Introduction

Role of multi-detector CT scan in pre and post operative assessment of liver transplantation

Orthotopic liver transplantation (OLT) is currently the treatment of choice for patients with severe acute or chronic liver failure for which no other therapy is available. Liver failure can have a number of causes, including autoimmune hepatitis; chronic viral hepatitis; alcoholic liver disease; metabolic diseases (alpha-1-antitrypsin deficiency, hemochromatosis, Wilson disease); cholestatic liver disorders (primary biliary cirrhosis, primary sclerosing cholangitis, biliary atresia); and severe acute liver failure due to viral hepatitis, drug-induced hepatitis (e.g., by acetaminophen or isoniazid), or hepatotoxins (e.g., mushrooms) (***Sergi et al., 2001).***

Multidetector CT is proving to be valuable in the evaluation of potential living liver donors, contributing to donor safety and providing comprehensive information about the hepatic vascular anatomy, the liver parenchyma, and graft and remnant liver volume ***(Ana et al., 2005).***

Multidetector CT is an excellent tool for mapping out the hepatic vascular anatomy; it is essential that the radiologist to be familiar with the normal liver anatomy and should be able to recognize the presence of variants, especially those considered relative or absolute contraindications for donation, those requiring reconstruction or multiple anastomoses, and those that may alter the surgical Approach ***(Dushyant et al., 2004).***

In the majority of potential donors, CT angiography depicted a wide range of vascular anatomic variations that traverse the hepatectomy plane (***Michael et al., 2003).***

Multi–detector row computed tomography (CT) offers distinct advantages over traditional spiral CT. Multi–detector row CT scanners are faster and allow thinner collimation than single– detector row spiral CT scanners. The use of multi–detector row CT combined with postprocessing of the imaging data with a variety of three-dimensional reformatting techniques (e.g., maximum intensity projection, shaded surface display, volume rendering) allows creation of vascular maps whose quality equals or exceeds that of maps created at classic angiography for many applications ***(Heoung et al., 2007).***

Liver transplantation is currently an accepted first line treatment for patients with end stage acute or chronic liver disease, but postoperative complications may limit the long term success of transplantation. The most common and most clinically significant complications are arterial and venous thrombosis and stenosis, biliary disorders, fluid collections, neoplasms, and graft rejection. Early diagnosis is crucial to the successful management of all these complications, and imaging plays an important role in the diagnosis of all but graft rejection ***(Angela et al., 2007).***

Aim of work

The aim of this work is to highlight the crucial role of multi-detector CT scan as a non invasive technique in pre and post operative assessment of liver transplantation.

Anatomy of the Liver

Introduction:

The liver is the most massive of the viscera, occupying a substantial portion of the abdominal cavity. It is essential to life, since it carries out a multiplicity of metabolic activities necessary for homeostasis, alimentation and defence. It is composed largely of epithelial cells (hepatocytes) where most of these biochemical operations occur, bathed by blood derived from the hepatic portal veins and hepatic arteries, and draining into the inferior vena cava through the hepatic veins ***(Bannister et al., 1999).***

External Features:

The liver (hepar) lies in the upper right part of the abdominal cavity, occupying most of the right hypochondrium and epigastrium and extending into the left hypochondrium as far as the left lateral line (Rouiller 1964). In males it generally weighs 1.4–1.8 kg, and in females 1.2–1.4 kg, with a range of 1.0–2.5 kg ***(Bannister et al., 1999).***

The liver is a wedge-shaped, rather rounded organ, its narrow end pointing left, and its anterior edge directed downwards. It is convex in front, to the right, above and behind, where it abuts the curved surfaces of the anterior body wall and diaphragm, and it is somewhat concave inferiorly where it is moulded to the shapes of the adjacent viscera. The liver is attached in front to the body wall by the falciform ligament, and above and behind to the diaphragm by the coronary ligament with its lateral limits, the right and left triangular ligaments (forming reflexions of the peritoneum from the liver surface on to the diaphragm). Below, it is attached to the stomach and first part of the duodenum by the lesser omentum, along the right (free border) of which the hepatic arteries, hepatic portal vein, lymphatics, nerves and hepatic ducts enter or leave the liver at the porta hepatis (the door to the liver), an area also termed the hilus. The gallbladder adheres to the anterior part of the liver's inferior surface ***(Bannister et al., 1999).***

The inferior surface is marked near the midline by a sharp fissure which anteriorly receives the ligamentum teres (the obliterated fetal left umbilical vein) from the free edge of the falciform ligament, and posteriorly contains the ligamentum venosum, another obliterated relic of the fetal circulation. The lesser omentum is reflected on to the liver along the posterior half of this fissure ***(Bannister et al., 1999).***

Posteriorly, the liver is deeply grooved where it partially surrounds the inferior vena cava (the caval groove) which receives the large hepatic veins in this region ***(Bannister et al., 1999).***

Lobation and Segmentation:

The liver has four lobes or eight segments, depending on whether it is defined by its gross anatomical appearance or by its internal architecture. Classification of the liver by internal architecture divides it into lobes, segments or sectors. The biliary, hepatic arterial and portal venous supply of the liver tend to follow very similar distributions used to define the hepatic segments. The value of the segmental classification, according to vascular and biliary supply, is that surgical resection of a segment, multiple segments or a whole lobe, may be planned and performed to encounter the fewest possible major vascular structures ***(Toogood et al., 2005).***

Gross anatomical lobes:

Historically the gross anatomical appearance of the liver has been divided into right, left, caudate and quadrate lobes by the 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 the porta hepatis. The quadrate lobe lies anteriorly, the caudate lobe posteriorly. The gallbladder usually lies in a shallow fossa to the right of the quadrate lobe ***(Toogood et al., 2005).***

Right lobe:

The right lobe is the largest in volume and contributes to all surfaces. It is demarcated by the line of attachment of the falciform ligament superiorly. Inferiorly the fissure for the ligamentum teres, the groove for the ligamentum venosum, and the attachment of the lesser omentum, mark its border.

The inferior border of the right lobe, to the right of the gallbladder, often demonstrates a bulge of tissue, which when pronounced, is referred to as Riedel's lobe. Although the right inferior border of the liver is not usually palpable, the presence of a Riedel's lobe may be clinically detectable and may give rise to confusion as an apparent pathological right upper quadrant mass ***(Toogood et al., 2005).***

Quadrate lobe:

The quadrate lobe is only visible from the inferior surface. It is bounded by the gallbladder fossa to the right, a short portion of the inferior border anteriorly, the fissure for the ligamentum teres to the left, and the porta hepatis posteriorly. In gross anatomical descriptions it is said to be a lobe arising from the right lobe; however, it is functionally related to the left lobe ***(Toogood et al., 2005).***

Caudate lobe:

The caudate lobe is visible on the posterior surface. It is bounded on the left by the fissure for the ligamentum venosum, below by the porta hepatis, and on the right by the groove for the inferior vena cava. Above, it continues into the superior surface on the right of the upper end of the fissure for the ligamentum venosum. Below and to the right, it is connected to the right lobe by a narrow caudate process, which is immediately behind the porta hepatis and above the epiploic foramen.. In gross anatomical descriptions this lobe is said to arise from the right lobe, but it is functionally separate ***(Toogood et al., 2005).***

Left lobe:

The left lobe is the smaller of the two 'main' lobes. It lies to the left of the falciform ligament, has no subdivisions, and ends in a thin apex pointing into the left upper quadrant. Since it is substantially thinner than the right lobe it is more flexible. It is nearly as large as the right lobe in young children, possibly due to a more even distribution in portal and hepatic arterial supply, which may progressively come to favour growth of the right lobe during development of the body cavity ***(Toogood et al., 2005).***

Segmental liver anatomy:

Although a variety of definitions have been used to describe the anatomy of the liver segments, the most widely accepted clinical nomenclature is that described by Couinaud (1957). The internal architecture of the liver is divided into segments, commonly referred to as Couinaud's segments. Couinaud based his work on the distribution of the portal and hepatic veins ***(Fig 1) (Toogood et al., 2005).***

The liver is divided by the 'principal plane' into two halves of approximately equal size. The principal plane is defined by an imaginary parasagittal line from the gallbladder anteriorly to the inferior vena cava posteriorly. The usual functional division of the liver into right and left lobes lies along this plane. The liver is further subdivided into segments, each supplied by a principal branch of the hepatic artery, portal vein and bile duct. Segments I, II, III and IV make up the functional left lobe, and segments V, VI, VII and VIII make up the functional right lobe. The right lobe can be further divided into a posterior and anterior section or sector. The right posterior section is made up of segments VI and VII, and the right anterior section is made up of segments V and VIII. The left lobe can also be divided into sections: segment IV is referred to as the left medial section, and segments II and III as the left lateral section. The hepatic veins lie in liver parenchyma between the sections. Segment I corresponds to the gross anatomical caudate lobe and segment IV to the quadrate lobe. The delineation of the internal liver architecture has been confirmed by cross- sectional imaging techniques as well as hepatic portography and arteriography ***(Toogood et al., 2005).***

On axial CT and MRI, segment I is situated posterior and to the right of the inferior vena cava; segments VII, VIII, IV and II run in a clockwise fashion above the portal vein; and segments VI, V, IV and III are situated in a similar manner below the portal vein ***(Toogood et al., 2005).***

The value of the identification of the liver segments and sections according to vascular and biliary supply is that surgical resection of a segment, section, multiple segments, a lobe or greater volume of tissue may be performed whilst encountering the least number of possible major vascular structures ***(Toogood et al., 2005).***

Table (1): segmental anatomy of the liver

Goldsmisth and woodbrune classification	Couinad Classification	Bismuth classification
Caudate lobe	Segment 1	Segment 1
Left lateral segment: Superior subsegment Inferior subsegment	Segment 2	Segment 2
	Segment 3	Segment 3
Left medial segment: Superior subsegment Inferior subsegment	Segment 4	Segment 4a
		Segment 4b
Right anterior segment: Inferior subsegment Superior subsegment	Segment 5	Segment 5
	Segment 8	Segment 8
Right posterior segment: Inferior subsegment Superior subsegment	Segment 6	Segment 6
	Segment 7	Segment 7

(Quoted from Ansert-Hagan, 2000)

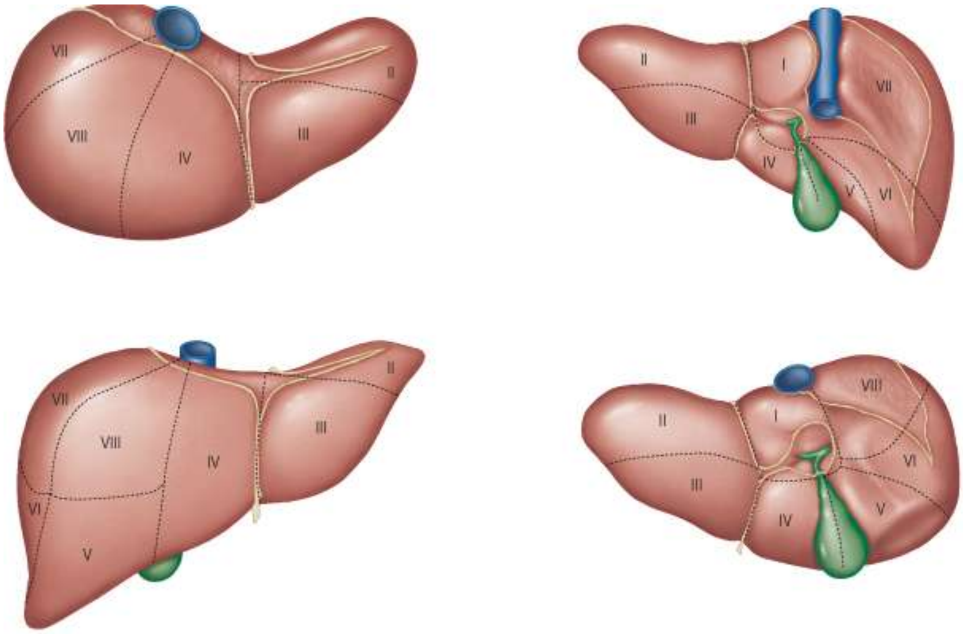

Fig. (1): Segmentation of the liver - Couinaud. Top left, superior view; top right, posterior view; bottom left, anterior view; bottom right, inferior view. The segments are sometimes referred to by name - I, caudate (sometimes subdivided into left and right parts); II, lateral superior; III, lateral inferior; IV, medial (sometimes subdivided into superior and inferior parts); V, anterior inferior; VI, posterior inferior; VII, posterior superior; VIII, anterior superior. Quoted from ***(Toogood et al., 2005).***

Liver resection:

Surgical resection of the liver for primary and secondary neoplasia is now routine, and there is very low morbidity and mortality. Knowledge of the internal anatomy of the liver is essential. As much as 80% of the liver mass can be removed safely. The liver has the unique capacity of regeneration, and will regrow to its original size within 6-12 months after resection.

The identification of the hepatic arterial and portal venous segmentation means that lesions seen on cross-sectional imaging can be placed within segments, so that the feasibility of resection can be assessed. Although detailed arterial and portal venous imaging is usually required to allow definitive surgical planning, understanding the segmental anatomy of the liver has allowed considerable advances to be made. Since the hepatic venous anatomy differs widely from the portal and arterial anatomy, resections rarely lie within wholly convenient vascular planes. Currently, the main limitation to liver resection is not the difficulty of segmental anatomy but the involvement of vital structures such as the inferior vena cava, or the need to preserve an adequate volume of functioning liver tissue after resection ***(Chaib et al., 2005).***

Resection of the liver can be described as either non-anatomical or anatomical. Non-anatomical resections are usually minor and the lines of resection are not related to Couinaud's segments ***(Chaib et al., 2005).***

Liver transplantation:

Liver transplantation is an established form of treatment for patients with end stage liver disease. Orthotopic transplantation involves a standard hepatectomy including the hepatic inferior vena cava. The implant of the graft then requires a superior and inferior caval anastomosis, followed by anastomosis of the portal vein. In adults, most surgeons use venovenous bypass during the anhepatic phase of the transplant. This allows splanchnic and systemic venous blood to return to the heart via the internal jugular vein. The transplant is completed by performing the arterial and biliary anastomoses ***(Chaib et al., 2005).***

Vascular supply

The vessels connected with the liver are the portal vein, hepatic artery and hepatic veins. The portal vein and hepatic artery ascend in the lesser omentum to the porta hepatis, where each bifurcates. The hepatic bile duct and lymphatic vessels descend from the porta hepatis in the same omentum.The hepatic veins leave the liver via the posterior surface and run directly into the inferior vena cava ***(Toogood et al., 2005).***

Hepatic artery:

In adults the hepatic artery is intermediate in size between the left gastric and splenic arteries. In fetal and early postnatal life it is the largest branch of the coeliac axis. After its origin from the coeliac axis, it passes anteriorly and laterally below the epiploic foramen to the upper aspect of the superior part of the duodenum. The artery may be subdivided into the common hepatic artery - from the coeliac trunk to the origin of the gastroduodenal artery - and the hepatic artery 'proper' - from that point to its bifurcation. It passes anterior to the portal vein and ascends between the layers of the lesser omentum. It lies anterior to the epiploic foramen and passes in the free border of the lesser omentum medial to the common bile duct and anterior to the portal vein. At the porta hepatis it divides into right and left branches before these run into the parenchyma of the liver. The right hepatic artery usually crosses posterior (occasionally anterior) to the common hepatic duct. It 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 gallbladder. The segmental arteries are macroscopically end arteries although some collateral circulation occurs between segments via fine terminal branches ***(Mlakar et al., 2005).***

Normal variants:

There are a small number of normal variants, which are important to demonstrate angiographically because they may influence surgical and interventional radiological procedures. A vessel which supplies a lobe in addition to its normal vessel is defined as an accessory artery. A replaced hepatic artery is a vessel that does not originate from an orthodox position and is the sole supply to that lobe. Rarely a replaced common hepatic artery arises from the superior mesenteric artery. More commonly a replaced right hepatic artery or an accessory right hepatic artery arises from the superior mesenteric artery. In this case they run behind the portal vein and bile duct in the lesser omentum. Occasionally, a replaced left hepatic artery or an accessory branch arises from the left gastric artery. This provides a source of collateral arterial circulation in cases of occlusion of the vessels in the porta hepatis and may be injured during mobilization of the stomach as it lies in the upper portion of the lesser omentum. Rarely, accessory left or right hepatic arteries may also arise from the gastroduodenal artery or aorta. The hepatic artery gives off right gastric, gastroduodenal and cystic branches as well as direct branches to the bile duct from the right hepatic and sometimes the supraduodenal artery ***(Mlakar B et al., 2005).***

Viens:

The liver has two venous systems. The portal system conveys venous blood from the majority of the gastrointestinal tract and its associated organs to the liver. The hepatic venous system drains blood from the liver parenchyma into the inferior vena cava ***(Mlakar et al., 2005).***

Portal vein:

The portal vein begins at the level of the second lumbar vertebra and is formed from the convergence of the superior mesenteric and splenic veins. It lies anterior to the inferior vena cava and posterior to the neck of the pancreas. It lies obliquely to the right and ascends behind the first part of the duodenum, the common bile duct and gastroduodenal artery. At this point it is directly anterior to the inferior vena cava. It enters the right border of the lesser omentum, and ascends anterior to the