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Use of computed tomography as an aid to hepatic resections

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The clinical interest in hepatic tumor resection has increased the importance of knowing the segmental anatomy of the liver. Classical descriptions of the gross anatomic divisions of the liver were based solely on surface structures. These classicall divisions of hepatic anatomy are of little help to the surgeon because the surface anatomy poorly reflects the organ's internal vascular structure. A »surgical vascular subdivision« is a valuable technique for showing abnormalities of the liver whether diffuse or focal.
Cross-sectional imaging of the liver with CT provides excellent demonstration of the hepatic vasculature and of the lesions to be removed[1-3] allowing surgeons to plan resections according to anatomic principles.

Key words: liver neoplasms-surgery; tomography, x-ray computed

Hepatic anatomy

Traditionally, the liver was divided into four lobes right, left, caudate, and quadrate, based on the external configuration of grooves on the visceral surface of the liver. The falciform ligament divides the right lobe from the left lobe. Some authors generalized even further and used the falciform ligament to divide the right lobe from the left lobe. Thus, the »right lobe« includes the right, quadrate, and caudate lobes.

However, logic and surgical need dictate dividing the liver on the basis of the vascular anatomy and not external configuration. Two commonly used hepatic segmental nomenclatures based on the branching of the portal triad have been developed. The one usually used in the American and English literature has been outlined by Goldsmith and Woodburne.[4] Based on this functional system of hepatic division, known as »American system«, the liver is divided into the right, left, and caudate lobes. The right lobe of the liver is further divided into anterior and posterior segments and left lobe into medial (formerly known as the quadrate lobe) and the lateral segments (formerly known as the left lobe) Figure 1a). The caudate lobe occupies much of the posterosuperior surface of the liver and is bounded posteriorly by the fossa of the inferior vena cava and anteriorly by the fissure of the ligamentum venosum. It is considered a separate and distinct lobe, since it receives its vascular supply and biliary drainage from both the right and left lobes.

Couinaud developed another system of hepatic anatomical description, and the French surgeon Bismuth demonstrated the practical utility of this system (»Couinaud's system«).[4] According to Couinaud's description, the three main hepatic veins divide the liver into four sectors. He terms the planes through which the hepatic veins course the *portal scissurae*. The right, main and left portal scissurae define the four sectors, each of which receives a portal pedicle (Figure 1b). The main portal scissura divides the liver into right and left livers. The right portal scissura divides the right liver into anterior and posterior sectors. Each of this sectors contains two segments. The anterior sector has segment V inferiorly and segment VIII superiorly. The posterior sector contains segment VI inferiorly and segment VII superiorly. The left portal scissura divides the left liver into superior and posterior sectors. The umbilical fissure divides the anterior sector

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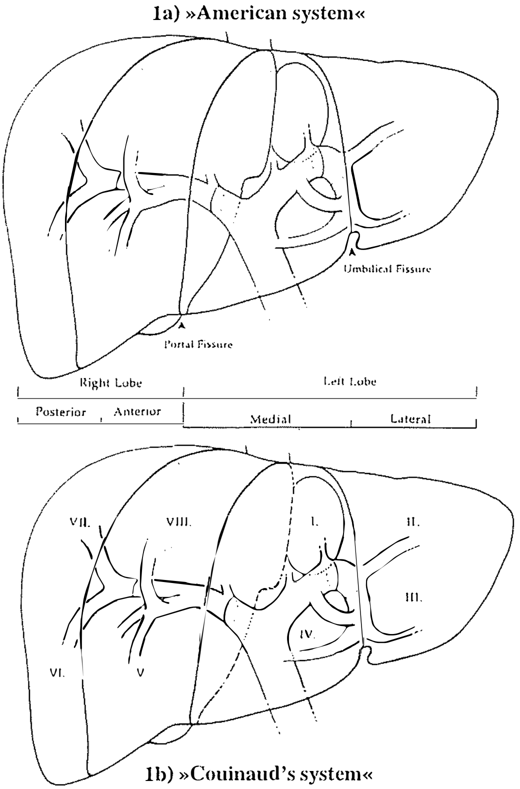

Figure 1. Segmental anatomy of the liver a) »American system«, b) »Couinaud's system«.

into two segments, medially segment IV and laterally segment III. The posterior sector has only one segment, segment II, thas forms the posterior part of left lobe. The caudate lobe comprises segment I, which is vascularized independently from portal division, receiving branches from both right and left portal vein and hepatic arteries. Its hepatic veins drain directly into the vena cava. The portal vein and hepatic arterial branches correspond to segmented anatomy. Likewise, the bile ducts provide segmental drainage.

Cross-sectional imaging

Cross-sectional imaging of the liver with computed tomography provides excellent demonstration of eight hepatic segments (according to Couinaud's system) on the basis of the vascular anatomy. They are defined principally on the position of the three major hepatic veins (right, middle and left), and are numbered spirally from the caudate lobe (segment I). From these boundaries multisegmental resections can be performed. A CT study of the liver entails imaging of the entire organ from its superior border at the dome of the diaphragm to its caudal tip. Contigious 10 mm thick slices are obtained, usually before and after intravenous injection of contrast medium. On CT the unenhanced normal liver is homogenous in density (50–70 HU) except for the portal veins, identifed as linear or circular structures of lower attenuation. The porta hepatis is visible as a fat containing horizontal cleft on the medial border of the right lobe of the liver with the quadrate lobe anteriorly and caudate lobe posteriorly.[5] Following intravenous contrast enhancement, attenuation values of liver parenchyma rise to 60–90 HU.[4]

The right and left lobes of the liver can be indicated by projecting a line from the gallbladder fossa to the inferior vena cava. The portal vein branches are largest at the level of the porta hepatis whereas the hepatic veins are larger in the more cephalad sections and are recognizable by their relationship to the normal inferior vena cava.[4] Normal calibre intrahepatic bile ducts are not demonstrable; only the major biliary radicles at the porta hepatis are identifiable as discrete structures. The common bile duct is situated anterolateral to the portal vein throuhgout its length.[5,6]

The larger blood vessels can be seen in normodense, noncontrasted hepatic tissue as hypodense structures with a typical configuration. They may be invisible on CT scans when parenchymal density is even slightly reduced (eg. fatty infiltration) but they appear hyperdense as fatty infiltration increases.[7] Bolus administration of contrast medium ensures reliable demonstration of even small portal venous radicles which can be distinguished from parallel biliary ducts, particulary if the latter are dilated. The variable shape of the porta hepatis is extensively filled out by the vascular band of the portal vein, which is accompanied by the hepatic artery and by the common bile duct. This triad relationship is also seen in the further branches located in the liver periphery. The supply areas of tertiary rami correspond to the eight hepatic segments (according to Couinaud's system) which can be localized via computed tomography (Figures 2, 3 and 4). The three main branches of the hepatic veins drain below the diaphragm (stellate pattern) into the inferior vena cava. Therefore, left (C), mid-

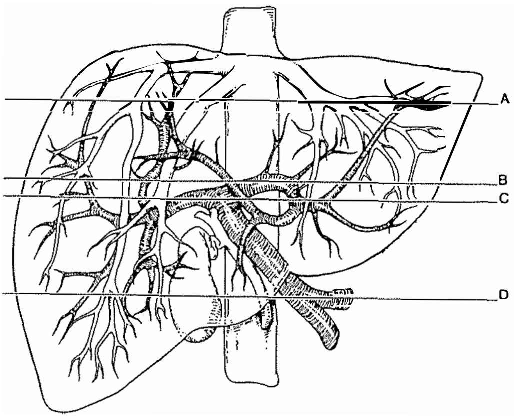

Figure 2. Lines A to D indicate the anatomic levels of images shown in Figs. 3. and 4.; A) on the level just below venous angle in the liver, B) directly above the bifurcation of the portal vein, C) on the same level as the bifurcation, D) below the bifurcation of the portal vein.

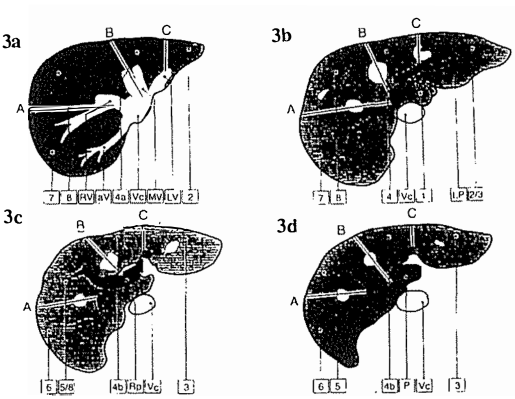

Figure 3. Segmental anatomy of the liver in transverse section. The intersegmental veins join into three cranial trunks, the right (a), middle (b), and left (c) main veins, which divide the liver into four sectors (modified according to references 7 and 8).

dle (B) and right (A) main hepatic veins can usually be demonstrated on one section. They divide the liver into four sectors. These sectors are subdivided horizontally by the plane in which the portal vein branches into fissure that cannot be seen on the surface of the liver and that contains a major hepatic vein (Figure 2). The right main hepatic vein divides the right lobe of the liver on the one side into anterior segments V and VIII, as well as into dorsally located posterior segments VI and VII. Segments VII and VIII form the dome of the liver. The caudate lobe comprises the first liver segment, which drains via smaller veins directly into inferior vena cava.[7, 8]

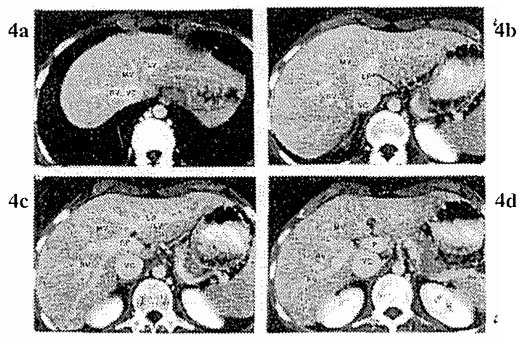

Figure 4. Hepatic segments in CT (same levels as Figure 3 and 4) (modified according to references 7 and 8).

1–8 = hepatic segments
LV = left main vein of the liver (plane C)
MV = middle main vein of the liver (plane B)
RV = right main vein of the liver (plane A)
P = portal vein
IVC = inferior vena cava
Rp = right main branch of the portal vein
Lp = left main branch of the portal vein

Resectability of the liver lesions

The indications for major liver surgery, particulary resection, continue to include predominantly focal parenchymal diseases. The decision of when and upon whom to perform major liver resection depends on the disease, the certainty of its diagnosis, the overall fitness of the patient to withstand major surgery, and, of course of the location and extent of the disease. The simpliest hepatic resection is wedge excision which consists of nonanatomic removal of a small amount of superficial hepatic tissue. The procedure is referred to as nonanatomic because the tissue removed does not correspond to a hepatic segment. Wedge excision can be performed successfully only if the vascular and biliary structures supplying the remaining hepatic parenchyma are left intact.[9] Thus, nonanatomic wedge excisions are performed only in the hepatic perifery, usually to remove small tumors.[10]

The more commonly performed hepatic resections are procedures in which one, two, or three hepatic segments are removed. The right lobe of the liver is frequently removed in a resection termed a right lobectomy.[11] The medial segment of the left lobe may be resected along with the right lobe, as described by Starzl in 1975.[11] This procedure is termed right trisegmentectomy, since the posterior, anterior, and medial hepatic segments are removed.

It is possible to remove the posterior segment of right hepatic lobe (posterior segmentectomy). However, this procedure is tehnically difficult and is rarely performed. A left lobectomy consist of removal of the medial and lateral segments of the left lobe.[11] The caudate lobe may be left in place or removed along with the left lobe.[11] The left lateral segment can be readily removed in procedure termed lateral segmentectomy.[4, 11] In 1982 Starzl described the left trisegmentectomy, in which both segments of the left lobe are resected along with anterior segment of the right lobe.[12] In general, hepatic lesion are resectable if it is tecnically feasible to remove all gross hepatic lesions and to leave a sufficient volume of viable liver parenchyma in situ to support life.[13] In order for the remaining hepatic tissue to be viable, its vascular supply and venous and biliary drainage must remain intact.[8] Lesions in the liver are easily resectable if they spare the porta hepatis are confined to the area of one of the five major resections.[14] A lesion is generally considered unresectable if it encases or invades the main portal vein, the proper hepatic artery, both intrahepatic ducts or the major branch of any of these structures contralateral to the hepatic lobe in which the lesion originates.[14, 15] Continuity of tumor with vessel wall does not necessairly mean the vessel has been invated, the attainability of a tumor-free margin in such case frequently cannot be predicted by computed tomography.[3] In patients with severe hepatic parenchymal disease and limited hepatic reserve, hepatic tumor frequently cannot be resected unless the amount of resected tissue can be minimized.[15, 16]

Conclusion

Hepatic resections are technically demanding procedures that require accurate knowlege of internal hepatic vascular anatomy which is not readily apparent to the surgeon on inspection of its surface. Cardinal rule of major hepatic resection is that the vascular supply and the hepatic venous and biliary drainage must remain intact. Classically, the liver is anatomically divided into right and left lobes by the falcirorm ligament and fissure for the ligamentum teres. This classical division is not particularly helpful for surgical planning because resection has to follow the vascular distribution. Computed tomography can detect the normal anatomy of the liver and can identify with precision focal masses. Consequently, this imaging technique play a crucial role in the resection of hepatic lesions allowint surgeons to plan resections according to anatomic principles, making the resection technically easier.

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