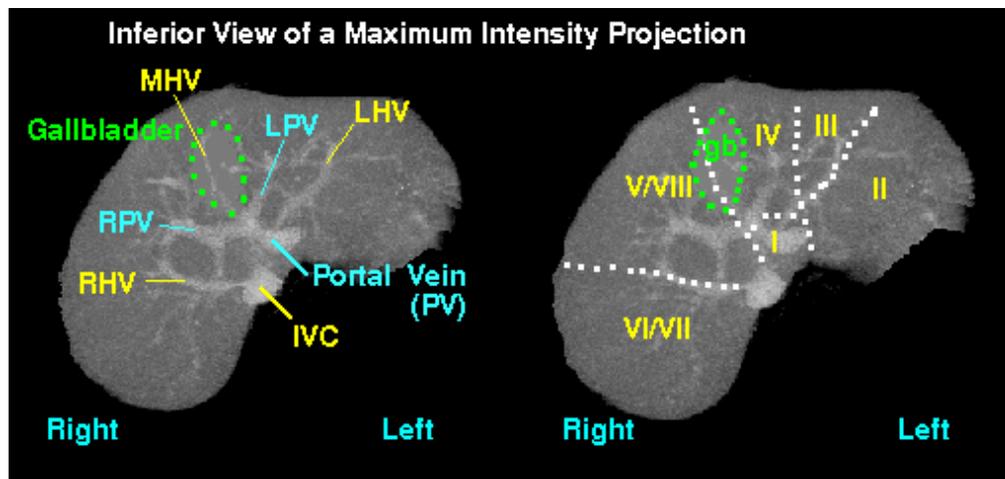


Fig. (9): Definition of the segments is shown with maximum intensity projections from an inferior view of the entire 3-dimensional data set much as seen on the standard CT scan except that the "see through" nature of data allows us to see the courses of the portal and hepatic veins in one view. Quoted from (*Gazelle et al., 1999*).

In the projections of the entire 3dimensional data set below, you are looking through the entire liver, and the course of the portal and hepatic veins are seen in a single view (left panel). The right panel maps the peripheries of the Couinaud segments with dotted lines. Note that the portal branches supply

the middle of the segments while the hepatic veins drain the periphery of the segments. Note also that segments I, II, VI, and VII are mostly posterior and hidden from the surgeon's view in the operating room. Before surgical resection, focal liver lesions must be defined in relation to the deep vessels and the segmental anatomy (**Gazelle et al., 1999**).

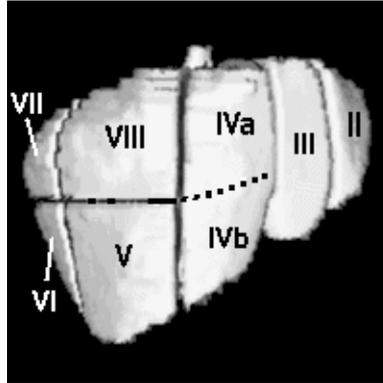


Fig. (10): Surface Projection of the liver showing the 8 Liver Segments as defined by the underlying vascular planes. Note that the plane of the portal vein subdivides segment IV into two parts (IVa and IVb). Quoted from (**Gazelle et al., 1999**).

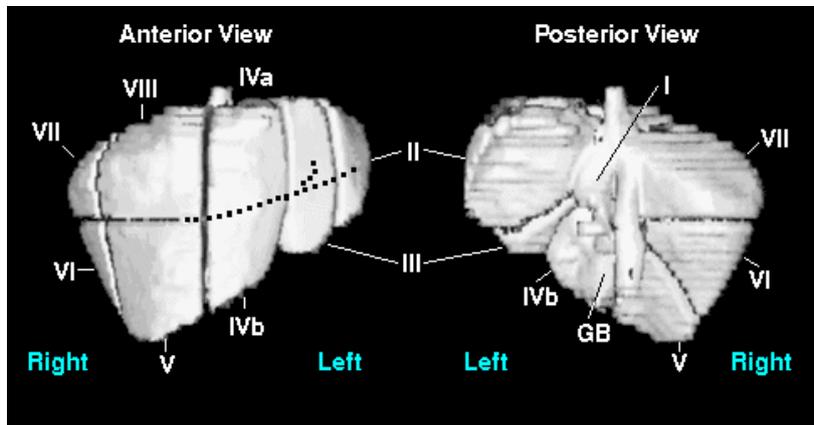


Fig. (11): Anterior and posterior view of liver showing 3-dimensional reconstructions of helical CT scan data in shaded surface projections which have been segmented according to the Couinaud classification. Quoted from (**Gazelle et al., 1999**).