PORTACAVAL FIBROUS CONNECTIONS: LITTLE KNOWN ANATOMICAL STRUCTURES OF LIVER

Prof. Ilia Chanukvadze, MD, PhD
Tbilisi State Medical University, Georgia

ABSTRACT

Background & Aims. Studies dealing with the architecture of the portal and caval canals of liver have overlooked the probability of the fibrous connections between the major portal complexes and hepatic veins when they touch each other. Such a probability is essential for both theoretical and practical medicine.
Methods. We studied macro- and micro-morphological specimens from 104 normal adult and 18 normal embryonic and fetal livers.
Results. We found that the fibrous sheathes of the portal complexes and hepatic veins fuse in certain areas where these structures cross each other. This anatomical relationship between the portal tracts and hepatic veins is a normal occurrence in human liver and originates at 11th-12th week of embryogenesis.
Conclusions. The paper is an effort to demonstrate anatomical and clinical significance and embryogenesis of the portacaval fibrous connections.

Keywords: intrahepatic portacaval fibrous connections; portal complex; glands of bile ducts; hepatic veins

INTRODUCTION

There are little known anatomical structures within human liver formed through the confluence of connective tissue sheathes of the portal complexes and of the hepatic veins in some areas where these structures come in contact and cross each other (Fig. 1). The common fibrous capsule of the portal triad ensheathes not only the elements of the triad (the portal vein, hepatic artery, and bile ducts), but also the hepatic vein as the fourth element. We suggest the term "portacaval fibrous connections" for the anatomical structures formed through the confluence of the connective tissue sheathes of the portal complexes and those of the hepatic veins. The present paper discusses anatomical and clinical aspects of these formations.

METHODS

The sample consisted of 104 apparently normal adult cadaveric livers. The autopsied livers were obtained from patients with no history of hepatobiliary diseases or prior hepatobiliary surgery. In order to reveal the potential fibrous connections between the portal complexes and hepatic veins, 56 livers were dissected through gradual maceration of the parenchyma and separation of the portal complexes and hepatic veins from the visceral surface of the liver.

The gross histotopographic slices from 44 livers were used to study bilio-vascular and stromal architecture. The embryogenesis of the portacaval fibrous connections was studied on gross histotopographic and histological specimens from 18 embryonic and fetal livers. The specimens were stained by hematoxylin and eosin, van Gieson, and Weigert. The bile ducts of all sizes and their mucous glands were identified using 40% India ink-gelatin solution retrogradely injected into the common bile duct. We followed the Couinaud model of liver segmental anatomy (1).

RESULTS

Anatomical forms of the intrahepatic portacaval fibrous connections (IPCFC). The four principal forms of the fusion of the connective tissue sheathes of the portal complexes and the hepatic veins were identified:

Adresa de corespondență:
Prof. Ilia Chanukvadze, MD, PhD, Tbilisi State Medical University, 16 Dariali Street, Apt. 4. 0162 Tbilisi, Georgia,
E-mail: iljachan@rambler.ru

1. Complete connection. This type of the IPCFC is formed by the complete fusion of connective tissue sheathes of the portal complexes and the hepatic vein, with the surfaces facing each other (Fig. 1, 2), and can be seen in 72.5% of all cases. The caliber of the portal tracts and hepatic veins participating in this type of connection ranges from 2 to 17 mm and from 2 to 20 mm, respectively. This type of connections is principally observed in Couinaud Segments 2, 3, 4, and 7.

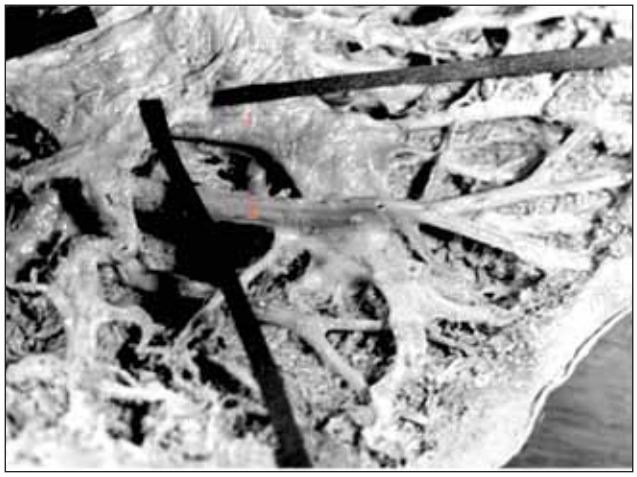

FIGURE 1. *Hepatic segment 3. A 42 year old male. Major portal complex (1) and left hepatic vein (2) form complete fusion of the intrahepatic portacaval fibrous connections.*

2. Partial connection. This type of the IPCFC occurs in 23.5% of cases, when the common fibrous capsule of the portal complex and the fibrous sheath of the hepatic vein fuse with only portions of their surfaces, leaving the space among them filled with the hepatic parenchyma. This type of fibrous connections is found in the portal tracts and hepatic veins with the caliber of 5-20 mm and 3-20 mm, respectively. The partial fusion is mainly found in Couinaud Segments 2, 3, 6, and 7.

3. Fan-shaped connection. This peculiar type of the IPCFC was invariably present in 3. Couinaud segment 1 (caudate lobe) on all liver specimens. The portal complex participating in the IPCFC originates from the major portal complex of the liver hilum, traverse the segment 1 parenchyma, extends into the sheath of the inferior vena cava (IVC), becoming arranged in a fan-shaped manner on the walls of the IVC, and contributes its blood and nerve supply.

4. Laminar connection. This form of the IPCFC occurs in 14% of the cases and is made possible by a fibrous lamina stretching from the common fibrous capsule of the portal complex to the sheath of the hepatic vein (Fig. 2). Its dimensions vary from 3 X 5 mm to 5 X 18 mm. On dissection, it is easily detached from the parenchyma; provides a firm connection between the portal tract and the hepatic vein, and contains small blood vessels and lymph ducts. The laminar IPCFC are found mostly in the right hepatic lobe, in Segments 7 and 8, where the portal and caval canals lie at a relatively large distance from each other.

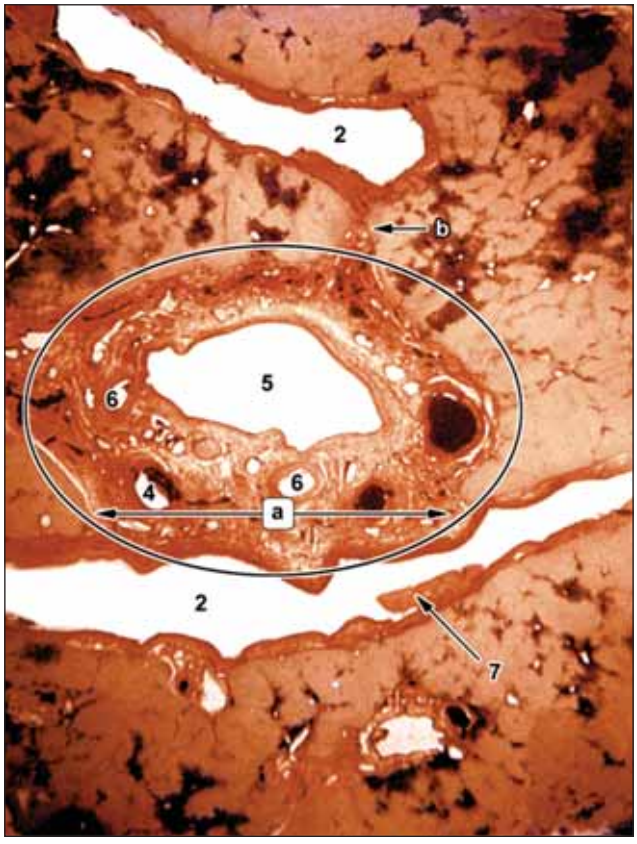

FIGURE 2. *Intrahepatic portacaval fibrous connections. Complete connection. Gross histotopograph from the left hepatic lobe. A 32 year old male; x 8. 1. Major portal complex; 2. Hepatic vein; 3. Portal vein; 4. Bile duct; 5. A space in the portacaval fibrous connection; 6. Laminar intrahepatic portacaval fibrous connections; 7. Hepatic parenchyma.*

Anatomical relationship between the portal triad elements and hepatic vein in the IPCFC areas. We found that, within the areas of the IPCFC, the hepatic vein was most frequently bordered by a bile duct (78.2%). Moreover, it is frequently the only structure to have a direct contact with the hepatic vein (49.4%). A bile duct is in close relationship with the hepatic vein together with an accompanying portal vein branch (24.4%) or hepatic artery branch (4.4%). Consequently, the direct anatomical contact between the hepatic vein and bile duct is a characteristic feature of the IPCFC and can be explained by the fact that on the slices of portal complexes the bile ducts outnumber other elements of

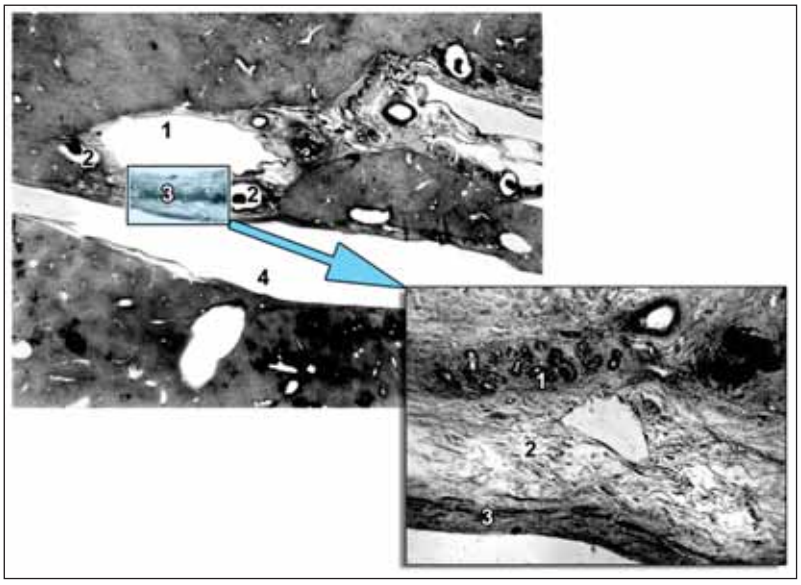

FIGURE 3. *Histotopograh of the left hepatic lobe. A 27 year old female. 1. Portal vein; 2. Bile duct; 3. Mucous gland of the bile duct reaching the hepatic vein wall (4) Hepatic vein. Insert: 1. Mucous gland of the bile duct; 2. Loose connective tissue with lymphatics; 3. Hepatic vein wall.*

the triad (portal vein, and a hepatic artery) and occupy peripheral location towards them within the portal canal (2). Therefore, the bile ducts, through the peribiliary tissue, are found nearest to the hepatic vein wall (Fig. 2). Anatomical relationship between the bile duct system and hepatic veins within the IPCFC is also characterized by the presence of mucous glands of bile ducts which are extramurally located, extend beyond the portal complex, and, traversing the IPCFC, reach the hepatic vein wall, thereby augmenting the bilio-caval anatomical contact (Fig. 3).

In the zone of the IPCFC, a contact of only the portal vein with hepatic vein is found in 15.6% of cases. In all other cases, the portal vein along with other elements of the portal complex is oriented towards the hepatic vein wall. The exception is the hepatic segment 3, where the major portal complex and left hepatic vein are in contact in all livers and, of the triad elements, the portal vein is oriented towards the hepatic vein wall (Fig. 4).

Embryogenesis of portacaval fibrous connections. The portal complexes and hepatic veins can already be distinguished from each other in the 9-10 week old embryos and individual elements of the portal complex become discernable in the 11-12 week old embryos. In the central portion of the liver, connection between the fibrous sheathes of the portal tracts and those of the relatively large hepatic veins can be observed (Fig. 5). By the 16th week of fetal development, afferent and efferent blood vessels increase in number and frequently intermingle. The fibrous connections among these vessels also increase.

FIGURE 4. *Histotopograph of hepatic segment 3. A 68 year old male. 1. Portal vein; 2. Hepatic vein; 3. A space in the portacaval fibrous connection (x 6). Arrows point to the area of potential endovascular surgery for portacaval shunts.*

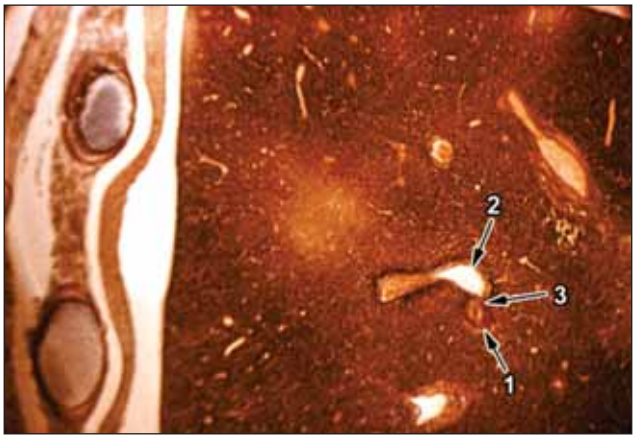

FIGURE 5. *Histotopograph of the human embryos liver. The 11-12 week old embryos*
1. Portal complex; 2. Hepatic vein; 3. portacaval fibrous connection.

DISCUSSION

Anatomical significance of the IPCFC. Like other fascial nodes and fibrous connections in the human body, the IPCFC is an area of confluence of fibrous sheathes of major afferent and efferent bilio-vascular elements of various directions, which connects two well-defined fascial-aponeurotic zones in the anterior abdominal wall and the posterior abdominal wall: the umbilical fibrous node in the anterior abdominal wall and the posterior fascial node of liver. The round ligament of liver stemming from the umbilical fibrous node in the anterior abdominal wall converge with the fibrous skeleton of the main portal complex, with the round ligament fibers extending on fibrous sheathes of other elements of the portal complex.

A posterior fascial node of liver tightly connected with the vertebral column and formed through the fusion of the fibrous sheath of the inferior vena cava, its own ligament, and the posterior hepatic fascia, continues with its collagen and elastic fibers into the fibrous sheathes of the hepatic veins (3,4).

Thus, the IPCFC, formed through the confluence of the fibrous sheathes of the portal complexes and hepatic veins, is an intrahepatic continuation of the fibrous-aponeurotic nodes of the anterior abdominal wall and the posterior abdominal wall. Hence, the IPCFC can be viewed as elements of the connective tissue of the liver intersected among the bilio-vascular systems, with a role in fixation of intrahepatic structures.

It can be imagined that, with the movement of the anterior abdominal wall, the round ligament stretches the portal complexes forward and downward, while the inferior vena cava and its intrahepatic branches (hepatic veins) remain fixed posteriorly and superiorly to the posterior abdominal wall through the posterior fascial node of the liver. Thus, two opposing forces directed towards the anterior and posterior abdominal walls, respectively, act within the liver (Fig. 6). Overstretching of the portal and caval branches during physical straining would have probably more easily disrupted the hepatic tissue, but the continuity of its connective tissue, in the form of portacaval fibrous connections, provides what some authorities have described as a "biological reliability of tissues" (3,5).

Possibility of using the IPCFC in surgical treatment of portal hypertension. Transjugular Portacaval shunting has been increasingly used as a palliative surgery for portal hypertension complicated with esophageal variceal bleeding. This procedure reduces mortality from portal hypertension bleeding (6,7,8).

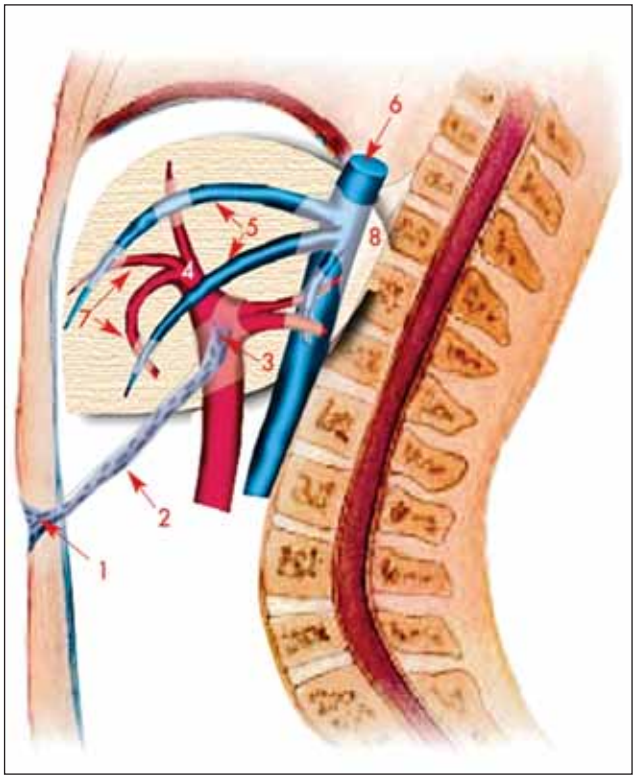

FIGURE 6. *1. Umbilical; 2. Round ligament; 3. fibrous nodes of Round ligament with portal complex; 4. Portal complexes; 5. Hepatic veins; 6. Inferior vena cava; 7. Portacaval fibrous connections; 8. Posterior hepatic fascia.*

A stent graft is placed through the parenchyma between the major branches of portal and hepatic veins, or between the inferior vena cava and the main trunk of portal vein, i.e., the vessels that are at a considerable distance from each other (3 to 8 cm). The longer this distance, i.e., the longer a stent graft, the higher the risks of thrombosis, occlusion, or transposition (6,8-10).

However, the intrahepatic portacaval fibrous connections, naturally occurring extra-parenchymal communication between the hepatic veins and the larger branches of the portal vein (5-20 mm in diameter), can serve as an area for endovascular portacaval shunting without a stent graft or with a graft of a minimal length.

Also, importantly, the number of portacaval fibrous connections in different livers varies from 4 to 22 (mean 9±3.4), which, in contrast to the currently used stent grafting technique, may allow for simultaneous placement of two or more portacaval shunts and more effective relief of portal hypertension. More stable anatomical conditions for this can be found in segments 2 and 3, where the left hepatic vein, through the IPCFC, is in close contact with the left major branch of the portal vein (Fig. 4). I also assume that in portal hypertension, at some

point, a dilated portal vein exerts pressure on a hepatic vein wall within the zone of the IPCFC, and, thus, provides a greater opportunity for an intrahepatic portacaval shunt placement.

Possible effect of pathology of the portal complexes on hepatic veins in the zones of IPCFC. In the past I noted the extramural location of intrahepatic mucous glands of bile ducts (2,11,12), the fact that was later also reported by other researchers. Due to such location, these structures came to be known as peribiliary glands (13,14,15).

In the areas of IPCFC, a bile duct wall is in close contact with the hepatic vein wall through the peribiliary tissue. This relationship is made more pronounced by the extension of the extramural mucous glands of bile ducts to the hepatic vein walls. We can thus conjecture that inflammation in cholangitis involving the peribiliary tissue and bile duct glands may provide a possibility for extending the pathological process to the hepatic vein wall.

The structure and development of liver stroma has been described in details (16-19). However, we have been unable to find in the available literature any information pertaining to the existence and development of potential fibrous connections between the portal and caval systems.

The authors interested in the study of vascular architecture and innervation of the liver have encountered these structures between the hepatic and portal veins, but have recognized in them a result of pathological or age-related adhesions of the portal and hepatic veins. For example, Ostroverkhov and Zabrodskaya posited that "the distance between the portal and hepatic veins, which is 1-2 cm, decreases as a result of atrophy of hepatic parenchyma (atrophic cirrhosis, aging). In this case, branches of the portal and hepatic veins may come in intimate contact and even adhere to each other" (20). Fagaraşanu and colleagues assume that the portal and caval vascular "pedicles cross one another without coming in direct contact" (21).

An established view has it that "the liver tissue is pervaded by two systems of tunnels, the portal tracts and the hepatic central canals which dovetail in such a way that they never touch each other" (22,23). This is true for the extremely proximal, lobular zones, while the distal portions of the major portal and caval canals do touch each other, forming the IPCFC.

The fact that the IPCFC has not been studied and described as an anatomical structure can probably be explained by the fact that all major works dedicated to the intrahepatic biliary and vascular architecture have relied mainly on a corrosion cast method which ensure that vascular and ductal lumens are retained and provide a real picture of the spatial relationships of these structures (1.24-30). However, the fibrous connections, together with the parenchyma, disappear in the process of corrosion and remain unnoticeable.

Thus, the major portal complexes and hepatic veins, at the areas of their overcrossing, form, through the fusion of their connective tissue sheathes, a anatomical, node-like structure we refer to as the intrahepatic portacaval fibrous connections. Within the IPCFC, the hepatic vein comes in immediate contact with the portal triad elements. This is not the result of pathological or age-related atrophy of the liver tissue, but a regular occurrence in normal human liver, which originates at the 11^{th}-12^{th} weeks of gestation. We deem that the intrahepatic portacaval fibrous connections, as a distinct anatomical formation, should be assigned an appropriate place in anatomical nomenclature.

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