DIFFUSION WEIGHTED MRI IN EVALUATION OF HEPATIC FOCAL LESIONS

ESSAY

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Introduction

Accurate detection and characterization of focal liver lesions (FLL) are important for treatment planning for patients with liver neoplasms such as hepatocellular carcinoma (HCC) and metastases. The size and number of lesions can affect therapy. For example, patients with limited resectable metastatic lesions may benefit from curative resection ***(Jamison et al 1997)***,and patients with fewer than three small HCCs are candidates for liver transplantation ***(Mazzaferro et al 1996)***.Patients with more extensive disease should instead undergo transarterial
chemoembolization, radiofrequency ablation, or systemic chemotherapy ***(Heslin et al 2001)***.

For detection and characterization of FLL common imaging techniques used are ultrasound (US) and computed tomography(CT) due to their wide availability and high accuracy .Magnetic resonance imaging (MRI) of the liver is less commonly used than either CT or US. For FLL detection and characterization, MRI relies on T1-weighted, T2-weighted, and dynamic gadolinium-enhanced T1-weighted imaging ***(Hussain et al 2002).***

Diffusion-weighted (DW)-MRI is a novel functional imaging method allowing in vivo measurements of tissue water mobility. DW-MRI offers the potential to serve as a non-invasive biomarker for liver tumor diagnosis and therapy response and as an interventional tool for functional guidance of liver tumor biopsies ***(Deng et al 2006)***.

DW-MRI can help characterize FLLs by enabling measurement of lesion apparent diffusion coefficient ***(Parikh et al 2008)***.

DW imaging could potentially improve care of patients with cancer and cirrhosis by improving liver lesion detection over that achieved with standard breath-hold T2-weighted imaging ***(Parikh et al 2008)***.

The aim of this work is to highlight on the current role of diffusion weighted MRI in evaluation of hepatic focal lesions.

List of abbreviations

3D = three dimensional.
ADC = apparent diffusion coefficient.
AIDS = auto immune deficiency syndrome.
BW = bandwidth.
CCA = cholangiocellular carcinoma.
CHA = common hepatic artery.
CT = computed tomography.
DWI = diffusion weighted imaging.
DW EPI = diffusion weighted echo planner imaging
DW MRI = diffusion weighted magnetic resonance imaging.
ECG = electrocardiography.
EHE = epithelioid heamangioendothelioma.
EPI = echo planner imaging.
FLC = fibrolamellar carcinoma.
FLL = focal liver lesions.
FNH = focal nodular hyperplasia.
FSE = fast spin echo.
Gd = gadolinium.
Gd-EOB-DTPA = gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid (hepatocyte-specific contrast agent taken by hepatocytes and excreted into biliary system).
GRE = gradient recalled echo.
HBV = hepatitis B virus.
HCC = hepatocellular carcinoma.
HCV =hepatitis C virus.
IVC = inferior vena cava.
MnDPDP = Manganese dipyridoxyl diphosphate (liver specific contrast agent).
MRI = magnetic resonance imaging.
PET-CT =positron emission tomography-computed tomography.
RFA = radiofrequency ablation.
RHA= right hepatic artery.
SE = spin echo.
SMA =superior mesenteric artery.
SNR =signal to noise ratio.
SPAIR = spectral selection attenuated inversion recovery (fat suppression MRI technique).
SPIO = super paramagnetic iron oxide (tissue specific contrast agent taken up by reticuloendothelial system).
STIR = short tau inversion recovery (fat suppression MRI technique).
T = tesla.

T1 W = T1 weighted.
T2 W = T2 weighted.
TACE = transhepatic arterial chemoembolization.
Tc = technetium .
TSE = turbo spin echo.

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ANATOMY OF THE LIVER

1-Gross anatomy

The liver, the organ found in the right upper quadrant of the abdomen is formed by eight independent functional units, each with specific vascular and biliary connections. The identification of these units or segments – first described in its current naming by the French surgeon and anatomist Claude Couinaud – in each individual organ is the key to a reproducible and clinically meaningful description of where liver lesions are localized, and to modern liver surgery ***(Majno et al. 2005).***

The anatomy of the liver can be detailed based on the external appearance of the organ (external or descriptive anatomy) or based on its vascular and biliary architecture (vascular or functional anatomy) ***(Majno et al. 2005).***

External or Descriptive Anatomy of the Liver:

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) ***(Majno et al. 2005).***

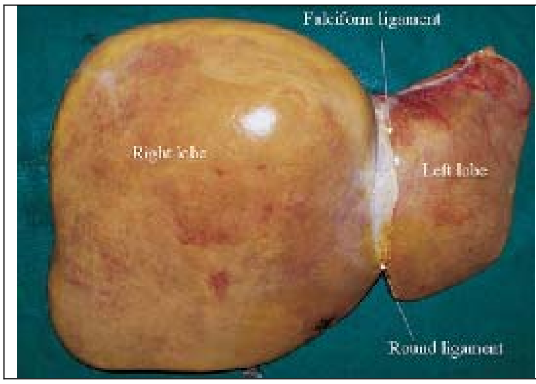

Fig. 1. Superior (diaphragmatic) aspect of the liver. The only landmarks that can be recognized are the falciform and the round ligament(ligamentum teres), separating the left lobe from the right lobe(Quoted from Majno et al).

The inferior surface(fig.2) is more varied : The round ligament(ligamentum teres)continues into with the umbilical portion of the left portal vein (at an anatomical landmark called Rex's recessus)(fig. 3). 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 ***(Majno et al. 2005).***

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 (ligamentum venosus) 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 ***(Lencioni et al. 2005)***.

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 ***(Majno et al. 2005)***.

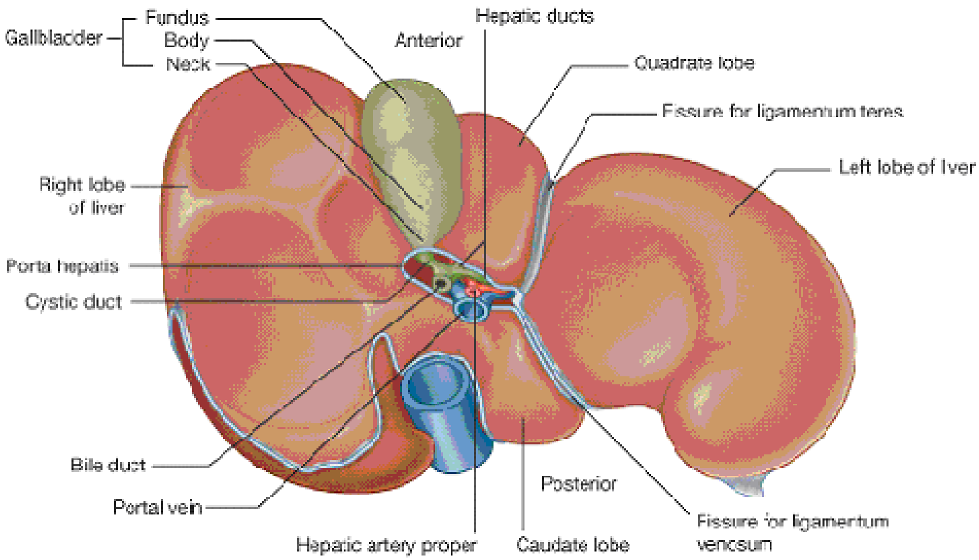

Fig. 2. Visceral surface of the liver (Quoted from Standring. 2008).

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. 2005).***

The ventral surface of the liver lies in contact with ,and is slightly moulded by:

-The esophagus ,stomach and the lesser omentum on the left.
-The pancreas (through the lesser omentum)and the duodenum in the midline ;and
-The right kidney , adrenal and hepatic flexture of the colon on the right ***(Ryan et al. 2004)***.

Vascular or Functional Anatomy of the liver :

The simplified scheme of vascular anatomy(Fig. 3 and table 1) 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 henceforth) and is collected by three hepatic veins (left, middle and right) inserting into the inferior vena cava . 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 ***(Lencioni et al. 2005).***

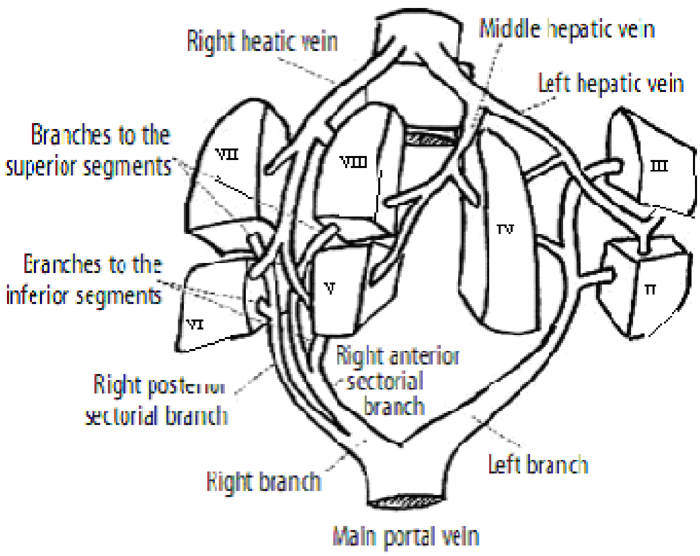

Fig. 3. Simplified scheme of the liver segments (Quoted from Majno. 2005).

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 ***(Majno et al. 2005).***

On the left, 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.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***(Lencioni et al. 2005).***

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 ***(Majno et al. 2005).***

American	*International*	*Number*
Caudate	Caudate	I
Left lobe :		
Lateral	Left lateral superior subsegment	II
	Left lateral inferior subsegment	III
Medial	Left medial subsegment	IV a (superior)
		IV b (inferior)
Right lobe :		
Anterior	Right anterior inferior subsegment	V
	Right anterior superior subsegment	VIII
Posterior	Right posterior inferior subsegment	VI
	Right posterior superior subsegment	VII

Table 1. American and International Nomenclature for Anatomic Segments of the Liver (quoted from Dodd. 1993).

Couinaud named the eight segments of the liver from the centre (segment 1) clockwise. The clockwise pattern refers to the liver as seen by an anatomist or a radiologist on traditional contrast studies, from in front, while in the new era of axial imaging the liver is seen from below, the numbering progresses anti-clockwise and not all segments of the right liver are visible on all slices: the superior segments will appear on slices above the portal bifurcation and the inferior segments on slices below the portal bifurcation ***(Lencioni et al. 2005).***

The boundaries between the segments can not be defined, with the exception of segment 3 and 4 (the round ligament), of segment 4 and 5 (the gallbladder bed) and of the left part of segment 1, corresponding to the Spigel's lobe ***(Majno et al. 2005).***

The vasculature of the liver :

1-Arterial anatomy:

Approximately 25% of the blood flow into the liver supplied by the hepatic artery, while the remainder by the portal vein ***(Ryan et al. 2004).*** About three quarters of patients show conventional arterial anatomy with CHA arising along with the splenic and left gastric arteries from the celiac axis. The CHA then divides to form the gastro-duodenal artery and the proper hepatic artery which itself divides to form the left and right hepatic arteries ***(Robinson and Ward. 2006).***

The most frequent variation is that in which the RHA arises from the SMA . The variant RHA supplies part or the whole of the right lobe of the liver. An accessory or replaced RHA arising from the SMA can be recognized in axial sections because it lies posterior to the portal vein unlike the normally placed CHA which lies anterior to the vein. Another fairly common anomaly is the origin of CHA from SMA. With this variation, the hepatic arteries may be anterior or posterior to the portal vein. Less common anomalies include the origin of the left hepatic artery from the left gastric artery or directly from the celiac axis. Combinations of these anomalies may also occur in the same patient ***(Robinson and Ward. 2006).***

In the native liver, loss or reduction in arterial supply has little effect as long as the portal venous supply is maintained because of numerous collateral pathways by which arterial blood can reach the biliary tree. In the transplanted liver these collaterals do not exist, so a patent hepatic artery is essential to maintain the integrity of the biliary system. Unlike the rest of the liver parenchyma, the bile ducts receive their nutritive flow from the hepatic arterial route rather than from the portal venous system ***(Robinson and Ward. 2006).***

2- Venous anatomy:

Two venous systems exist in the liver ; the portal vein which supplies the liver by oxygenated blood and hepatic veins which drains the liver to the general venous circulation. ***The portal vein*** normally forms posterior to head of pancreas by the union of the superior mesenteric vein and splenic vein at the level of the L1-L2 disc space. It ascends anterior to IVC and passes to the right in the posterior aspect of the free edge of the lesser omentum. It runs posterior to the bile duct and hepatic artery to the porta hepatis. Anatomic anomalies of the portal veins are uncommon, very rarely the portal vein is double caused by non-union of superior mesenteric and splenic veins ***(Ryan et al. 2004)***.

The hepatic veins drain the liver to the IVC without an extra hepatic course. The distribution of these hepatic veins differs from that of the hepatic artery ,the bile ducts and the portal vein. Right ,middle and left hepatic veins drain corresponding thirds of the liver. The middle hepatic vein lies in the principle plane and may unite with the left hepatic vein and have a common final course to the IVC. A lower group of small veins drain directly to the IVC from the lower parts of the right and caudate lobes. Hepatic veins have no valves ***(Ryan et al. 2004).***

The most common significant variation of hepatic venous anatomy is one or more accessory right hepatic veins which may drain part or the whole of segments 5 and 6. In patients who are candidates for tumor resection, the existence of accessory hepatic veins may allow surgical procedures which would be otherwise impossible ***(Robinson and Ward. 2006).***

Lymphatic drainage from the liver:

Most of the deep and superficial parenchymal liver lymphatics drain to the porta hepatis and into the nodes ranged along the vessels and ducts in the lesser omentum. From there, the main drainage is into the celiac nodes. The liver parenchyma adjacent to the bare area (area not covered by peritoneum), which typically includes parts of segments 8 and 4, but sometimes includes parts of segments 7 or 2, drains via diaphragmatic lymphatics into the phrenic nodes which lie just superior to the diaphragm and adjacent to the right cardiophrenic angle ***(Robinson and Ward. 2006).***