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Ultrasound of the liver

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Inhalt

Topographic remarks

The liver is located inside the intraperitoneal cavity and under the right hemidiaphragm, but can also extend across the midline reach to the left hemidiaphragm and to the spleen in some cases. The liver is fixed to the diaphragm by the *pars affixa* and to the ventral abdominal wall by the ligamentum falciforme (falciform ligament) and its strong margin, the ligamentum teres hepatis. The minor omentum consists of the ligamentum hepatogastricum and the ligamentum hepatoduodenale. The hepatoduodenal ligament carries three vessels – two containing blood (the portal vein and hepatic artery) and one carrying bile (common bile duct (CBD)). The further course of these three vessels (known as Glisson's triad) is mainly parallel.

The structures of the liver hilum are accompanied by a number of ventrally and dorsally (in relation to the portal vein) located lymph nodes, which can be routinely demonstrated by ultrasound [(1-6)]; however, lymphatic vessels are too small to be visualised on ultrasound.

The liver has three main (hepatic) veins – left, middle and right – that drain the liver blood to the inferior vena cava (IVC) located in the retroperitoneum. The IVC is variably surrounded by liver parenchyma.

The organs and structures of the peritoneal cavity surround the liver, as well as pleural and pericardial structures. Neighbouring structures adjacent to the liver are numerous and include (clockwise) basal lung portions separated by the muscular layers of the right

diaphragm (and more or less the left diaphragm as well), heart, stomach, intestine (*e.g.* upper duodenal loop and right colonic flexure), abdominal aorta, IVC, right adrenal gland and right kidney.

The interposition of the colon between the liver and the anterior abdominal wall can prevent sonographic approach to the right liver lobe in cases of Chilaiditi's syndrome. Finally, in the case of complete or incomplete situs inversus, topographic relations are inverted.

Liver anatomy

Anatomical orientation

Liver anatomy is defined by ligaments and fissures as well as by vascular architecture *i.e.* the branches of the hepatic artery, portal vein and bile ducts define the centers of liver segment anatomy by their parallel course [(7)].

Liver segment anatomy

A simplified anatomy divides the liver into the larger right lobe (including segment V, VI, VII and VIII) [http://media.falkfoundation.de/index.php?id=122&L=1]; the left lobe with its medial (IVa,b) and lateral segments (II, III) [http://media.falkfoundation.de/index.php?id=119&L=1 and http://media.falkfoundation.de/index.php?id=120&L=1]; and the caudate lobe (I).

Couinaud classification

The widely accepted Couinaud [(8, 9)] system describes liver segment anatomy. This classification, modified by Bismuth (segment IVa, b), is based on eight segments, each of which has its own arterial and portal venous vessel architecture (Glisson's triad) for vascular inflow, outflow and biliary drainage [(10, 11)]. As a result of this division into self-contained units, each can be resected (alone or in groups) without damaging the remaining segments because the vascular inflow, outflow and biliary drainage is preserved. Depending on the three-dimensional volume orientation of the liver (longitudinal or oblique), the interpretation of the Couinaud classification can be inconsistent in the literature. While the

portal vein plane has often been described as transverse, it may also be oblique because the left branch runs superiorly and the right runs inferiorly. In addition to forming an oblique transverse plane between segments, the left and right portal veins branch superiorly and inferiorly to project into the centre of each segment.

Liver segment nomenclature

In a clockwise fashion starting with the caudate lobe as segment I, the left posterolateral segment is number II, followed by the left anterolateral, segment III; left superomedial, segment IVa; left inferomedial, segment IVb; right anteroinferior, segment V; right posteroinferior, segment VI; right posterosuperior, segment VII; and right anterosuperior, segment VIII. This appears more complicated than it actually is. For more details see "EFSUMB examination technique videos", http://www.efsumb.org/blog/?page_id=1750.

Right liver lobe

Anterior segments V and VI are separated from the posterior segments VII and VIII in the plane of the right hepatic and portal veins. The anterior and posterior divisions are further sub-divided by a plane defined by the right main branch of the portal vein.

Segments IVa (superior) and IVb (inferior) are situated to the left of the plane separating the right and left liver lobes. Segments V and VIII are to the right and segment VIII is more superior and dorsal to segment V.

In the Couinaud classification, the plane defined by the middle hepatic vein sub-divides the liver into the true right and left lobes. A standard right or left lobectomy requires division along the plane of the middle hepatic vein. Segments IVa and IVb are located to the left of the plane, while segments V and VIII are located to the right; segment VIII being more superior to V. In Couinaud nomenclature, the plane defined by the right branch of the portal vein divides the anterior and posterior portions of the right liver superiorly and inferiorly, thus dividing the right lobe into four segments (V-VIII) [(9)].

Left liver lobe

The "umbilical level" separates segments IVa and IVb from the lateral segments II and III. Remarkably, this level is the only plane with a vertical orientation not defined by a hepatic vein. The left liver lobe can be defined on the surface of the liver by its associated landmarks. It extends from the umbilical fissure anteriorly through the ligamentum venosum along the

lateral aspect of the caudate lobe. Structures within the plane of the umbilical fissure include the falciform ligament, ligamentum venosum (remnant of the ductus venosus) and the ligamentum teres (remnant of the umbilical vein).

The left hepatic vein plane is somewhat controversial. The left hepatic vein courses laterally to the umbilical fissure. Most investigators believe that the plane defined by the left hepatic vein is a true intersegmental boundary and is not the same as the plane of the umbilical fissure. However, others claim the true division between segments II and III is formed by the transverse plane of the left portal vein. We will define the plane of the left hepatic vein as the boundary between segments II and III. The medial segment of the left lobe can be divided into two segments by the plane of the portal vein (IVa and IVb).

Caudate lobe (segment I)

The most unique of the Couinaud segments is segment I, which is part of the caudate lobe (sometimes called the Spiegel lobe). This segment is located posteriorly and adjacent to segment IV. Its medial and lateral boundaries are defined by the IVC and ligamentum venosum, respectively. The caudate lobe has a variable vessel anatomy that differs from the rest of the liver; its portal inflow is derived from both the left and right branches of the portal vein, and it has its own short (and usually small) hepatic veins that connect directly to the IVC. Owing to the variable and extensive crossing of vessels, and its position relative to the liver hilum and IVC, segment I is frequently not resected, unless absolutely necessary.

Surgical resection

Surgical resections proceed along the vessels that define the peripheries of the segments. In general, this means resection lines are parallel to the hepatic veins to preserve the hepatic arteries, portal veins and bile ducts that provide vascular inflow and biliary drainage through the centre of the segment. When a lesion occurs within the lateral segment of the left lobe, usually both Couinaud segments II and III are removed together based on the plane formed by the umbilical fissure (known as left lateral segmentectomy). Note that because the plane of the left hepatic vein is oblique, it forms a division between segments III anteriorly and segment II posteriorly.

Additional anatomical structures

The falciforme ligament runs between the ventral abdominal wall and the liver, ending with its free caudal margin as the ligamentum teres containing the obliterated umbilical vein. It can be identified at the left lateral border of segment IVb (in the quadrate lobe), and it is often mistaken to form the anatomical border between the left and right liver lobe, which is not the case. This border follows a plane along the middle hepatic vein between the IVC and the longitudinal gallbladder axis. It is identified by ultrasound only in patients with one-sided biliary obstruction and a subsequent different fluid content between the right and left liver lobes in cholangiocellular carcinoma (CCC) in the Klatskin's position.
The ventral border of segment I is delineated by the ligamentum venosum (remnant of duct of Arantii in the foetus), which runs caudally to the hepatic artery and can be identified in this way.

Ultrasound examination technique

Patient preparation

It is recommended that patients undergo a period of fasting prior to upper abdominal imaging to maximise the distension of the gall bladder and reduce food residue and gas in the upper gastrointestinal (GI) tract, which may reduce image quality or preclude liver imaging [(12-14)]. This is essential for full imaging of the liver and related biliary tree, but may not be required in an acute situation, such as trauma where immediate imaging of the gall bladder is not essential. A patient may have small amounts of still water by mouth prior to the scan, *e.g.* for medication. There is some evidence that smoking can reduce image quality when scanning the upper abdominal structures and it is good practice to encourage the patient not to smoke for 6-8h prior to an ultrasound scan. This is because smoking increases the gas intake into the upper GI tract, which can reduce image quality, and some chemicals in tobacco are known to cause contraction of the smooth muscle of the GI tract, which can cause contraction of the gall bladder, even after fasting.

Examination

The liver is a large, pyramidal shaped organ and liver sectional anatomy may be best described, imaged and defined using real-time ultrasound imaging (see “Liver segment anatomy” [http://www.efsumb.org/blog/?page_id=1750]). Conventional real-time ultrasound produces images of thin slices of the liver on screen, therefore it is essential that the operator always scans the entire organ systematically in at least two anatomical planes to ensure the entire volume of the liver tissue and structures have been imaged. The operator must then use this two-dimensional information to visualise a three-dimensional map of the individual patient’s liver anatomy and pathology. This requires good hand-eye-brain coordination [(15)].

For orientation, the central portion of the liver can be differentiated into three levels:

- Level of the confluences of the hepatic veins (Figure 1).
- Level of the pars umbilicalis of the (left) portal vein branch (Figure 2).
- Level of the gall bladder (Figure 3).

Figure 1 **First level, confluences of the hepatic veins. This "junction" level is the first in ultrasound examination of the right liver lobe by sub-costal scanning sections steeply "looking" upwards, preferably in deep inspiration [http://media.falkfoundation.de/index.php?id=121&L=1]. VCI, inferior vena cava; LLV, left liver vein; MLV, middle liver vein; C, confluens of the LLV and MLV; RLV, right liver vein. The RLV often separately joins the inferior vena cava, whereas the LLV and MLV often reveal a common trunk (c).**