INTRODUCTION

Cirrhotic livers are characterized by irreversible remodeling of the hepatic architecture, including bridging fibrosis and a spectrum of hepatocellular nodules ***(Parente et al., 2012).***

Common causes of cirrhosis include; hepatitis C virus (55% of cases), hepatitis B virus (16%), alcohol consumption (13%), and other causes including; cryptogenic nonalcoholic fatty liver disease and nonalcoholic steatohepatitis (16%). Nonalcoholic steatohepatitis is considered to be an advanced stage of nonalcoholic fatty liver disease ***(Hussain et al., 2009).***

Cirrhosis-associated hepatocellular nodules undergo carcinogenesis along a spectrum, ranging from benign regenerative nodules to dysplastic nodules to malignant HCC ***(Arif-Tiwari et al., 2014)***. The major changes that characterize the progression from regenerative nodules through the steps of HCC development are progressive loss of portal vascularity and increased arterial blood flow which determines their distinguishing imaging characteristics ***(Parente et al., 2012)***

In 1995, an International Working Party panel published a set of guidelines for classifying and describing nodular hepatocellular lesions. According to those guidelines, there are two categories of hepatocellular nodules; regenerative lesions, dysplastic and neoplastic lesions.

Regenerative nodules: represent an attempt by the liver to replace the damaged hepatocytes resulting from continuous injury to the liver parenchyma and compensate for lost liver function.

Lesions with dysplastic features are classified as low or high grade dysplastic nodules according to the degree of dysplasia ***(Bruix & Sherman, 2005).***

Hepatocellular Carcinoma: They are malignant neoplasms composed of dedifferentiated hepatocytes. The classic system of macroscopic classification of hepatocellular carcinomas in use since 1901 includes three major types; nodular, massive and diffuse ***(Robert et al., 2008),***

MRI plays an increasingly important role for assessment of patients with chronic liver disease. MRI has numerous advantages, including lack of ionizing radiation and the possibility of performing multiparametric imaging ***(Taouli et al., 2009).*** In comparison with computed tomography, MR imaging can image the whole liver with better soft-tissue contrast especially with the introduction of faster sequences, it is also useful for assessing a larger number of tissue properties, and provides greater sensitivity to contrast media ***(Bartolozzi et al., 2007).***

Imaging characterization of focal lesions in cirrhosis is of the utmost importance for appropriate patient management

(Galia et al., 2014) MR imaging can successfully help to detect the increasing size and vascularity of nodules. It also provides support for the concept of stepwise carcinogenesis ***(Van Den Bos et al., 2006).***

With recent advances in technology, advanced MRI methods such as diffusion, chemical shift based fat-water separation and MR spectroscopy can now be applied to liver imaging to improve hepatocellular nodules characterization ***(Taouli et al., 2009)***

Chapter (1)

ANATOMICAL CONSIDERATIONS OF THE LIVER

The liver is the largest visceral organ in the body weighting 1400-1800 gm. in adults and is primarily in the right hypochondrium and epigastric region, extending into the left hypochondrium ***(fig 1).*** It performs a wide range of metabolic activities necessary for homeostasis, nutrition and immune defense ***(Standring, 2005).***

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 5th left intercostal space to the right MCL down to the right costal margin ***(Schiff et al., 2007).***

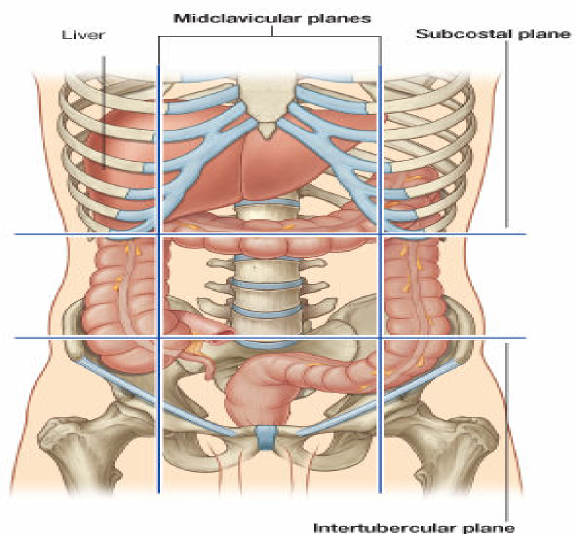

Figure (1): Position of the liver in the abdomen ***(Quoted from Drake et al., 2007).***

I. Gross Anatomy:

A. Morphological and functional Anatomy

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, 2006).***

(*i*) **Morphological Anatomy;**

Historically the gross anatomical appearance of the liver ***(fig. 2)*** has been divided into **right, left, caudate** and **quadrate** lobes by surface peritoneal and ligamentous attachments ***(Standring, 2005).***

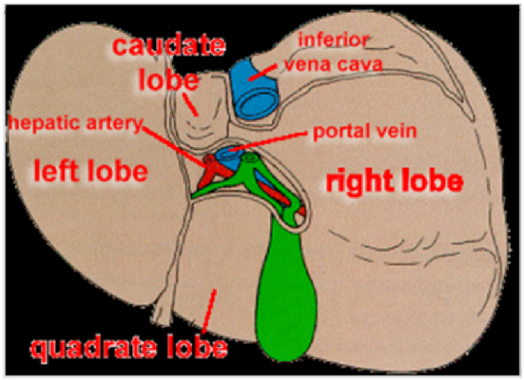

Figure (2): Gross anatomical lobes of the liver **(*Quoted from Rubin, 2006).***

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., 2005).***

a- The Right Lobe (Lobus Hepatis Dexter):

It is much larger than the left & occupies the right hypochondrium and it is separated from the left lobe on its upper surface by the falciform ligament. Its inferior and posterior surfaces are marked by three fossae: the porta hepatis, and the fossae for the gall-bladder and inferior vena cava which separate its left part into two smaller lobes; the quadrate and caudate lobes ***(Standring et al., 2005).***

b- **The Quadrate Lobe (Lobus Quadratus)**:

It is situated on the inferior surface of the right lobe, bounded; in front by, the anterior margin of the liver; behind by, the porta hepatis; on the right, by the fossa for the gall-bladder; and on the left, by the fossa for the umbilical vein ***(Standring et al. 2005).***

c- The Caudate Lobe (Lobus Caudatus; Spigelian Lobe)

It is situated on the posterior surface of the right lobe of the liver opposite the 10^{th} and 11^{th} thoracic vertebrae. It is bounded; below, by the porta hepatis; on the right, by the fossa for the inferior vena cava; and on the left, by the fossa for the ductus venosus ***(Standring et al., 2005).***

d- The Left Lobe (Lobus Hepatis Sinister):

It is situated in the epigastric and left hypochondrial regions. Its upper surface is slightly convex. It's under surface includes the gastric impression and omental tuberosity. The medial segment of the left lobe is oblong and situated on the postero-inferior surface of the left lobe. In front it is bounded by the anterior margin of the liver, behind by the porta hepatis, on the right by the fossa for the gall bladder, and on the left by the fossa for the umbilical vein ***(Standring et al., 2005).***

(ii) **Functional (Segmental) anatomy of the liver:**

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 ***(Sibulesky, 2013).***

The system proposed by ***Couinaud, 1957*** provides the surgically relevant imaging techniques and is easily applicable to sectional imaging techniques ***(Robin Smithuis, 2006).*** This classification was based on the distribution of the portal and hepatic vein*s* that divide the liver into eight functionally independent segments ***(Schiff et al., 2007).***

Each segment has its own vascular inflow, outflow and biliary drainage. The main portal vein divides into two branches, right and left, defining a right liver and a left liver. The plane of separation can be approximated as a plane going from the gall bladder fossa anteriorly to the IVC posteriorly in which runs the middle hepatic vein ***(Majno et al., 2005).***

- **The Right hepatic vein** divides the right lobe of the liver into anterior and posterior Segments.
- **Middle hepatic vein (MHV)** divides the liver into right and left lobes (or right and left hemi liver),
- **Left hepatic vein** divides the left liver into medial and lateral segments.
- **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

(Sibulesky, 2013)

The numbering of segments is in a clockwise manner ***(fig.3)***. Segments II and III, which are known as the anterior and posterior segments of the left lobe, respectively, are also known collectively as the left lateral segment of the liver. Segment IV is the medial segment of the left lobe. Segments II, III, and IV collectively make up the functional left lobe of the liver. The functional right lobe of the liver is made up of segments V and VIII, the anterior segments, and segments VI and VII, the posterior segments. Segment I, the caudate lobe, is located posteriorly. The outflow of the liver is provided by the three hepatic veins ***(Sibulesky, 2013).***

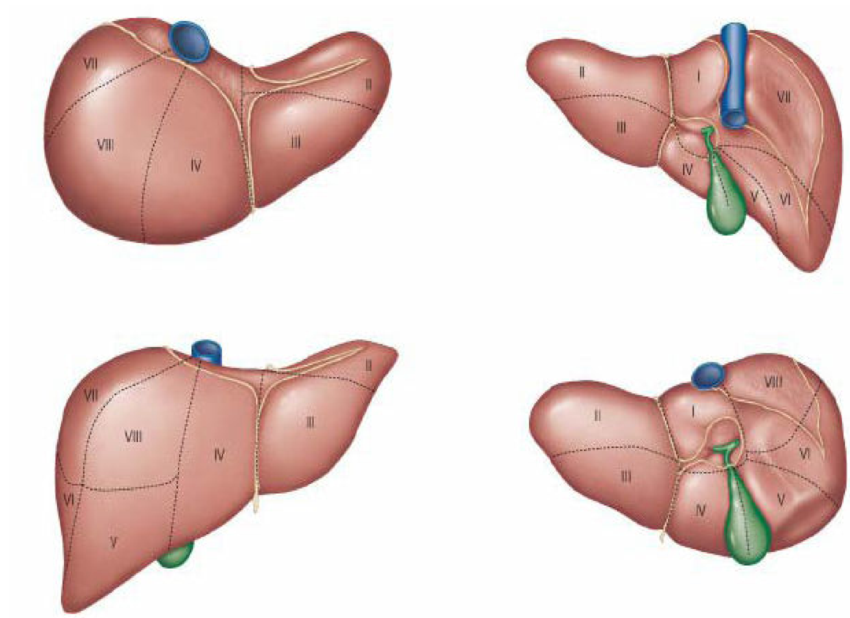

Figure (3): Segments of the liver (after Couinaud). **A**, superior view; **B**, posterior view; **C**, anterior view; **D**, inferior view. The segments are sometimes referred to by number (name) – I (caudate) (sometimes subdivided into left and right parts called segment IX); II (left lateral superior); 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, 2005).***

B. Hepatic Surfaces and Relations *(Fig 4)*

The liver is usually described as having superior, anterior, right, posterior and inferior surfaces, and has a distinct inferior border. However, superior, anterior, right surfaces are continuous with no definable borders. It would be more appropriate to group them as the diaphragmatic surface which is mostly separated from the inferior or visceral Surface by a narrow inferior border ***(Giovannelli et al., 1997).***

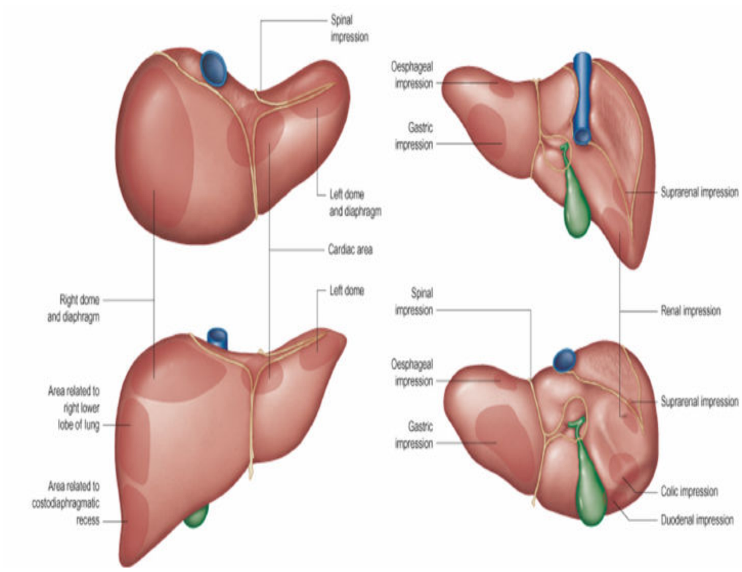

Figure (4): Showing the relation of the liver: Top left, superior view; top right, posterior view; bottom left, anterior view; bottom right, inferior view ***(Quoted from Standring et al, 2005).***

1. Diaphragmatic surface

The diaphragmatic surface ***(fig. 5)*** is smooth and dome shaped ***(Moore et al., 2006).*** It is perfectly fitted and affixed by intervening connective tissue to a triangular section of the undersurface of the diaphragm, termed the bare area ***(Boll et al., 2009).***

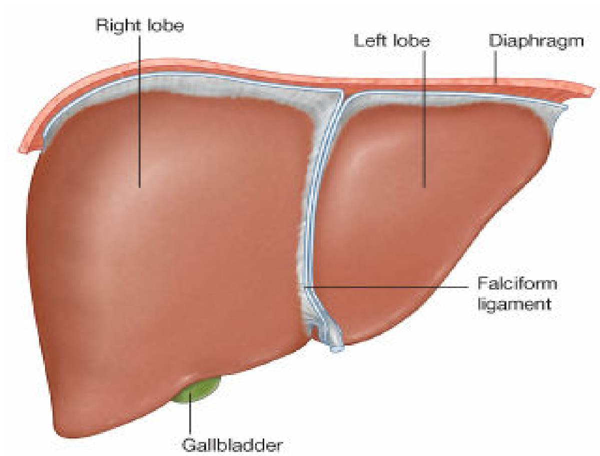

Figure (5): Diaphragmatic surface of liver ***(Quoted from Drake et al., 2007).***

Associated with it are the subphrenic and hepatorenal recesses which are continuous anteriorly. The **sub phrenic recess** separates the diaphragmatic surface of the liver from the diaphragm and is divided into right and left areas by the falciform ligament, which extends between the liver and the anterior abdominal wall ***(Drake et al., 2009).***

The hepatorenal recess is a part of the peritoneal cavity on the right side between the liver and the right kidney and right suprarenal gland. It communicates anteriorly with the right sub phrenic recess ***(Moore et al., 2006)***

a. Superior surface:

It is related to the right diaphragmatic pleura, base of the right lung, pericardium, ventricular part of the heart, part of the left diaphragmatic pleura and base of the left lung ***(Hagen, 2001).***

b. **Anterior surface**

The anterior surface is triangular and convex. It is covered by peritoneum except at the attachment of the falciform ligament. ***On the right***, the diaphragm separates it from the pleura and six to tenth ribs and cartilages, ***on the left*** from the seventh and eighth costal cartilages ***(Standring et al, 2005).***

c. Right Surface:

It is covered by peritoneum and lies adjacent to the right dome of the diaphragm which separates it from the right lung; pleura and seventh to eleventh ribs ***(Standring et al., 2005).***

d. **Posterior surface:**

Much of the posterior surface is attached to the diaphragm by loose connective tissue which forms the so-called "**bare area"** which is an anterior relation of the upper pole of the left suprarenal gland. **The IVC** lies in a groove in the medial end of the (bare area). To the left of IVC the **caudate lobe** is present. To the left of caudate lobe, the fissure for the ligamentum venosum is present ***(Standring et al., 2005).***

2. Visceral (Inferior) surface

The visceral surface bears multiple fissures and impressions ***(fig 6);*** two sagittal fissures, linked centrally by the transverse porta hepatis, form the letter H on the visceral surface. The right sagittal fissure formed anteriorly by the fossa for the gallbladder and posteriorly by the groove for the vena cava; The left sagittal fissure formed anteriorly by the fissure for the ligamentum teres or round ligament, and posteriorly by the fissure for the ligamentum venosum ***(Moore et al., 2006).***

The lesser omentum, enclosing the portal triad (bile duct, hepatic artery, and portal vein) passes from the liver to the lesser curvature of the stomach and the first 2 cm of the superior part of the duodenum. The thick, free edge of the lesser omentum extends between the porta hepatis and the duodenum (the hepatoduodenal ligament) and encloses the structures that pass through the porta hepatis ***(Moore et al., 2006)***

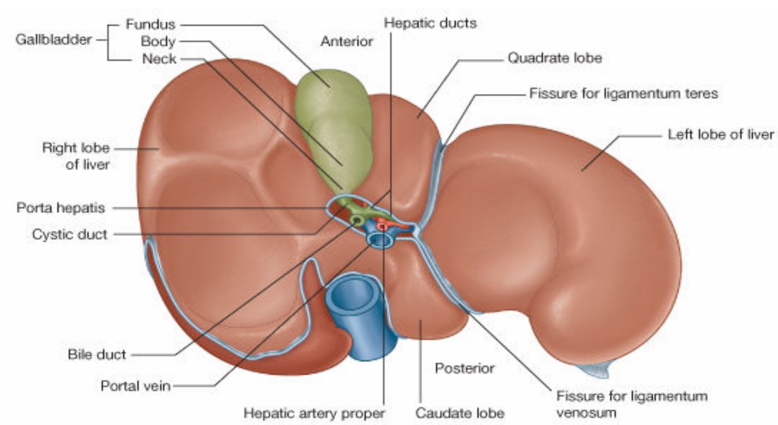

Figure (6): Visceral surface of liver ***(Quoted from Drake et al., 2007).***

C. Liver Support:

The liver is supported in its position in the upper abdomen by several factors. Tone in the anterolateral abdominal muscles is important in holding the liver in place. Ligamentous attachments of the liver capsule to the diaphragm ***(fig. 7)*** and anterior abdominal wall provide some support**,** and prevent rotation of the liver ***(Standring et al., 2005).***

1. Falciform Ligament

The two layers of this ligament descend from the posterior surface of the anterior abdominal wall and diaphragm and turn onto the anterior and superior surfaces of the liver. On the dome of the superior surface, the right leaf runs laterally and is continuous with the upper layer of the coronary ligament. The left layer turns medially and is continuous with the anterior layer of the left triangular ligament ***(Rubin, 2006).***

2. Ligamentum Teres

The ligamentum teres *(obliterated left umbilical vein)* runs in lower free border of the falciform ligament and continues into a fissure on the inferior surface of the liver ***(Hagen, 2001).***

3. Coronary Ligament

The anterior and posterior layers of the hepatic coronary ligament converge on the right and left margins of the bare area, forming the right and left triangular ligaments ***(Boll et al., 2009)***