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Review

Radiological anatomy of the liver

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Abstract

The liver is an important organ of interest to the physician, surgeon, pathologist, anatomist and the radiologist. The liver develops by proliferation of cells from the blind ends of a Y-shape diverticulum, which grows from the gut into the caudal part of the septum transversum (ventral mesogastrum) that transmits the vitellum vein. Variation in the orientation of the liver is seen in different individuals as a result of the body built. Segmental anatomy and vascular distribution of the liver is well demonstrated in radiologic imaging. Ultrasound measurement appears to be the most reliable and reproducible method of assessing and estimating the liver size invivo.

Keywords: Liver, Ultrasound, Anatomy, Radiology, Computed Tomography.

INTRODUCTION

The largest organ in the body is the liver with a mean weight of 1.2- 1.5kg, which constitutes about 25% of the adult body weight (Kenichi and Kunio, 1997). The anatomical position of the liver is a key to fulfilling its functions as it controls the release into the systemic circulation of all absorbed nutrients from the gut via the portal system. In addition to its function in metabolizing nutrients, the liver is able to store and release a variety of substrates, vitamins and minerals. It also plays a crucial role in drug and bilirubin metabolism.

In disease conditions there is variation in liver size and morphology. Variation in the orientation is also seen in individual as a result of body build (Niederau et al. 1983, Onwuchekwa et al. 2012). This makes it difficult to accurately assess the liver size by manual palpation as is done in the clinics. With introduction of radiologic imaging and especially the cross sectional imaging into medical practice, assessment of the liver could be done in details.

The aim of this review is to portray the importance of the knowledge of the radiological anatomy of the liver in interpreting radiologic images and localizing lesions in the liver.

Embryology and gross anatomy of the liver

The liver is an important organ of interest to the physician, surgeon, pathologist, anatomist and the radiologist. Anatomically, emphasis has been laid on the

massive size of the liver and the anatomical variations in the shape, size and the vasculatures.

The liver develops by proliferation of cells from the blind ends of a Y-shape diverticulum, which grows from the gut into the caudal part of the septum transversum (ventral mesogastrum) that transmits the vitellum vein. Numerous anastomoses arising from this diverticulum form a rich venous plexus into which the proliferating liver break through and grows freely in the blood stream; thus in the adult liver the blood in the sinusoids is in direct contact with the liver cells (Last1984).

The diverticulum from the endoderm of the foregut becomes the bile duct, its Y-shaped bifurcation producing the right and left hepatic ducts. A blind diverticulum from the common bile duct becomes the cystic duct and gallbladder (Last 1984). Due to this pattern of development and acquisition of blood vessels, different anatomical variations exist in the vascular supply and drainage of the liver. The right hepatic vein has variations which Lucio De Cecclus et al. (2000) classified into types based on the length of the vein trunk, the confluence of 2 or 3 main tributaries that form a trunk and accessory right hepatic veins that modify the venous drainage of the right side of the liver. It is also worthy of note that variation exists in the arterial supply. Knowledge of the exact arterial supply to the liver may be important to surgeons when planning arterial reconstruction (Thomas et al., 1995).

In the same study it was found out that only 55% of

the study population have celiac artery which continued into the common hepatic artery, and distributed into the right, middle and left hepatic arteries. The remaining percentage has variation different from the conventional pattern described above.

The configuration of hepatic lobes and segments varies considerably among individuals; either the major lobe or any segment may be considerably smaller than normal or completely absent, in which case the remainder of the organ is likely to be unusually large (Wegener 1992).

Presence of Riedel's lobe is also one of the morphological variations in which the right lobe protrudes beyond the costal margin (rat tail pattern) commonly seen in females but also occurs in males (David, 1988).

Variation in the orientation of the liver is seen in different individuals as a result of the body build. Niederau et al. (1983) in their study found that the liver is oriented longitudinal in slender subjects and transversely in heavy subjects. Thus both the longitudinal and anteroposterior diameters need to be measured, since the longitudinal diameter alone will give too high or too low a value. Onwuchekwa et al. (2012) reported in their study on liver size of adults that the liver size is larger in the obese than in the non obese subjects.

Radiological features of the liver

Radiography

Plan abdominal radiograph demonstrates the shadow of the liver in the right hypochondrium as a generalized opacity. It is limited by air filled surrounding organs and fat planes. Based on these features the border of the liver can be classified as true or apparent border (Gelfand 1992). The true border of the normal liver can only be identified if outlined against fat or fat permeated tissues. Such fat is found extraperitoneally, retroperitoneally, properitoneally and intraperitoneally (pericolic or omental).

Apparent borders are found against gas in adjacent organs. The lungs with the diaphragm intervening usually provide good evidence of the liver outline superiorly in the absence of pulmonary, pleural or subdiaphragmatic disease (Gelfand 1992).

The inferior margin of the liver extends anteriorly to (and often beyond) the respective gas containing lumina of the stomach, duodenum and hepatic flexures of the colon. The situation of these structures on the plain film therefore provides an unreliable indication of the position of the inferior margin of the liver. The properitoneal fat usually delineates the lateral border of the right lobe down to the inferior angle.

The divergent x-ray beam during supine filming tends to be tangential to the visceral surface outlining it against both retroperitoneal and intraperitoneal fat. In slender people with a rather steep visceral surface only the inferior border itself can be tangential to beam and will not often present true outline against intraperitoneal fat. The inferior border of the left lobe is rarely visible on plain film.

Scintigraphy

Anatomical imaging of the liver is performed using 2-15mci (74-555MBq) of ^{99m} Tc Sulphur colloid (Gelfand 1992).

The normal liver scan identifies an organ, which occupies most of the volume beneath the diaphragm and the lower costal margin of the rib cage. The right lobe comprises of the bulk of the organ, with the left lobe being smaller and compressed by the spine and stomach. An indentation is produced by the round ligament, the inferior margin of the falciform ligament, and separates the right lobe and the quadrate lobe from the left lobe. The gallbladder fossa creates an indentation on the inferior border of the right lobe. The hepatic vein may create a triangular impression on the superior margin of the liver, and the porta hepatis creates a central defect where there is a confluence of ducts and blood vessels (Gelfand 1992).

Angiography

Arteriography displays the arterial arrangement of the liver (figure 1). A complete vascular study is obtained when arteriography is performed (Rasmussen 1972, Rubaltelli 1980). The normal arterial arrangement is for the common hepatic artery to arise as one of the three major branches of the celiac axis, however a number of variations have been documented (Rubaltelli 1980).

Hepatic venography

Hepatic venography will demonstrate the three hepatic veins which enter the inferior vena cava either as a single trunk or more commonly, the right vein enters separately and middle and left veins form common trunk; sometimes all three enter the inferior vena cava separately. The caudate and right lobes are also drained by several smaller veins, which enter the inferior vena cava separately.

Computed Tomography

Computed tomography of the liver gives a good anatomical image of the liver in axial sections, however this image could be reformatted to obtain coronal or sagittal image of the liver as the case may be. The



Figure 1: arteriography demonstrating the hepatic arteries.



Figure 2: CT image showing the hepatic veins and the liver segments.

intrahepatic vasculatures and biliary channels are well demonstrated as well as the different lobes and fissures (figure 2). The segmental anatomy of the liver is well delineated. The liver is divided into eight segments by four scissurae (Isam et al., 1996). One scissura is oriented in the axial plane at the level of the right and left main portal trunk (transverse scissura), and three are oriented in the plane of the three hepatic veins (longitudinal scissurae). With use of axial imaging such as US, CT and MRI, lines drawn from the inferior venae cava straight through the three hepatic veins have been shown to coincide with the boundaries between segments, which are the longitudinal scissurae (Isam et al., 1996, Sexto and Zeman 1983, Mukai et al., 1983). In addition the anatomical relations such as the right kidney, stomach, inferior vena cava and esophagus are clearly seen (Gelfand 1992).

Magnetic Resonance

Magnetic Resonance Imaging (MRI) gives a similar anatomical image as computed tomography, but has the advantage of displaying the image in axial, coronal and sagittal plain. It also gives a better contrast and display the vessels clearer (Farr and Allisy-Roberts, 1999).



Figure 3: ultrasound image demonstrating the hepatic veins and the liver segments



Figure. 4: longitudinal ultrasound image showing the intra hepatic portal vein.

Unlike computed tomography, there is no danger of radiation to the patient as it does not use x-ray in imaging. It utilizes magnetic resonance and radio waves.

Ultrasonography

The normal liver shows a uniform echo pattern with linear echoes arising from small vessels and connective tissue framework. Portal branches and tributaries of the hepatic veins are seen as small round or tubular transonic structures within the liver framework (figure 3 and 4). The portal branches cross the liver transversely and therefore appear round on sagittal section. They are easily located at the hilum and are surrounded by a band of stronger echoes. The hepatic veins are easily identified in the sagittal plane in the sub-diaphragmatic region. Their calibers increased in a cranial direction. Normally, branches of the hepatic artery and the intra-hepatic biliary tree are not seen as their caliber is small. The



Figure 5: Segmental anatomy of the liver using the Couinaud's segments.

relationship of the liver to the vena cava, aorta and pancreas is clearly seen in the sagittal sections performed in the midline or to right or left of the midline.

Sagittal sections further to the right will show the right lobe of the liver, the gallbladder, and the right kidney between the liver and the posterior abdominal wall. The right hemidiaphragm can be clearly delineated in all cases and its motility studied by scanning during inspiration and expiration. The left hemidiaphragm may be more difficult to see due to presence of bowel gas. Transverse scan in the subxiphoid region will clearly display the right and left lobe with large abdominal vessels and spine behind. More caudally the gallbladder and kidneys are seen although the left kidney will often not be visible due to bowel gas (Gelfand 1992).

The falciform ligament or ligamentum teres situated between the medial and lateral segments cause a mass of dense echo in the left lobe. In serial scans this is seen to move anteriorly towards the surface of the liver and posteriorly towards the porta hepatis (David, 1988). It is also possible to display the fissure of the venous ligament containing the ligamentum venosum and part of the lesser omentum that separates the caudate lobe from the left lobe and also the fissure between the quadrate and right lobes (the gallbladder fossa) (Parulekar 1979). This enables the identification of the various segments of the liver, which is very useful to the surgeon when planning an operation (David, 1988).

The liver is made up of two lobes with two segments each (figure 5). The right lobe is divided into anterior and posterior segments whilst the left lobe is divided into medial and lateral segments. The portal and hepatic veins separate the different segments. The middle hepatic vein that courses within the main lobar fissure separates the right lobe from the left lobe and a longer branch of the right hepatic vein divides the anterior and posterior segment of the right lobe. The cephalic and caudal part of the medial and lateral segments of the left lobe is divided by the left hepatic vein and falciform ligament respectively. In transverse section the caudate lobe is delineated by the left portal vein in front, the vena cava at the back and the fissure of the ligamentum venosum on the left.

The left portal vein and its connective tissue can simulate the posterior margin of the left lobe in transverse section and the liver tissue posterior to it can be misinterpreted as lying outside the liver (Filly et al., 1979).

Methods of assessing the liver size

Different modalities can be used to assess and measure liver size (Skrainka et al., 1986). Of these methods, ultrasound measurement appears to be the most reliable and reproducible. The measurement is taken at a specific point. The right midclavicular or parasagittal line has been found to be an easy and practical point for routine use (Skrainka et al., 1986, Sapira and Williamson, 1979). The craniocaudal length and anterior posterior span of the liver can be measured from a single real time image from ultrasound. Volume estimation by ultrasound is more reliable than other methods because it uses longitudinal section which is superior in volume calculation than transverse section (Fritschy et al., 1983). Application of Doppler also aids in the assessment of hepatic vessels perfusion and diameter (Adeodu et al., 2001). Mean liver span at the midclavicular line was found to be 14.5+ 1.6cm by Wolfgang et al. (2003), with an average of 14.5+1.6cm in males and 13.5+1.7cm in females. This differs slightly from the finding by Niederau et al. (1983); who observed a mean value for the craniocaudal dimension at the midclavicular line of 10.5+1.5 and an anterioposterior dimension of 8.1+1.9cm. Ultrasound estimation of liver volume has

been found to correlate well with the actual liver volume as determined by water displacement method (Gladisch et al., 1988). In this study the estimated liver volume was 1402cm³ for males and 1257cm³ for females. Liver size can be estimated from plain erect abdominal radiograph, however this method has been found to overestimate the size of the liver when compared to ultrasonography (Unal 2004). In the plain abdominal radiograph study, it was found that the mean value for normal liver length was 20cm while evaluation with ultrasound gave a mean value of 15.2+3.5cm. The difference in the two modes of measurements was presumed to be due to both magnification and change in liver shape.

Factors influencing normal liver size

Gender becomes a factor when liver size, possibility of hepatomegaly or liver transplant is being considered in a patient. It has been found that the size of the liver is larger in males than in females. Obradovic et al. (1991) showed that the average liver length in males of the regional population is 26cm, while in the female it is 25cm. Similarly the average liver thickness in males of the regional population is 22cm in males and 20cm in females, and the average liver height both in males and female subjects is 7cm. The average liver weight in males of the regional population is 1700g and females 1600g. The difference in liver size between males and females has been explained by the higher rate of liver growth in males at a certain age than that of the females. In Germany, Chouker et al. (2004) showed that liver weight increases with age, reaching a maximum value between 41 and 50 years in men and between 51 and 60 years in women. Thereafter liver weight decreases again. This lost in liver weight starts earlier in men, while liver weight continues to rise in women. Thus the difference between men and women is lost above the age of 50years.

However, in children liver size is independent of age as established in the study by Assadamongkol et al. (1989) in Thai on school children. Variation of liver size with age was reported by Chouker et al. (2004) and supported by the study done in Italy by Boscaini and pietri, (1987). They carried out a prospective study to calculate, by fast and simple ultrasonic method, the size of the liver in 75 subjects and found a hepatic volumetric index (HVI) between 90 and 140 in 95% of normal subjects below 65years of age.

Hepatic volumetric index was 80 to 135 in those above 65 years, which proved to be in accordance with the involution of liver size in the elderly Leung et al. (1986). Body mass and body height have been found to correlate well with liver size. Wolfgang et al. (2003) in their study found that the body mass index and body height are the most important factor associated with the diameter of the liver measured at the midclavicular line. Similarly, Leung et al. (1986) made the same assertion that correlation was found between liver volume and body weight, height and surface area, with body weight showing the closest correlation. In the same study, it was also found that patients who continue to abuse alcohol showed persistent increase in hepatic volume.

CONCLUSION

Radiological imaging is essential for final decision on surgical interventions on the liver. Knowledge of the exact arterial supply to the liver may be important to surgeons when planning arterial reconstruction. The axial imaging modalities which include ultrasonography, computed tomography and magnetic resonance imaging are invaluable for evaluation and description of the anatomical details of the liver and its surrounding organs. Further researches on other imaging modalities for liver assessments are necessary especially with the new advances on liver imaging.

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