INTRODUCTION

The hepatocellular carcinoma (HCC) is an epithelial tumor originating in the liver and composed of cells with characteristics similar to those of normal hepatocytes ***(Van Malenstein et al., 2011).***

Various types of hypervascular lesions are common among patients with cirrhosis. The ability to differentiate between malignant and benign nodules is limited; nodules are primarily characterized on the basis of differences in vascularity. Regenerative and low-grade dysplastic nodules have predominantly portal venous blood supplies and demonstrate as much enhancement as the liver parenchyma. High-grade dysplastic nodules and HCCs demonstrate a loss of portal vascularization and have more nontriadal arteries. High-grade dysplastic nodules and early HCCs usually are hypovascular, but they may enhance in the arterial phase, whereas those that are larger and more advanced usually appear as hypervascular nodules. The transition from regenerative and dysplastic nodules to HCC is not characterized by discrete steps; rather, it is marked by a continuum of vascular pattern changes. Many of the intermediate stages are atypical, making their characterization difficult ***(Bruix and Sherman, 2011).***

MR imaging can provide comprehensive and highly accurate diagnostic information concerning diffuse and focal hepatic lesions as well as vascular and biliary abnormalities.

MR provides soft tissue characterization unachievable with other imaging modalities. MR imaging can visualize several tissues and anatomic components of the liver separately based on T1-weighted imaging including(chemical shift imaging for the detection of small amounts of fat), T2-weighted imaging provides information for distinction between solid and nonsolid liver lesions based on fluid content, diffusion weighted imaging provides unique information that reflects tissue cellularity and organization, and flow sensitive sequences (inflow MR angiography MRA) provides information about vascular abnormalities ***(Veiseh et al., 2010).***

Lack of ionizing radiation and relative lack of operator dependence are additional advantages over computed tomography and ultrasound respectively. Moreover, it enables the radiologist to take axial, sagittal and coronal images when evaluating the liver ***(Suh et al., 2011).***

The magnetic field strength of choice currently employed for body MRI is 1.5 T which provides an optimal combination of SNR and speed, allowing optimization of rapid acquisition techniques. Motion from respiration, heart and bowel peristalsis may cause marked image deterioration. Consequently, a single shot approach using the minimum possible TR is utilized. Such sequences include the so-called magnetization prepared rapid acquisition gradient echo (MP-RAGE) and turbo-fast low angle shot (Turbo FLASH) sequences. Usage of motion correction method such as respiratory gating is also helpful to overcome image deterioration ***(Buzoianu et al., 2013).***

Diffusion weighted echo planar imaging is fast becoming a routine part of the MRI liver protocol to improve lesion detection and characterization of liver lesions ***(Maniam et al., 2010).***

Although MR imaging usually has higher sensitivity than CT, characterizing hypervascular lesions in patients with cirrhosis is challenging at any modality, especially when lesions are small. Differentiating HCC from other hypervascular lesions is a key step in treating patients and is the responsibility of the radiologist ***(Omata et al., 2017).***

AIM OF THE WORK

The purpose of this study is to study the role of MRI in characterization of hypervascular hepatic focal lesions in cirrhotic patient on unenhanced, dynamic contrast-enhanced and diffusion weighted MR images for better patient management plan.

Chapter 1

ANATOMY

The liver is the largest solid organ in the body. It lies in the upper part of the abdominal cavity just beneath the diaphragm and mostly under cover of the ribs. It fills the right hypochondrium and extends across the epigastrium into the left hypochondrium ***(Standring et al., 2015).***

The normal liver is shaped like a wedge with its base against the right abdominal wall, and its tip pointing to the spleen and extends from the fifth left intercostal space to the right mid-clavicular line down to the right costal margin. It measures 12 to 15 cm coronally and 15 to 20 cm transversely. The median liver weight is 1800 gm in men and 1400 gm in women. The adult liver weight is between 1.8% and 3.1% of body weight. Liver weight in fetuses and children are relatively greater, being 5.6% at 5 months gestational age, 4% to 5% at birth, and 3% of body weight at 1 year of age ***(Schiff et al., 2017).***

Liver anatomy can be described using two different aspects:

Morphological anatomy and functional anatomy. The classical morphological description of the liver anatomy is based on the external appearance. On the diaphragmatic surface, the falciform ligament divides the liver into the right and left anatomical lobes which are very different from the functional right and left lobes. In this classical morphological description, the quadrate lobe belongs to the right lobe of the liver, but functionally it is part of left lobe ***(Rubin, 2016).***

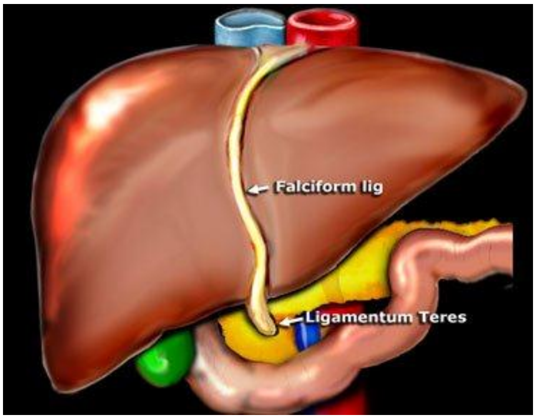

Fig. 1: Gross right and left anatomical lobes of the liver based on falciform ligament ***(Quoted from Rubin, 2016).***

Historically the gross anatomical appearance of the liver has been divided into right, left, caudate and quadrate lobes by surface peritoneal and ligamentous attachments. The falciform ligament superiorly and the ligamentum venosum inferiorly, mark the division between right and left lobes. On the inferior surface, to the right of the groove formed by the ligamentum venosum, there are two prominences separated by porta hepatis. The quadrate lobe lies anteriorly, and the caudate lobe (which in gross anatomical descriptions is said to arise from the right lobe, but it is functionally separate) lies posteriorly. The gall bladder usually lies in a shallow fossa to the right of the quadrate lobe ***(Standring et al., 2015).***

The traditional morphological anatomy is based on the external appearance of the liver and does not show the internal features of vessels and biliary ducts branching which is of obvious importance in hepatic surgery. The segmental division of the liver is first described by the French surgeon Couinaud (1957); this classification was based on the divisions of the portal veins that divide the liver into eight functionally independent segments ***(Schiff et al., 2017).***

Each segment has its own vascular inflow, outflow and biliary drainage. In the centre of each segment there is a branch of the portal vein, hepatic artery and bile duct. In the periphery of each segment there is vascular outflow through the hepatic veins. Couinaud divided the liver into a functional left and right liver by a main portal fissure containing the middle hepatic vein. This is known as Cantlie's line which runs from the middle of the gallbladder fossa anteriorly to the inferior vena cava posteriorly. Right hepatic vein divides the right lobe into anterior and posterior segments.

Middle hepatic vein (MHV) divides the liver into right and left lobes (or right and left hemiliver), this plane runs from the inferior vena cava to the gall bladder fossa. Left hepatic vein divides the left lobe into a medial and lateral part. Portal vein divides the liver into upper and lower segments, the left and right portal veins branch superiorly and inferiorly to project into the center of each segment ***(Rubin, 2016).***

Table 1: Segments numbering of the liver ***(Quoted from Hagen, 2011)***

Segment I: Caudate lobe.
Segments II and III: Left superior and inferior lateral segments.
Segment IVa and IVb: Medial segments of the left lobe.
Segments V and VI: Right inferior anterior and posterior segments.
Segments VII and VIII: Right superior posterior and anterior segments.

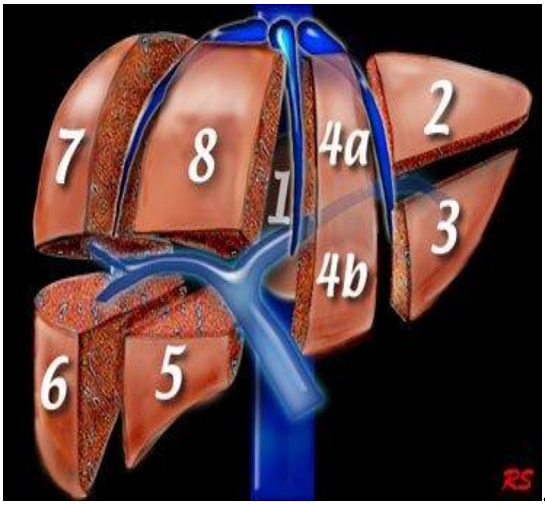

Fig. 2: Liver segmental anatomy according to Couinaud classification ***(Quoted from Rubin, 2016).***

Vascular Supply of the Liver:

Arterial Supply:

Approximately 25% of the blood flow into the liver is supplied by the hepatic artery while the remainder by the portal vein ***(Ryan et al., 2014).***

Portal Venous System

The portal system includes all the veins draining the abdominal-pelvic parts of the digestive tube with the exception of the lower anal canal. It also drains the spleen, pancreas and gallbladder. The portal vein conveys the blood from these viscera to the liver where it ramifies like an artery, and ends in the sinusoids from which vessels again converge to reach the inferior vena cava via the hepatic veins ***(Standring et al., 2015).***

The Main Portal Vein

In normal venous anatomy, the portal vein bifurcates at the hilum into right and left pedicles. The right pedicle in turn bifurcates into anterior and posterior branches while the left pedicle divides into three branches ***(Vohra et al., 2014).***

The Right Portal Vein

The right portal vein is the larger of the two branches. The right branch usually receives the cystic vein and then enters the right lobe. In common with the hepatic artery, it usually forms an anterior division supplying segments V and VIII, and a posterior division supplying segments VI and VII. The anterior division may give a branch to segment I ***(Standring et al., 2015).***

The Left Portal Vein

The left portal vein lies more anterior and cranial than the right one. It gives off branches to segments I (caudate), II, III and IV (quadrate) ***(Standring et al., 2015).***

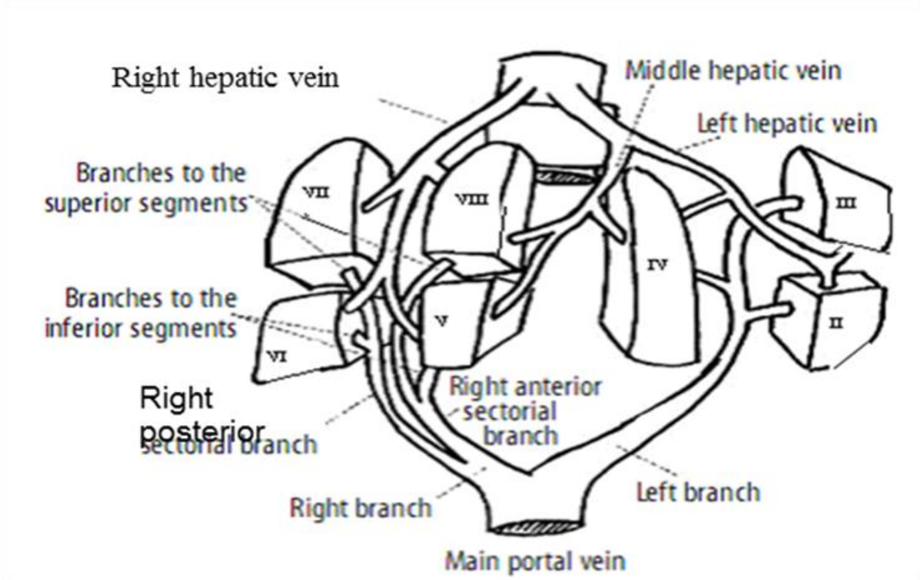

Fig. 3: Simplified scheme of the liver segments in relation to the portal vein branches ***(Quoted from Majno. 2015).***

Hepatic Artery

In normal arterial anatomy, the common hepatic artery arises from the celiac trunk from which the left gastric and splenic arteries arise also. The common hepatic divides into gastroduodenal and proper hepatic, the later one divides at the hilum into right and left branches ***(Vohra et al., 2014).***

The right hepatic artery almost always divides into an anterior branch supplying segments V and VIII, and a posterior branch supplying segments VI and VII. The anterior division often supplies a branch to segment I and the gall bladder. The artery to segment IV is usually considered a small branch from the left hepatic artery. The left hepatic artery is divided into medial and lateral segments supplying different left hepatic lobes ***(Standring et al., 2015).***

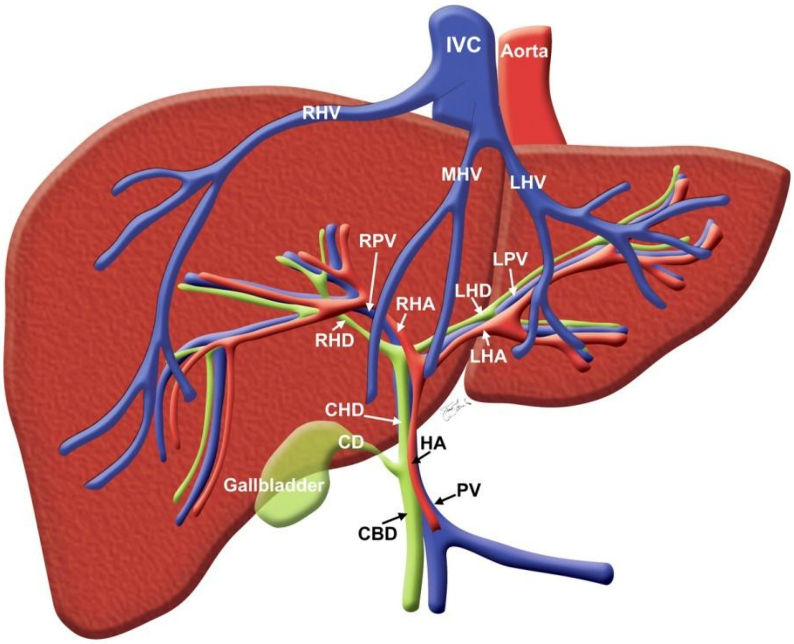

Fig. 4: Normal anatomy of the hepatic, venous and biliary tract ***(Quoted from Vohra et al., 2014).***

Venous Anatomy

The hepatic venous anatomy is extremely variable; the most common pattern consisting of three main hepatic veins. The right hepatic vein is often the largest of the three and drains the greatest part of the right lobe. MHV drains the central sector of the liver (segments IV, V, and VIII), and its branching and confluence pattern is quite variable. The MHV usually joins the LHV which drains segments II and III to form a common trunk that empties into the IVC ***(Vohra et al., 2014).***

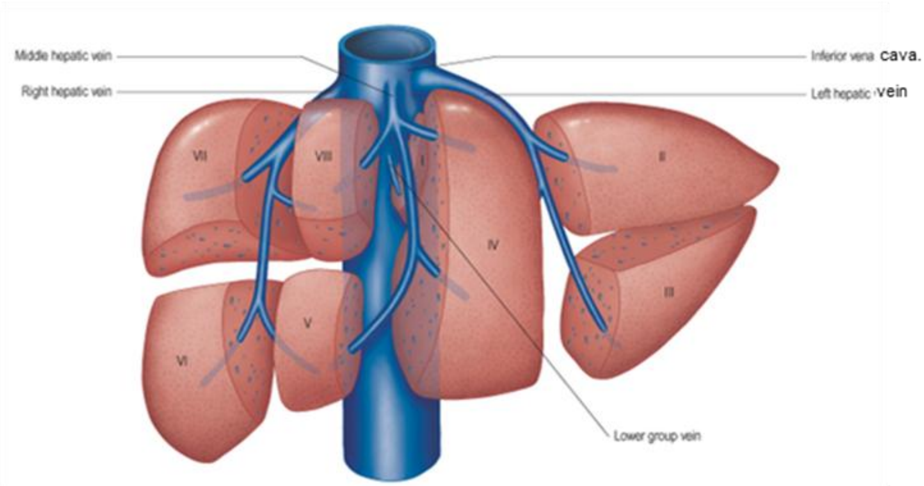

Fig. 5: Arrangement of the hepatic venous territories ***(Standring et al., 2015).***

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 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, 2016).***

Biliary System:

The biliary system consists of the organs and ducts (bile ducts, gallbladder, and associated structures) that are involved in the production and transportation of bile. The transportation of bile follows this sequence:

1. When the liver cells secrete bile, it is collected by a system of ducts that flow from the liver through the right and left hepatic ducts.

2. These ducts ultimately drain into the common hepatic duct.

3. The common hepatic duct then joins with the cystic duct from the gallbladder to form the common bile duct, which runs from the liver to the duodenum (the first section of the small intestine).

4. However, not all bile runs directly into the duodenum. About 50 percent of the bile produced by the liver is first stored in the gallbladder, a pear-shaped organ located directly below the liver.

5. Then, when food is eaten, the gallbladder contracts and releases stored bile into the duodenum to help break down the fats ***(Schiff et al., 2017).***

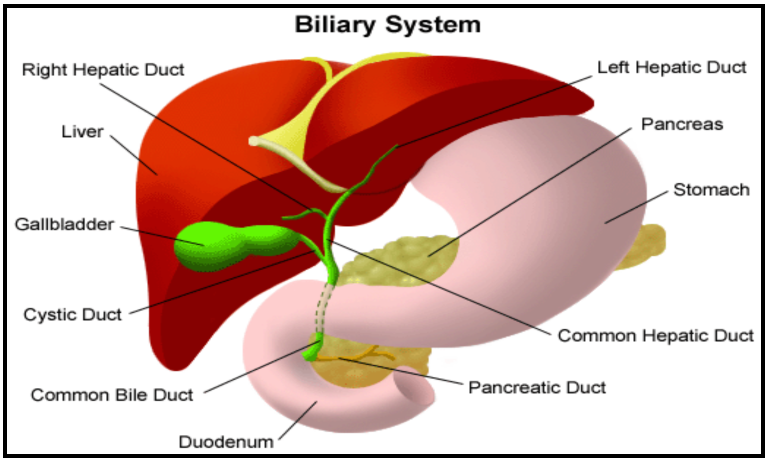

Fig. 6: Anatomy of the biliary system ***(Quoted from Standring et al., 2015).***

MR anatomy of the liver

MR imaging provides comprehensive evaluation of the liver including; the parenchyma, biliary system and vasculature. The inferior vena cava is consistently demonstrated as a round, signal-free structure grooving the postero-inferior surface of the liver between the right and caudate lobes. The hepatic veins lie in the planes between the lobes and segments of the liver. They are thus intersegmental and drain parts of adjacent segments. Typically, there are three major tributaries**:** The left hepatic vein separates segment 2 from 4. Middle hepatic vein separates segment 4 from segments 5 and 8. Right hepatic vein separates anteriorly situated segments 5 and 8 from posteriorly situated segments 6 and 7 ***(Robinson and Ward, 2016).***

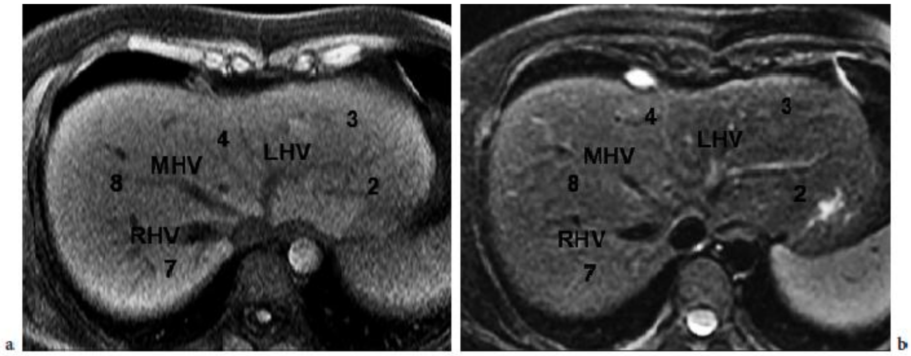

Fig. 7: Normal hepatic veins. Axial image T1 (a) and T2 (b) weighted plain images showing the normal orientation of the left (L), middle (M) and right (R) hepatic veins ***(Robinson and Ward, 2016).***

The course of the portal vein is usually seen on axial images as it passes from its retro pancreatic location through the hepatoduodenal ligament, and into the porta hepatis. Oblique coronal MR images can demonstrate the entire length of the main portal vein. The right portal vein has an anterior branch that lies centrally within the anterior segment of the right lobe and posterior branch that lies centrally within the posterior segment of the right lobe ***(Robinson and Ward, 2016).***

The sagittal sections, beside their role in the localization of the hepatic masses, they are usually acquired to evaluate the inferior vena cava and the aorta in their entire length. The inferior vena cava can be seen throughout it's intrahepatic course as a large signal free tubular structure situated posteriorly as it enters the right atrium. The middle hepatic vein can occasionally be seen on the same section which shows the inferior vena cava. The right hepatic vein could be identified in the sagittal cuts taken to the right of the midline in its caudo-cephalic direction. The left hepatic vein could