# INTRODUCTION

Liver fibrosis is a healing response to injuries caused by multiple types of chronic liver disease. Liver fibrosis in chronic liver disease results from excessive accumulation of an extracellular matrix in response to chronic inflammation ***(Feier D et al, 2015).***

Beyond being a marker of hepatic injury, fibrosis appears to play a direct role in the pathogenesis of cirrhosis, hepatocellular carcinoma, and portal venous hypertension, leading to increased morbidity and mortality. Viral hepatitis C infection represents the most common cause of hepatic fibrosis in Egypt ***(Castera L, 2012).***

Patients with hepatitis C virus infections are at high risk for the development of hepatic fibrosis that proceeds to cirrhosis, The assessment of liver fibrosis in patients with viral hepatitis is essential not only to determine prognosis but also to select patients who are in need for antiviral therapy ***(Ghany M et al, 2011)***.

Percutaneous liver biopsy is the gold standard for evaluating changes in fibrosis, although it is a relatively safe procedure when performed by experienced clinicians; it is an invasive procedure that has certain contraindications that can lead to complications ***(El Refaei M, 2015).***

This made the need for a noninvasive, fast, safe and reliable method that allows evaluation of liver fibrosis, and repetitive measurements for monitoring disease progression and treatment response ***(Kovač J et al, 2012).***

These noninvasive methods include routine biochemical and hematological liver function tests, serum markers of connective tissue, and scoring systems using a combination of clinical and/or laboratory tests ***(Ghany M et al, 2011).***

Imaging techniques are an attractive means of detecting liver fibrosis, given their availability and non-invasive nature, although their capacity to detect structural changes is dependent upon resolution and the stage of liver fibrosis. The search for the best diagnostic technique in terms of non-invasiveness and accuracy is still a major focus of recent research activities ***(Feier D et al, 2015).***

Recently, a wide variety of non-invasive promising imaging-based methods had been used for assessing hepatic fibrosis, including ultrasound, CT and MRI. The measurement of liver stiffness with ultrasound transient elastography (FibroScan) was proven to be accurate in the detection of significant fibrosis in patients with hepatitis C. However, transient elastography (TE) cannot be used in obese patients or patients with ascites or narrow intercostal spaces ***(Kovač J et al, 2012).***

Although magnetic resonance (MR) elastography has demonstrated the best diagnostic performance for the detection and staging of liver fibrosis thus far, it is impractical, since the technique remains expensive and is not widely included in routine imaging for patients with various liver diseases ***(Feier D et al, 2015).***

Diffusion-weighted imaging enables qualitative and quantitative assessment of tissue diffusivity. Random motion of water molecules in the liver can be quantified by calculation of the apparent diffusion coefficient (ADC). The ADC of livers with moderate or advanced fibrosis and cirrhosis has been reported to be lower than that of normal livers or livers with mild fibrosis across multiple studies ***(El Refaei M, 2015).***

The variability in reported ADC measurements is further complicated using different b values and acquisition methods based on breath-hold, free-breathing, or respiratory triggered techniques, which can affect ADC quantification ***(Richard K et al, 2010 & Taouli B and Koh D, 2010)***

Normalization of ADC using a reference organ that remains relatively constant across patients or systems may help reduce variability in ADC calculations. For instance, a recent study showed that normalized ADC (using the spleen) appeared to decrease the variability of ADC based on choice of b values for benign and malignant liver lesions. The spleen may be an ideal reference organ, because it maintains a relatively stable ADC even in the setting of liver disease ***(Richard K et al, 2010 & Papanikolaou N et al, 2010).***

# AIM OF WORK

To investigate the value of liver ADC normalization using spleen as a reference organ in liver fibrosis assessment, in comparison with transient elastography (Fibroscan).

# ANATOMY OF THE LIVER

## Gross anatomy

The liver is the second largest organ in the body. It lies in the right hypochondrium under the diaphragm ***(Kapoor V, 2018).***

## Hepatic capsule:

The liver is covered by thin connective tissue capsule (Glisson capsule) that become thicker at the hilum ***(Lowe M and D'Angelica M, 2016).***

## Hepatic surfaces:

The liver has three surfaces: superior, inferior and posterior. **The superior surface** is attached to the diaphragm and anterior abdominal wall by a triangular or falciform fold of peritoneum, the falciform ligament **(Fig 1)**. The line of attachment of the falciform ligament divides the liver into two parts, termed the right and left lobes, the right being much the larger ***(Gray H, 2008)***.

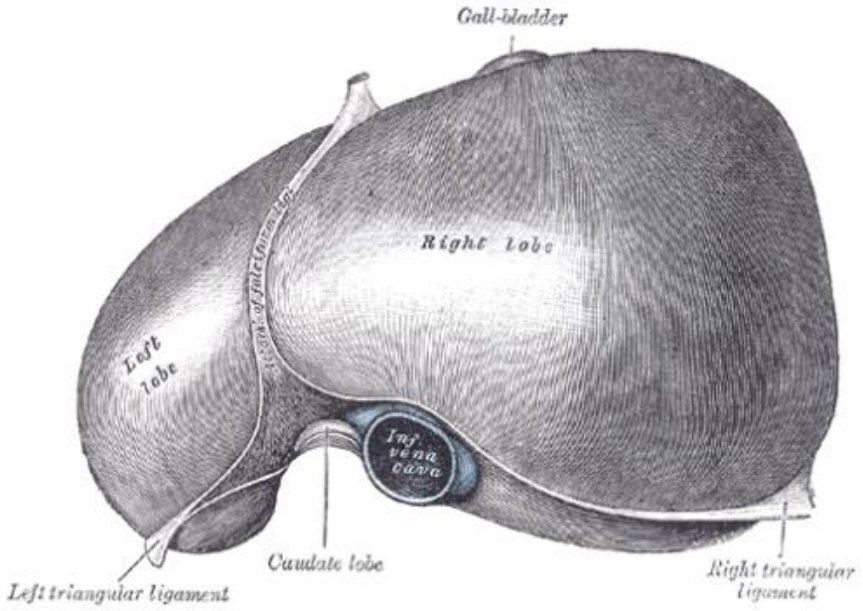


**Figure (1):** Liver superior surface showing falciform ligament attachment ***(Quoted from Gray H, 2008)***

**The inferior and posterior surfaces** is divided into four parts giving H shape where the left limb of the H divides the liver into right and left lobes; it is known as the left sagittal fossa, and consists of two fosses, the fossa for the umbilical vein in front and the fossa for the ductus venosus behind **(Fig 2**). The right limb of the H is formed in front by the fossa for the gallbladder, and behind by the fossa for the inferior vena cava; these two fosses are separated from one another by a band of liver substance, termed the caudate process. The bar connecting the two limbs of the H is the porta (transverse fissure); in front of it is the quadrate lobe, behind it the caudate lobe **(Fig 3**) ***(Gray H, 2008)***.

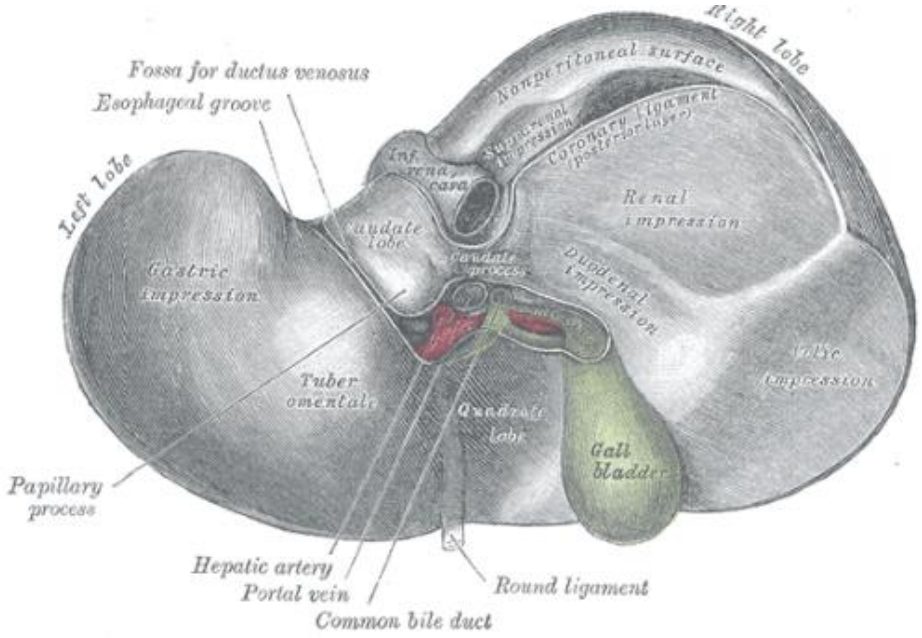


**Figure (2):** Inferior surface of the liver ***(Quoted from Gray H, 2008)***

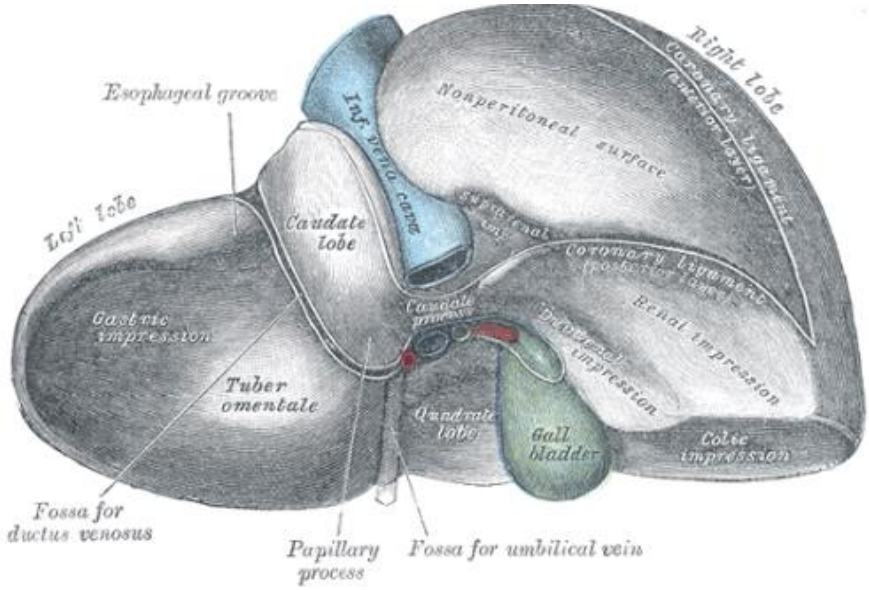


**Figure (3):** Posterior and inferior surface of the liver ***(Quoted from Gray H, 2008)***

## A-Anatomical lobes of the liver:

### (1) Right lobe:

The right lobe of the liver is the largest in size and contributes to all surfaces; it exceeds the left lobe by a ratio of 6:1. It occupies the right hypochondrium and is bordered on its upper surface by the falciform ligament, on its posterior surface by the left sagittal fossa, and in front by umbilical notch. It's inferior and posterior surfaces are marked by three fossae; the porta hepatis, the gall bladder fossa, and the inferior vena cava. A congenital variant, Riedel's lobe, can sometimes be an anterior projection of the liver ***(Healy J et al, 2008).***

### (2) Left lobe:

The left lobe of the liver is the smaller of the two main lobes. It lies in the epigastric and left hypochondrium regions. It's under surface includes the gastric impression and omental tuberosity. 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 ***(Healy J et al, 2008).***

### (3) Caudate lobe:

The caudate lobe is a small lobe visible on the posterior surface. It is bounded on the left by the fissure for ligamentum venosum, below by the portahepatis, on the right by the groove

for the inferior vena cava. Above it continues into the superior surface. In gross anatomical descriptions this lobe is said to arise from the right lobe, but it is functionally separate ***(Healy J et al, 2008).***

**(4) Quadrate lobe:**

The quadrate lobe is only visible from the inferior surface, it appears somewhat rectangular. It is bounded on the right by the fossa for the gall bladder, on the left by the fissure for ligamentum teres, in front by the inferior border, and posteriorly by the porta hepatis. In gross anatomical description it is said to be a lobe arising from the right lobe, however, it is functionally related to the left lobe ***(Healy J et al, 2008).***

**B-Segmental anatomy of the liver (Functional anatomy):**

Based on Couinaud classification, the three main hepatic veins separate the liver into four sectors (eight segments) **(Fig 4**), each has a portal pedicle that includes a branch of the hepatic artery, portal vein, and bile duct. The middle hepatic vein divides the liver into the right and left lobes, the right hepatic vein divides the right lobe into anterior and posterior segments. And the left hepatic vein divides the left lobe into medial and lateral segments ***(Abdel-Misih S& Bloomston M, 2010).***

The portal vein divides the liver into the upper and lower segments. The numbering of segments is in a clockwise

manner. Segments II, III, and IV collectively make up the functional left lobe of the liver. Segments II and III are the lateral segments of the left lobe while segment IV is the medial segment. The functional right lobe is made up of segments V, VIII (the anterior segment).

VI and VII segments (the posterior segment). Segment I is the caudate lobe. The segmental liver anatomy is important to radiologists and surgeons, especially in view of the need for an accurate preoperative localization of focal hepatic lesions ***(Krishna M, 2013)***.

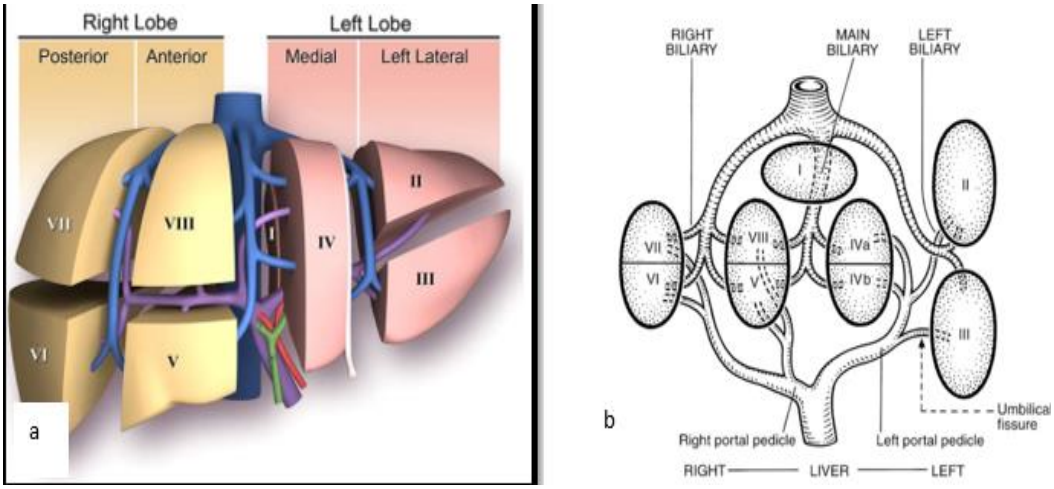


**Figure (4):** a- Couinaud classification ***(Quoted from Krishna M, 2013),*** **b**-The segmental anatomy of the liver, which is determined by the portal inflow and hepatic outflow) ***(Quoted from Blumgart L, 2012)***

## Ligamentous Attachments

The liver is almost entirely covered by visceral peritoneum and is associated with several peritoneal ligaments. The postero-cranial aspect of the liver, adjacent to

the dorsal body wall, is not completely covered by peritoneum, resulting in the so-called "bare area".

1- The falciform ligament **(Fig 5)**: extends from the umbilicus and continues onto the anterior aspect of the liver. It was used to divide it into left and right lobe.

2- The ligamentum teres: it is the lower edge of the falciform ligament.

3- The ligamentum venosum: is a remnant of the obliterated umbilical vein, it lies within a fissure on the inferior surface of the liver between the caudate lobe posteriorly and the left lobe anteriorly.

4- The coronary ligament: consists of an upper and a lower layer. The upper layer is formed by the reflection of the peritoneum from the upper margin of the bare area of the liver to the under surface of the diaphragm. The lower layer is reflected from the lower margin of the bare area on to the right kidney and suprarenal gland and is termed the hepatorenal ligament ***(Sibulesky L, 2013)*.**

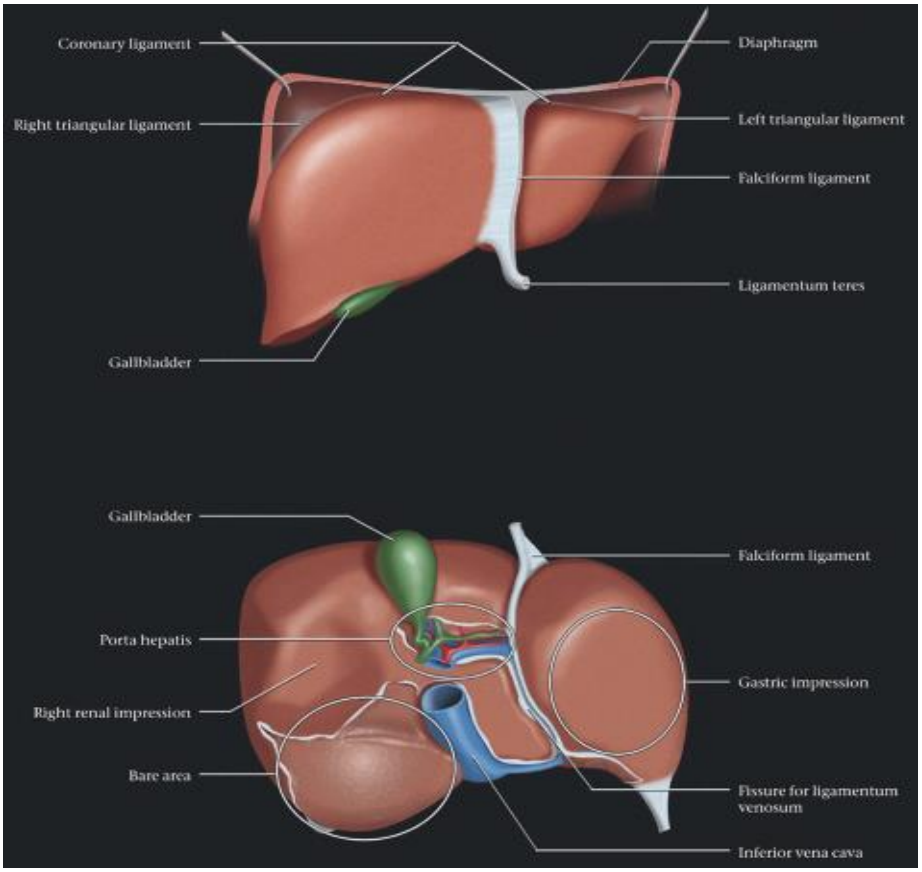


**Figure (5):** Hepatic Ligaments ***(Quoted from Federle M, 2018)***

## Porta hepatis:

The porta hepatis is seen on the inferior surface of the liver situated between the caudate and quadrate lobes where major vessels and ducts enter or leave the liver. From posterior to anterior the porta hepatis has the portal vein, the right and left hepatic arteries and the right and left hepatic ducts, it also contains lymph nodes and nerves ***(Sharma M et al, 2018)***.

## Blood supply of the liver:

The liver receives a dual blood supply from both the portal vein (70%) and the hepatic artery (30%) ***(Ryan S et al, 2007).***

### A-Portal vein

The portal vein is formed by the confluence of the splenic and superior mesenteric veins behind the neck of the pancreas. It ascends behind the common bile duct and the hepatic artery into the hilus of the liver where it bifurcates into a larger right portal vein and smaller left portal vein **(Fig 6)**. The left branch enters the umbilical fissure and supplies the left liver. The right branch, which has a much shorter extrahepatic course, divides into the right anterior and the right posterior sectoral branches. The caudate lobe may be supplied by both right and left branches of the portal vein. The most common anatomic variation is the branching of the right portal vein with either a lack of a main right portal vein or separate origins of the anterior and posterior sectoral branches ***(Lowe M and D'Angelica M, 2016).***

- The right branch: enters the right lobe and gives an anterior division supplying segments V and VIII and a posterior division supplying segments VI and VII.

- The left branch: gives off branches to segments I, II, III, and IV. As it enters the left lobe it is joined by the para-umbilical veins ***(Lowe M and D'Angelica M, 2016).***

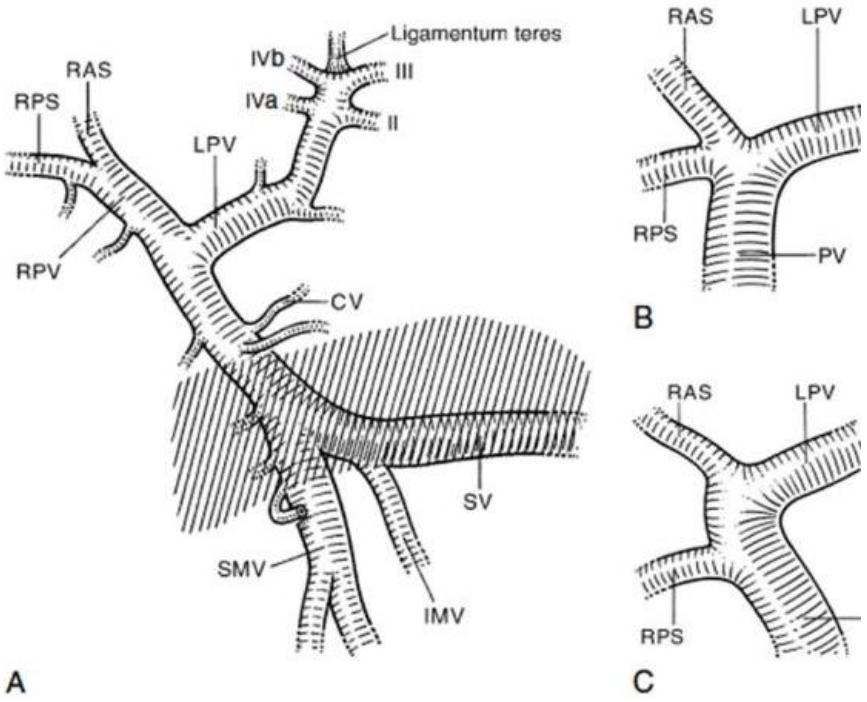


**Figure (6):** Variations in portal venous anatomy. In normal anatomy the splenic vein (SV) and superior mesenteric vein combine to form the portal vein, which branches into the right portal vein (RPV) and left portal vein (LPV). The RPV further branches in right anterior sectoral (RAS) and right posterior sectoral (RPS) branches (A). The RAS, RPS, and LPV can all arise independently from the main portal vein (B). The RPS may arise early from the portal vein, which then bifurcates in the RAS and LPV (C) ***(Quoted from Blumgart L, 2012).***

## B-The hepatic artery

It Supplies 20-25% of blood to the liver. Arises from the coeliac axis. It runs along the upper border of the pancreas, it turns upwards between the layers of the lesser omentum, lying

in front of the portal vein and medial to the common bile duct. At the porta hepatis, it divides into right and left branches. Its branches include the right gastric artery and the gastroduodenal artery. The common hepatic artery usually arises from the coeliac axis to form the gastroduodenal and proper hepatic artery which divides into right and left branches **(Fig 7).** A replaced or accessory right hepatic artery may originate from the superior mesenteric artery. A replaced or accessory left hepatic artery may arise from the left gastric artery. Rarely, the entire common hepatic artery arises as a branch of the superior mesenteric or directly from the aorta. Such anomalies are of great importance in liver transplantation ***(Balasubramanian P, 2016)***.

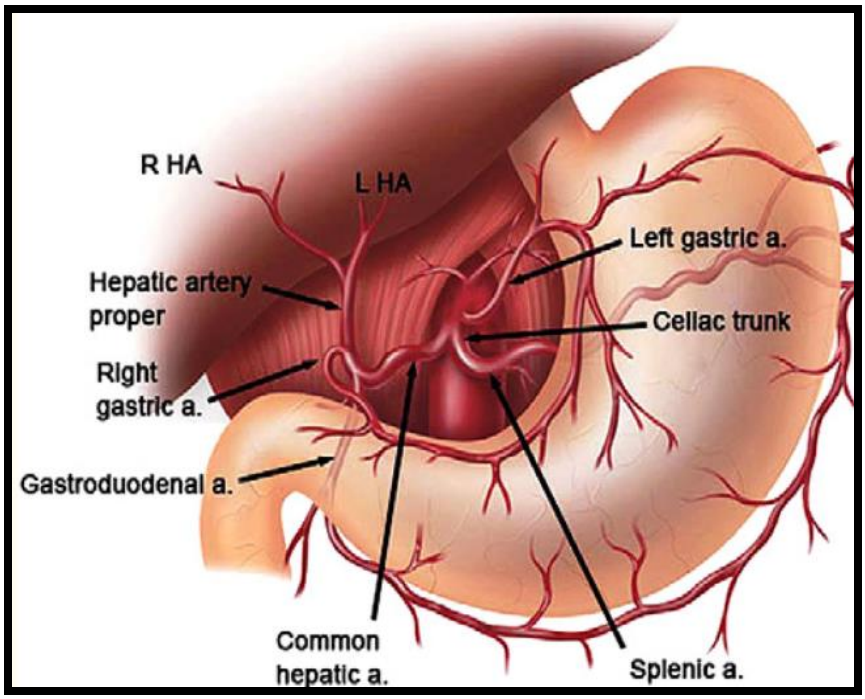


**Figure (7):** Hepatic artery and its branches ***(Quoted Abdel-Misih S& Bloomston M, 2010)***