

Introduction

Hepatocellular carcinoma (HCC) is the most common primary liver malignancy and is a leading cause of cancer-related death worldwide (*Julius Balogh et al., 2016*).

Surgical resection and local ablative therapies represent the most frequent first lines therapies adopted when liver transplantation cannot be offered (*Alessandro Cucchetti et al., 2013*).

Radiofrequency ablation has become the most widely used local thermal ablation method in recent years because of its technical ease, safety, satisfactory local tumor control, and minimally invasive nature (*KaiFeng and Kuan et al., 2014*).

After certain loco-regional treatments such as RFA, the assessment of tumor response remains difficult. The usual morphological criteria primarily based on the maximal lesion size cannot be used with confidence, as the induced ablation zones comprise the tumor and its margin (*Lu et al., 2012*).

Diffusion-weighted imaging represents a promising non-invasive diagnostic tool for the evaluation of HCC

treatment responses to loco regional therapies (***Johannes M et al., 2015***)

In addition, DWI can help characterize focal hepatic lesions by enabling measurement of lesion apparent diffusion coefficient (***Parikh et al.2008***)

ADC value changes have been shown to occur early after treatment and correlate well with tumor necrosis (***Johannes M et al.2015***)

Aim of work

To assess role of diffusion weighted MRI in evaluation of treatment response after radiofrequency ablation for hepatocellular carcinoma.

Chapter (1)

Anatomy of the liver

The liver, the largest internal organ and largest gland in the body, weighs about 1500 grams. It lies mainly in the right upper quadrant where it is hidden and protected by the thoracic cage and diaphragm. The normal liver lies deep to 7-11 ribs on the right side and crosses the midline toward the left nipple (**Moore & Agur, 2007**).

The liver is wedged shaped with its base towards the right abdominal wall, and its tip points to the spleen. It is 12-15 cm craniocaudally and 15-20 cm from the corner to the corner (**Schiff et al., 2007**).

The liver is enclosed within a thin fibrous hepatic capsule which is just beneath the visceral peritoneum. Septa are seen projecting into hepatic parenchyma from the hepatic capsule (**Bisthmus, 2013**).

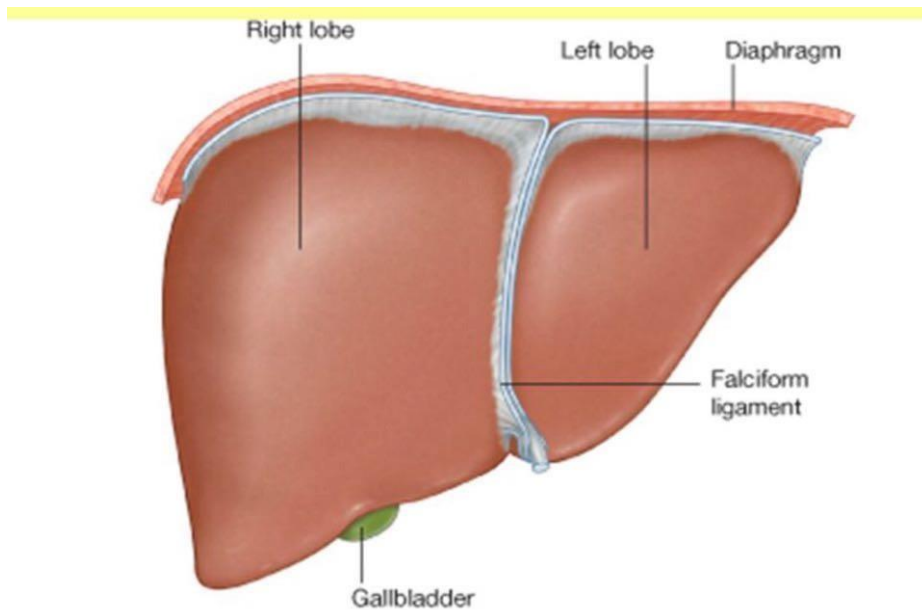


Figure (1): The anterior-superior surface of the liver (*Quoted from standing et al.,2005*).

Anatomical lobes of the liver:

(1)Right lobe:

The right lobe of the liver is the biggest lobe in size; it exceeds the left lobe by a ratio of 6:1. It occupies the right hypochondrium and is bounded on its superior surface by falciform ligament. Its inferior and posterior surfaces have three fossae; the portahepatis, the gall bladder fossa, and the inferior vena cava. Riedel's lobe is a congenital variant which can at times be seen as an inferior bulge of the liver (*Standring et al.,2008*)

(2) Left lobe:

The left lobe of the liver is smaller than the right lobe. It is seen in the epigastric and left hypochondrium regions. Its superior surface is convex. Its inferior surface has the gastric impression and omental tuberosity. It is bounded by the gall bladder on the right side and by the umbilical vein fossa on the left side (*Strasberg & Phillips 2013*).

(3) Caudate lobe:

The caudate lobe is seen on the posterior surface. It is a small lobe. It is bordered on the left side by the fissure for ligamentum venosum, inferiorly by the portahepatis & by the groove for the inferior vena cava on the right side. Superiorly it continues with the superior surface of the liver. Inferiorly and to the right it is attached to the right lobe of the liver by the caudate process (*Standring et al., 2008*).

(4) Quadrate lobe:

The quadrate lobe is only noticeable from the inferior surface, it appears to some extent rectangular. On the right it is bordered by fossa for gall bladder and by fissure for ligamentum teres on the left side. Anteriorly it is bounded by the inferior border and by the portahepatis posteriorly (*Standring et al., 2008*).

Segmental anatomy of the liver

Understanding of the anatomy of the segments of the liver is vital for localization and appropriate management of the liver tumors. The system projected is projected by Couinaud 1957 provides the surgically significant imaging technique (**Rubin, 2006**)

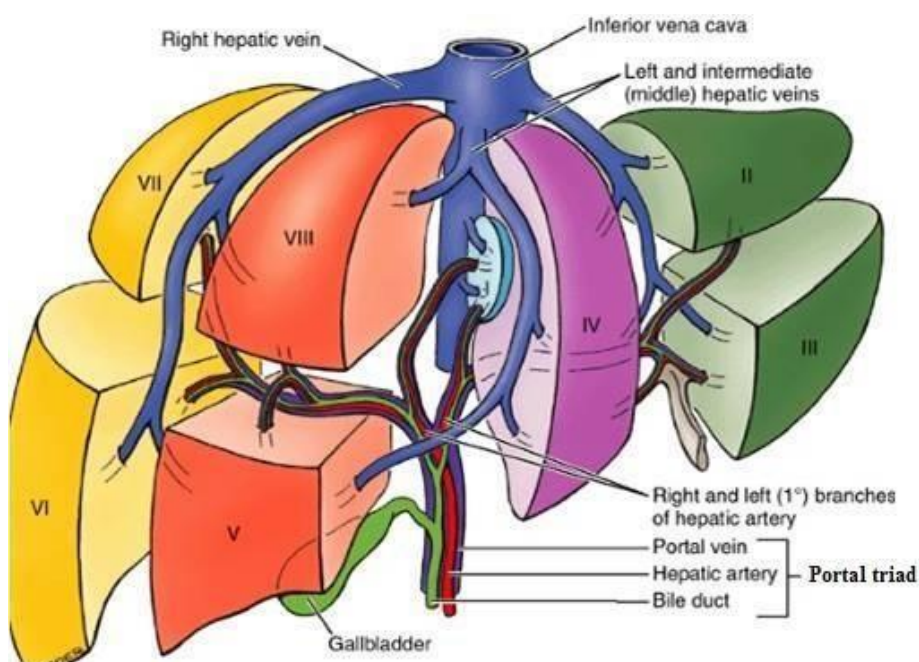


Figure (2): Diagram showing hepatic segmentation (*Quoted from Moore & Agur, 2007*).

The liver is divided according to Couinaud classification into 8 segments; each has its vascular flow, outflow and biliary drainage. The main portal vein is divided into two main branches: the right and the left branches.

The plane of demarcation between the right and the left liver can be approximated as a plane going from the gall bladder fossa to the vena cava in which the middle hepatic vein runs. (*Bisthmus, 2013*).

Segment one is the caudate lobe. The rest of the liver segments are divided as follows, the right hepatic vein is the first landmark. All of the segments located anterior and to the left of the right hepatic vein will be included in the right anterior section (segments 5 and 8) and all the segments located posterior and to the right will be included in the right posterior section (segments 6 and 7). The third order bifurcation of the portal vein will be the second landmark (where the right sectorial branches separate into segmental branches). It is not necessary to follow the segmental branches as the plane where the segmental branches begin can be the plane passing by the main portal bifurcation approximately. In each sector the inferior segments (5 and 6) will lie inferior to the portal bifurcation, and the superior segments (7 and 8) will be superior to it (*Majno et al., 2005*).

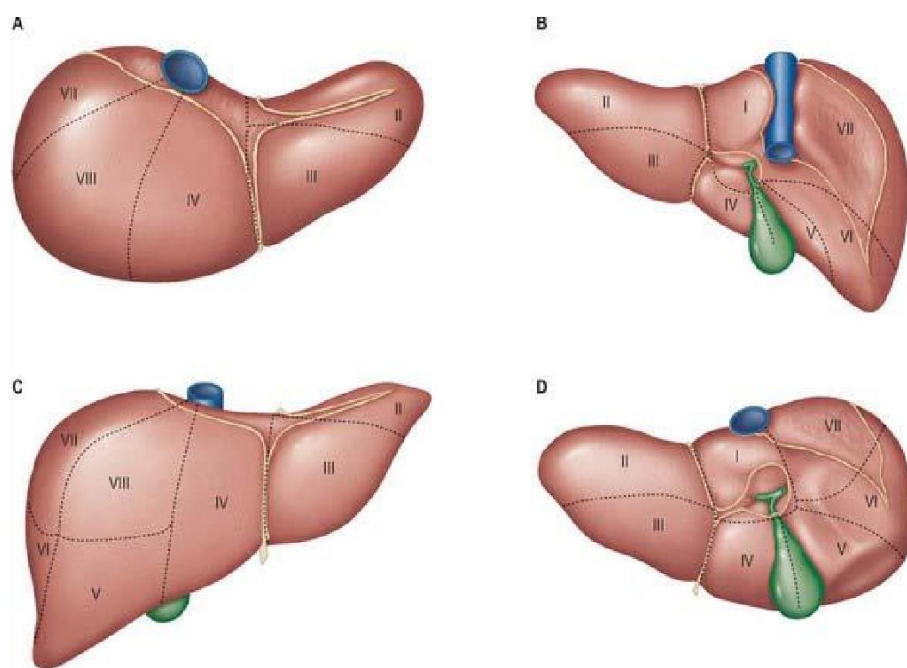


Figure (3): Segments of the liver (after Couinaud). **A**, superior view; **B**, posterior view; **C**, anterior view; **D**, inferior view. The segments are sometimes referred to by number (name) – I (caudate) (sometimes subdivided into left and right parts); II (left lateral superior); III (left medial inferior); IV (left medial superior) (sometimes subdivided into superior and inferior parts); V (right medial inferior); VI (right lateral inferior); VII (right lateral superior); VIII (right medial superior). (*Quoted from standring et al., 2008*).

Vascular supply of the liver:

The liver receives blood from two sources: the portal vein (PV) (75- 80%) and the hepatic artery (HA) (20-25%). The PV carries poorly oxygenated blood from the abdominal pelvic portion of the gastrointestinal tract. The portal vein is the final common pathway for the transport of venous blood

from the spleen, pancreas, gallbladder, and the abdominal part of the gastrointestinal tract. It is formed by the union of the splenic vein and the superior mesenteric vein posterior to the neck of the pancreas at the level of L2 vertebra. The HA, a branch of the celiac trunk, carries oxygenated blood from the abdominal aorta. At or close to the porta hepatis, the HA and PV terminate by dividing into right and left branches, which supply the right and left lobes of liver, respectively. Within each lobe, the primary branches of the PV & HA are consistent enough to form vascular segments ((*Moore & Agur, 2007*)).

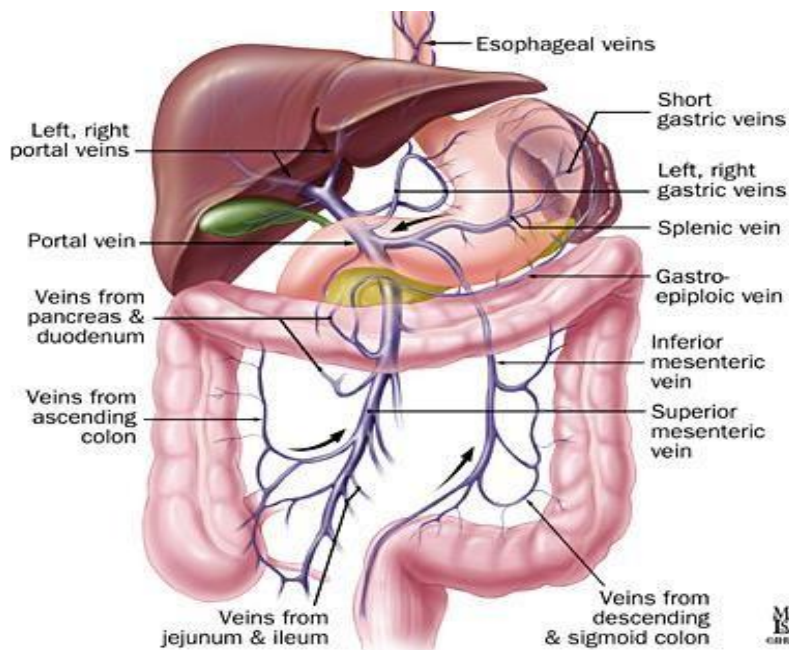


Figure (4): Anatomy of portal vein (*Quoted from Cichoz-Lach et al., 2008*).

Between the segments are the right, intermediate (middle), and left hepatic veins (HVs), which drain parts of adjacent segments. The HVs open into the IVC just inferior to the diaphragm. The attachment of these veins to the IVC helps hold the liver in position (*Moore&Agur, 2007*).

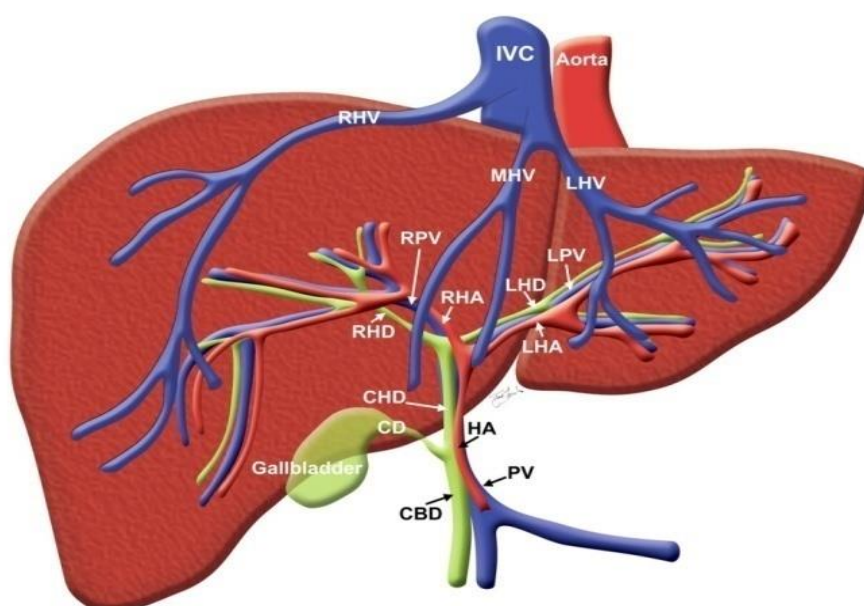


Figure (5): Normal anatomy of the hepatic arterial, venous and biliary tract (*Quoted from Torres et al., 2005*).

Magnetic resonance imaging anatomy of the liver

MR imaging provides complete assessment of the liver including the hepatic parenchyma, vascular supply & biliary system. Computed tomography and sonography are frequently used as the initial studies to evaluate the liver;

the role of MR is increasing nowadays as a primary imaging modality in addition to its capacity as a problem solving tool. MR provides better soft tissue characterization that couldn't be achieved with other imaging modalities, also lack of ionizing radiation and being operator independent are more advantages over computed tomography and ultrasound respectively (*Altun et al., 2015*).

Segmental MR liver anatomy:

The eight liver segments described by *Bithmus et al., 1982*, are numbered clockwise based on a frontal view of the liver beginning with the posterior superior segment of the left paramedian sector, which corresponds to the caudate lobe, and ending with segment VIII which is consistent with the posterior superior segment of the right paramedian sector (*Schneider et al., 2006*).

Anatomically, the borders of the liver segments are well-defined, but show a wavy-shaped course. However, in clinical routine, segmentation of the liver on cross-sectional MR imaging is sharply demarcated and usually based on certain landmarks that define the underlying borders (*Lee et al., 2006*).

Based on these landmarks, the IVC is considered the center point for liver segmentation. A line from the IVC to the middle hepatic vein and the gallbladder separates the left and right hemi liver and the corresponding liver segments V/VIII and I/IV a, b respectively. Whereas the axis between the IVC and right hepatic vein corresponds to the border between liver segments VI/VII and V/VIII, the line between the IVC, the left hepatic vein and the falciform ligament separates liver segments IVa and IVb from segments II and III (*Schneider et al., 2006*).

Whereas liver segments VII, VIII, I, IVa and II are located at the posterior aspect of the imaged abdominal situs and above the level of the left and right main portal vein, segments VI, V, IVb and III are located inferior to the level of the main portal vein at the anterior aspect of the liver. Segment I corresponds to the caudate lobe (**Fig. bellow**) (*Hussain, 2007*).

The axial sections:

The vascular structures are better demonstrated in the axial MR images spin echo MRI sequence where the vessels appear as areas of signal void (*Yan et al., 2013*).

The inferior vena cava is demonstrated as a round, signal-free structure grooving the posterior inferior surface of the liver

between the right and caudate lobes (between segments VII and VIII of the right lobe and segment I) (*Lomas, 2008*).

The hepatic veins lie between the lobes and segments of the liver. Classically there are three main branches. Segments 2 & 4 are separated by the left hepatic vein. Segment 4 is separated from segment 5 and 8 by the middle hepatic vein. The anteriorly situated segments 5 and 8 are separated from the posteriorly situated segments 6 and 7 by the right hepatic vein (*Yan et al., 2013*)

The portal vein course is typically seen on axial images where it passes from its location behind the pancreas, through the hepatoduodenal ligament, to the portahepatis. Oblique coronal MRI images can be used to demonstrate the entire length of the main portal vein (*Leyendecker et al., 2011*).

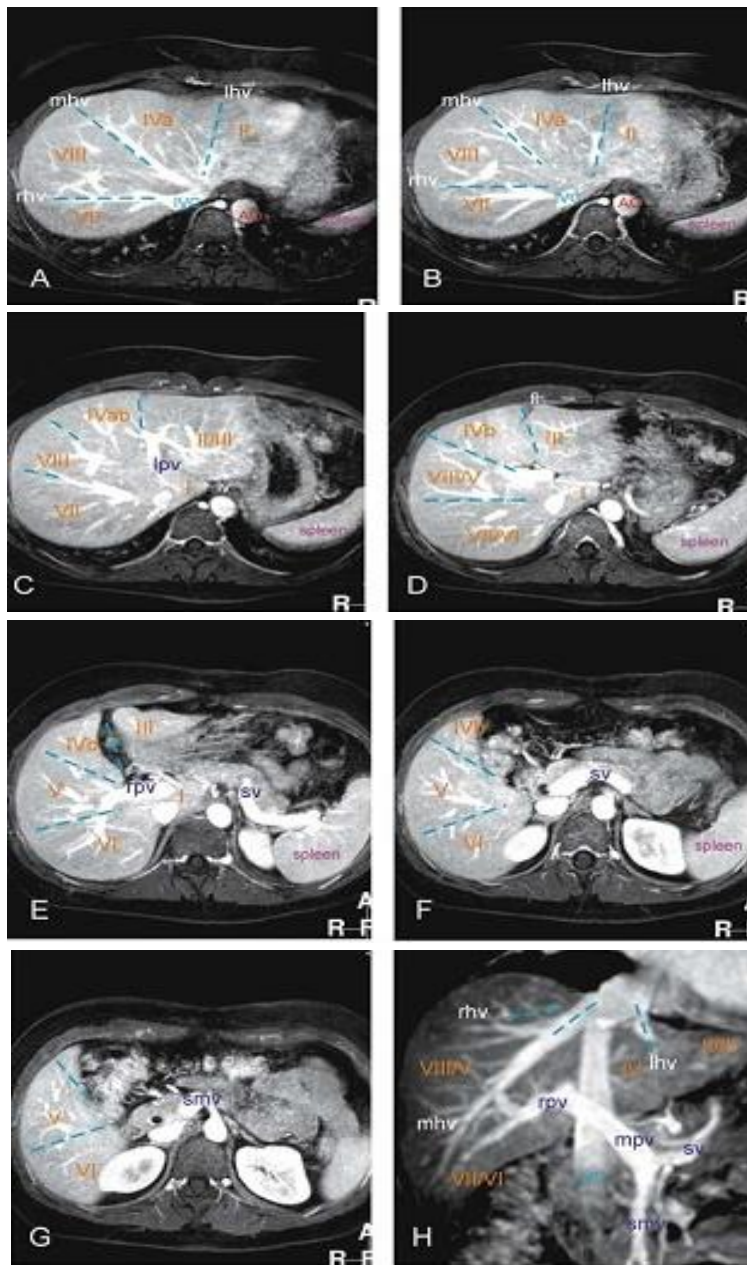


Figure (6): A–G Axial MIP based on 3D contrast - enhanced delayed phase gradient echo images at various levels shows the hepatic segments (I–VIII), 3 hepatic veins, PV, & ligaments. (H) Coronal reformat shows relationship among the hepatic segments, 3 hepatic veins, PV, & IVC (*Hussain, 2007*).