



Liver anatomy is king, three-dimensional reconstruction is queen, liver resections are princesses and princes

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Knowledge of liver anatomy is the key to perform precision surgery for liver tumors. Francis Glisson laid the first stone by describing the segmental anatomy of the liver in the seventeenth century. The first hepatectomies were however performed at the end of the nineteenth century. Based on livers' corrosions, Couinaud proposed, in the middle of the twentieth century, a classification, which defined segments delimited by portal veins inflow and sections (or sections) separated by hepatic veins (1). Progress in imaging showed that Couinaud's classification is not accurate, due to the high frequency of anatomical variations. Nonetheless, this classification has been adopted by many surgeons over the years and has the merit of standardizing the terminology of liver anatomy and liver resection.

As the knowledge of liver anatomy improved, the number of liver resection increased, with safer procedures and true anatomical resections. New surgical concepts also appear, such as parenchymal-sparing surgery (PSS) (2), and evolve with increased anatomical knowledge. Non-anatomical resection guided by the presence of communicating veins between main hepatic veins, proposed by Torzilli *et al.* (3), is one the most explicit example.

The progress in technology, with indocyanine green fluorescence and three-dimensional (3D) reconstructions have shown that liver anatomy is more complex and anatomical variations more frequent than we thought. Besides increasing our knowledge about anatomical variations, by showing the proximity of portal veins and

hepatic veins, 3D reconstructions offer the possibility of creating new and reproducible laparoscopic approaches, notably for postero-superior segments, such as the dorsal approach guided by the right hepatic vein (4,5).

Knowledge of liver anatomy is also fundamental for interventional radiologists, especially when considering preoperative portal vein embolization (PVE). For example, when a right hepatectomy extended to segment IV is planned, the future liver remnant (FLR) is frequently insufficient and hypertrophy procedures are required. About a decade ago, two strategies, which divided the surgical community, were proposed: the right + segment IV PVE or the associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) procedure (6,7). As segment IV PVE is a challenging procedure, liver anatomy could tailor the most appropriate strategy, or at least the most likely to be successful for FLR hypertrophy. Maurer *et al.* showed several anatomical variations in segment IV portal supply with 2 to 8 portal branches (8), which might explain the conflicting results published about the potential benefit of adding segment IV PVE to right PVE. As a result, ALPPS procedure, rather than segment IV PVE, would be more suitable in patients with more than 4 portal branches to segment IV.

In the article that accompanies this editorial, Zhang *et al.* made their contribution in the knowledge of liver anatomy by analyzing 336 computed tomography scans (9). The posterior section was historically considered as the liver

parenchyma located laterally and posteriorly to the right hepatic vein. Based on 3D reconstructions, the authors proposed 4 main types to describe the posterior section, the historical definition of the posterior section accounting for only 43.4% of the analyzed cases. The 2 anatomical variations are the caudal-redundant type, which is associated with an extended volume of the posterior section, located between segments V and VI; and the cranial-deficient type, which is associated with a reduced volume of the posterior section, located between segment VII and VIII. Finally, the combination of these 2 anatomical variations formed the third type of anatomical variation.

The liver volume concerned by these variations account for 4% to 11% of the total liver volume, corresponding to a volume of 53 to 126 mL that can be spared or sacrificed, depending on the liver resection planned. Hence, this observation has clinical implications, firstly in PSS, secondly in the management of peri-hilar cholangiocarcinoma, especially for left extended hepatectomy.

Some of the anatomical variations pictured in the paper of Zhang *et al.* (9) have already been described as anatomical variations of the right anterior section, with other naming though (10,11). It highlights the need for further standardization in the nomenclature of liver anatomy, which is one the next challenges of the surgical community (12). It is essential for education and training of young surgeons as the future of liver surgery is not how to cut the liver but how to navigate within the liver.

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