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REVIEW / *Gastrointestinal imaging*

Liver segmentation: Practical tips

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Abstract The liver segmentation system, described by Couinaud, is based on the identification of the three hepatic veins and the plane passing by the portal vein bifurcation. Nowadays, Couinaud's description is the most widely used classification since it is better suited for surgery and more accurate for the localisation and monitoring of intra-parenchymal lesions. Knowledge of the anatomy of the portal and venous system is therefore essential, as is knowledge of the variants resulting from changes occurring during the embryological development of the vitelline and umbilical veins. In this paper, the authors propose a straightforward systematisation of the liver in six steps using several additional anatomical points of reference. These points of reference are simple and quickly identifiable in any radiological examination with section imaging, in order to avoid any mistakes in daily practice. In fact, accurate description impacts on many diagnostic and therapeutic applications in interventional radiology and surgery. This description will allow better preparation for biopsy, portal vein embolisation, transjugular intrahepatic portosystemic shunt, tumour resection or partial hepatectomy for transplantation. Such advance planning will reduce intra- and postoperative difficulties and complications.

For a long time, the liver was described only by using a ''morphological'' anatomy referring to its outer appearance, as seen by laparotomy, for example. Since the beginning of the 20th century, a new approach based on a vascular division of the liver has been developed by several authors. Couinaud then formalised it in 1957 [1]. This so-called ''functional'' anatomy is currently most employed since it is best adapted for surgery and has become essential in monitoring intra-parenchymal lesions. Nevertheless,

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a study carried out at the Dijon University Hospital over a year on 138 CT-scan and MRI, examined for a second opinion for liver nodules, reveals the absence of liver segment indication in 27% of the cases. This study also revealed the existence of 39% topographic errors when the segment is indicated and notes the complete lack of information about the hepatic vascular anatomy in 100% of the cases. In fact, the segmentation and location of liver lesions is most often determined by using the modal anatomy of the vascular pedicles, without taking into account any anatomic variations leading to the errors [2]. In view of these results and the potential practical implications in interventional radiology or surgery, knowledge of portal and venous anatomy as well as the principle variants is essential in the proper systematisation of the liver, allowing for the exact detection of a lesion or the preparation of an intervention. Therefore, this review aims at explaining how to use simple anatomic references to quickly segment the liver during a routine examination and avoid mistakes.

After a brief review of embryology, we will return to the anatomy of the hepatic veins and portal system by noting their most common variants. Simple references will be provided to avoid mistakes in liver segmentation. We will then discuss the main practical, diagnostic and therapeutic applications.

Embryology review

The portal venous system forms during the second and third months of gestation from two vitelline (or omphalomesenteric) veins providing the drainage of blood from the yolk sac to the heart [3]. These two veins form a plexus around the duodenum by three anastomoses, then cross the septum transversum (future diaphragm). The proliferation of liver buds here breaks up this network and creates a vascular labyrinth, giving rise to the liver sinusoids. Above the liver, the vitelline veins become the right and left hepatic-cardiac canals and run into the sinus venosus. The subsequent disappearance of the left horn of the sinus venosus and the homolateral hepatic-cardiac channel redistributes the liver circulation towards the right hepatic-cardiac channel, giving rise to the suprahepatic segment of the inferior vena cava. The selective regression of paraduodenal anastomoses by hemodynamic laws favouring the shortest paths after the rotation of the duodenum [4], forms a single vessel: the portal trunk. Several portal variants result from a modification in the involution of these anastomoses [5]. The right sub-hepatic portion of the vitelline vein becomes the superior mesenteric vein; the left portion disappears after the degeneration of the yolk sac [6]. The umbilical (or umbilical-allantoid) veins, that transport oxygenated blood from the placenta, merge with the sinusoids during the development of the liver. Afterwards, the right umbilical vein and the hepatic portion of the left umbilical vein disappear, while an ''extra-hepatic shunt'' called Arantius' duct appears between the left umbilical vein and the inferior vena cava along with an increase in embryo circulation. This communication disappears at birth and the left umbilical vein gives rise to the round ligament and Arantius' duct gives rise to the venous ligament [7].

The morphology of the hepatic veins and the portal system, as well as the run of their branches, results from these successive stages in the development of the embryo. Any modification inducing anatomic variations may have diagnostic or therapeutic implications.

Radiological anatomy of the liver

Anatomy of the hepatic veins and variants

Most often, there are three hepatic veins (right, middle and left) that run into the inferior vena cava (Fig. 1). The left hepatic vein runs in the left portal scissura. It is formed by the union of drainage veins of segments II and III [8], giving rise to a short and posterior venous trunk. It adheres to Arantius' venous ligament to the rear, and forms a common trunk with the middle hepatic vein (Fig. 2) in 60% to 95% of all cases, according to the authors [9—11], before draining in the inferior vena cava. The middle hepatic vein is located in the middle or main portal scissura, separating the left liver from the right liver. It drains segment IV, and sometimes receives branches from segments V or VIII [8]. The right hepatic vein is the largest. It runs in the right portal scissura, and drains the veins of segments V, VI, VII and VIII [8]. It connects with the right border of the inferior vena cava, laterally and below the middle hepatic vein. Accessory hepatic veins (one to four) independently drain segment I in the retro-hepatic vena cava.

The hepatic venous variants, clearly seen in routine abdominal CT-scans, are more common in women than in men [12]. The main variant is the presence of an accessory right inferior hepatic vein in 52.5% of the cases [9], directly draining the right posterior-inferior segment in the middle part of the retro-hepatic inferior vena cava, or even two accessory veins (12%) (Fig. 3), or an accessory vein draining the caudal lobe (12%). Next come the absence of common trunk of the middle and left hepatic veins (Fig. 4), the absence of right hepatic vein and the splitting of the left or middle hepatic veins. In 9% of the population, a venous branch from segment VIII drains in the middle hepatic vein and may result in venous congestion, necrosis and atrophy of the segment if damaged during surgery [13,14].

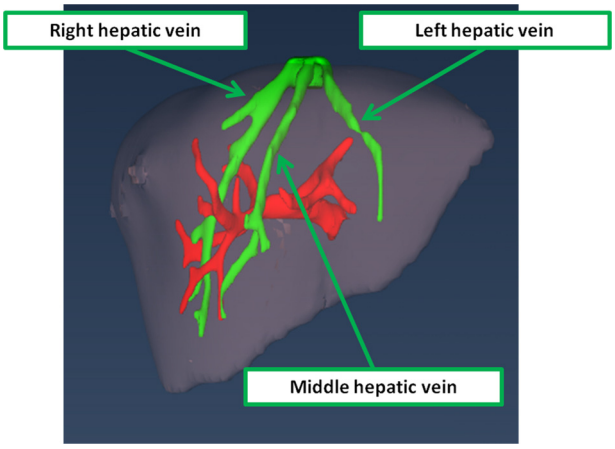

Figure 1. The hepatic veins (3D image).