

The Human Liver: Vascular Anatomy to Determine its Segments and Divisions

El Hígado Humano: Anatomía Vascular para Determinar sus Segmentos y Divisiones

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SUMMARY: This study aims at understanding the vascularization of the human liver to determine the correct way to divide it into "divisions" (sectors) and segments, for which we dissected 250 livers using the acrylic resin injection method. The results showed the role of the "Porta hepatis" in the hepatic vascular distribution, the existence of seven vascular pedicles for seven portal segments, and the role of portal fissures in the parenchymal division of the liver. Our research provides the definition of a portal segment and demonstrates the role of the hepatic portal vein in originating any liver parenchymal division.

KEY WORDS: Hepatic portal vein; Segments and liver "divisions" (sectors).

INTRODUCTION

The knowledge derived from our routine dissections of the human liver during anatomy classes differed from the one expressed in anatomy texts and journals. The concepts on which they are based to divide this organ into segments and divisions (sectors) are wrong. For these reasons, we decided to study the hepatic vascularization in order to propose a correct division of the liver (Botero & Strasberg, 1998; Standring, 2008; Moore *et al.*, 2009; Durand *et al.*, 2017; Manterola *et al.*, 2017).

MATERIAL AND METHOD

We dissected 250 necropsied human livers of both sexes, individuals of different races and ages (from fetuses to octogenarians). The blood vessels and bile ducts of 150 of these livers were washed with water to remove their contents. Then colored liquid acrylic was injected into the hepatic portal vein, the hepatic artery proper and its accessory arteries, main bile duct, inferior vena cava and the hepatic veins. The injected livers were immersed in water for 24 hours, then immersed in a 10 % hydrochloric acid solution to digest the liver parenchyma. The obtained acrylic molds were washed with water to have them ready for study. In addition, 50 fresh livers and 50 livers fixed with

formaldehyde were dissected using the knowledge obtained with the acrylic molds. We consider the hepatic portal vein as the most important vessel in the segmentation of the liver (the secondary branches of the portal vein attract the secondary branches of the hepatic artery proper or its accessory ones and the segmental biliary branches).

This investigation was made in Peru, where the Ministry of Health and the Ministry of Justice allow the study of human organs in medical schools without judicial permission or ethical declaration.

RESULTS

During the dissection of the parenchymal canal of the hepatic hilum (Porta hepatis) we found the following results:

The hepatic portal vein was divided into two primary branches, right and left, in 100 % of the cases. The hepatic artery proper was divided into two primary branches, right and left in 70 % of the cases; the hepatic artery proper was accompanied by a branch of the left gastric artery in 25 % of the cases; a branch of the left gastric artery plus a branch

of the superior mesenteric artery in 3 % of the cases, or a branch of the superior mesenteric artery in 2 % of the cases.

Segmental bile ducts (left or right) formed trunks with two or three bile ducts, which eventually formed the left or right hepatic duct.

The primary branches of the hepatic portal vein issued (on a monopodic form, one by one) seven secondary terminal branches destined for seven portal segments (Fig. 1). Each secondary portal branch was accompanied by a terminal secondary arterial branch and a segmental biliary branch (Fig. 2), forming seven vascular pedicles for seven parenchymal portions; this happened in 100 % of the cases. The most important variation was the birth of the secondary portal branch for segment V (Durand, 2017), which was originated from the right portal branch in 79 % of the cases, or from the left portal branch in 21 % of the cases.

The primary portal branches originated small terminal secondary branches for segments I, III and IV whose number varied between 1 and 4 branches for each segment; the most frequent characteristics of these branches were their inconstancy, their place of variable origin and their small caliber, also called sub-segmental branches. All this happened at the hepatic hilum (*Porta hepatis*).

The portal segmental branches were terminal; this caused that the segments did not present anastomosis among them, creating separation planes (portal fissures) among them. There were three vertical and three horizontal portal fissures found; the vertical ones were the right portal fissure, the main portal fissure and the left portal fissure or umbilical fissure. The right portal fissure tilted 60 degrees to the right in relation to the sagittal plane of the liver (Fig. 3), the main portal fissure tilted 30 degrees to the left in relation to the sagittal plane of the liver, the umbilical fissure tilted 50 degrees towards the left in relation to the sagittal plane of the liver. The content of the right portal fissure was the right hepatic vein in 99 % of the cases, the middle right hepatic vein in 5 % of the cases and the inferior right hepatic vein in 60 % of the cases. The content of the main portal fissure was the intermediate hepatic vein in 100 % of the cases. The umbilical fissure did not contain the left hepatic vein in 100 % of the cases.

The left hepatic vein had a path within segments III and II in 100 % of the cases (Fig. 1).

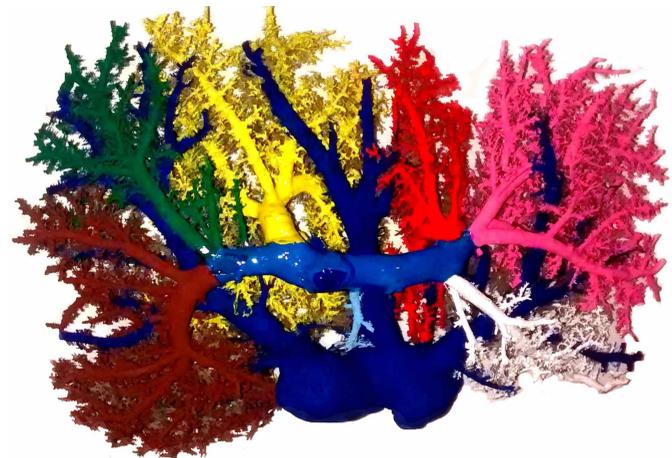


Fig. 1. Acrylic vascular mold of the liver, visceral surface: The portal vein (blue) is divided into right and left branches, which emitted seven secondary terminal segmental branches for seven portal segments. The segmental branches I, II, III and IV emerge from the left portal branch. The segmental branches V, VI and VII emerge from the right portal branch. Segmental branch I is light blue, II in white, III in pink, IV in orange, V in yellow, VI in green and VII in brown. The empty umbilical fissure is seen between segments III (pink) and IV (orange). The left hepatic vein (dark blue) crosses within segments II (white) and III (pink).

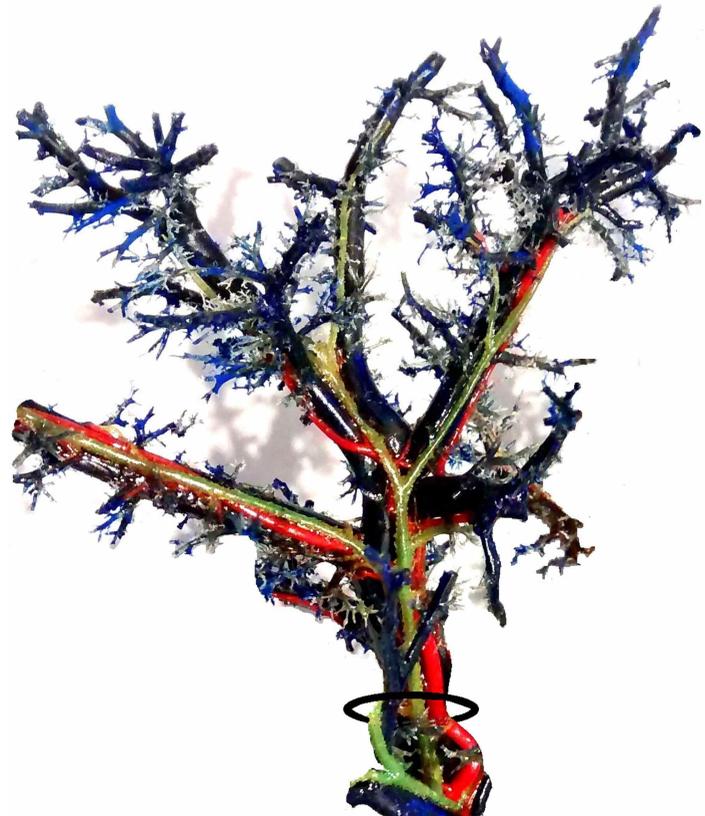


Fig. 2. Acrylic vascular mold of the liver. The segmental vascular pedicle (black ring) is formed by a secondary branch of the hepatic portal vein (blue) and a secondary terminal branch of the hepatic artery proper or its accessory artery (red), in addition to the segmental bile duct (green).



Fig. 3. Acrylic vascular mold of the liver, posterior view: The inclined right portal fissure is signed by the arrow, between the segments V (yellow) and VI-VII (green and brown).

The parenchymal canal that formed the lower limit of the umbilical fissure contained, from front to back, the round ligament of the liver, the umbilical portion of the left portal branch and the venous ligament.

Regarding the horizontal fissures, the first one was located between segments II and III; the second one, between the upper face of segment I and the lower face of the posterior half of segments IV and V; the third one, between segments VI and VII. The horizontal fissures had no content.

DISCUSSION

Kawarada *et al.* (2000) and Kelly *et al.* (2017) mentioned "Porta hepatis" as the place where the most important vessels are concentrated to perform liver transplant surgery.

Porta hepatis is a parenchymal channel formed by each and every portal segment, because here they receive their terminal vascular pedicle and drain their bile production. In this way, Porta hepatis becomes the place where the arterial and portal venous distribution of the liver is defined (Kalayci *et al.*, 2014; Sureka, 2015).

The seven terminal secondary branches of the hepatic portal vein irrigate seven parenchymal portions called portal segments (Hikspoor *et al.*, 2017a,b). This is the first structural action that the hepatic portal vein performs in the division of the liver. There was no case in which the secondary branches of the hepatic portal vein occupy the portal fissures, or in which they were destined for the "divisions" (sectors) of the liver. We also did not find that the secondary portal branches emit tertiary branches for each of the portal segments; these denied assertions are based on the imagination.

The terminal (segmental) portal secondary branches do not anastomose to each other, creating separation planes among the segments; these separation planes or portal fissures represent the second structural action of the portal vein in the division of the liver. The vertical portal fissures, which are larger than the horizontal ones, are present in 100 % of the cases. The three vertical portal fissures divide the liver as follows: The main portal fissure separates the right part, of the left part of the liver. The right part of the liver is divided by the right portal fissure into a right lateral "division" and another right medial "division". The left part of the liver is divided by the umbilical portal fissure into a left lateral "division" and another left medial "division". The hepatic veins (contained in the right portal fissure and the

main portal fissure) should not be used to delimit hepatic "divisions" for two reasons: the first reason is that a vein could be absent, and the second reason is that the left hepatic vein does not occupy the umbilical portal fissure in 100 % of the cases. The left hepatic vein has an intrasegmental trajectory in segments III and II (it cannot delimit segments or divisions since it is located within the segments); there is no structural equivalence among the hepatic veins, but the hepatic portal fissures. The descriptions used by the hepatic veins to delimit the hepatic "divisions" (sectors) are wrong, and this mistake is more evident when they consider that the left hepatic vein occupies the umbilical fissure.

Based on these findings, we conclude that Porta hepatis is the place where the vascular and segmental structure of the liver is defined.

The liver portal segment has three characteristics that define it: 1- It is a portion of the parenchyma irrigated by secondary terminal branches of the portal vein and the hepatic artery, drained by a segmental bile duct. 2- The portal segment is separated from other segments by portal fissures (arterial and biliary). 3- Each and every portal segment makes up the parenchymal canal of the Porta hepatis, where they receive their vascular pedicle and drain their bile production.

The portal segments of the liver are seven. The hepatic portal vein has a double function in the division of the liver; first, it creates seven vascular segments with their terminal secondary branches; second, due to the absence of anastomosis among its terminal secondary branches, it creates portal fissures that allow the liver to be divided into segments, divisions (sectors) and parts (right and left hemi-livers).

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RESUMEN: Quisimos estudiar la vascularización del hígado humano para determinar la forma correcta de dividirlo en "divisiones" y segmentos, para lo cual disecamos 250 hígados usando técnicas de inyección acrílica. Los resultados mostraron la función de la Porta hepatis en la distribución vascular del hígado, la existencia de siete pedículos vasculares para siete segmentos portales, y el rol de las fisuras portales en la división parenquimal del hígado. Ofrecemos la definición de lo que es un segmento portal y demostramos el rol de la vena porta hepática en originar cualquier división parenquimal del hígado.

PALABRAS CLAVE: Porta hepatis; Divisiones y segmentos de hígado.

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