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Association between the paracaval branches of the caudate lobe and the three major hepatic veins in liver casts: Locating the cranial boundary of the caudate lobe

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Abstract: According to Couinaud's definition, the cranial boundary of the caudate lobe is delineated by the three major hepatic veins. However, many branches of the caudate lobe go through the ceiling that is composed of these hepatic veins. The cranial boundary of the caudate lobe should be determined by employing the portal segmentation. We conducted a study based on the dissection of 37 colored resin liver casts to reveal the caudate branches of the liver. The paracaval portal vein branches (PCPvs) were defined as cranial portal branches from the main trunk or first-order branch of the portal vein distributed in front of the inferior vena cava, according to Kumon's classification. The PCVs were traced to reveal the cranial boundary of the caudate lobe. Results showed that in 18 cases (49%), the PCPvs reached the liver surface through the gap between the right and middle hepatic veins (type RM, n = 11), between the tiny branches of the middle hepatic vein (type M, n = 4), and between the middle and left hepatic veins (type ML, n = 3). The PCPvs did not reach the liver surface in 19 cases (type 0). No PCPvs reached the hepatic surface behind the right hepatic vein. Half of the PCPvs in the liver reached the hepatic surface beyond the boundary composed of the three major hepatic veins. Recognition of the PCPvs in the liver is indispensable to perform anatomically precise liver resections involving the major hepatic veins.

Keywords: caudate lobe, major hepatic vein, portal vein, cranial boundary, paracaval portal vein branches

Introduction

According to Couinaud's classification, the caudate lobe is located deep within the liver in front of the inferior vena cava (IVC), cranial to the hilar plate, and beneath the major hepatic veins (*1*). Therefore, a surgical resection of the caudate lobe for hepatic tumors is technically demanding and an anatomically accurate knowledge of the caudate lobe boundary is indispensable (*2,3*). A combined resection of the caudate lobe and other hepatic segments has become a standard step in the treatment of hilar cholangiocarcinoma to eradicate cancer lesions and improve patient survival (*4,5*). Recent advances in minimally invasive hepatectomy have made it possible to resect tumors in the caudate lobe using a laparoscopic or robotic approach (*6*). However, the definition of total caudate lobectomy is ambiguous, and the technical difficulty of a caudate resection varies according to the location of the tumor.

Couinaud defined the caudate lobe of the liver as one of eight segments and further categorized it into two parts, namely segment I and IX or segments IL and IR, based on the spatial position of the lobe behind the major hepatic veins (*7*). However, he abandoned his classification owing to the complexity of crossing glissonean branches in these segments (*8*). Conversely, in this study, we have defined the caudate lobe based on hepatic portal vein segmentation, i.e., the caudate portal venous branches are dorsal branches from the main trunk or from the first-order branches of the portal vein covering the hepatic region in front of the IVC (*9-11*), classifying it into three parts: the Spiegel lobe, the paracaval portion (PC) and the caudate process.

There is no consensus on the boundary of the caudate lobe, especially in relationship to the major hepatic veins. We dissected 37 colored resin hepatic casts to determine the relationship between the caudate lobe branches and the major hepatic veins.

Research design and sample size

The samples included in this study comprised 75 liver

casts prepared between July 1, 1981 and October 2, 1990 (*8-10*). The methods used to prepare the casts have been described previously (*10,11*). Casts weighing ≤ 400 g, with incomplete peripheral branches, damaged IVC or hepatic veins, or incomplete injection of resin were excluded; finally, 37 casts were included in this study.

The dissection of the peripheral branches was performed as described previously (*10,11*). We used forceps with fine tips and gently extracted the small Glissonean and venous branches, piece by piece. High-pressure water was sometimes used to clean up small branches, but was not suitable for revealing small peripheral branches. In some liver casts, the middle hepatic vein or right portal vein were divided to reveal the paracaval portal vein branches (PCPvs) and short hepatic veins. The final lateral view of the liver depicts the remnant left liver after right hemihepatectomy.

We used two cameras to capture stereoscopic photographs of the hepatic branches so that the readers could observe the liver casts three-dimensionally. The distance between the two cameras was 6.5 cm.

This study was approved by the National Center for Global Health and Medicine Research Ethics Committee/Institutional Review Board (approval number: NCGM-S-004739-00).

Relationship between PCPvs and the three major hepatic veins

The number of PCPvs was one in 34 cases and two in three cases. The PCPvs reached the hepatic surface through the ceiling that was composed of the major hepatic veins in 18 of 37 cases (48.6%). The relationship between PCPvs and the three major hepatic veins could be classified into four types.

i) Type RM: PCPvs reached the hepatic surface through the gap between the right and middle hepatic veins (n = 11) (Figure 1A and Figure 2A).

ii) Type M: PCPvs reached the hepatic surface through the branches of the middle hepatic vein (n = 4) (Figure 1B and Figure 2B).

iii) Type ML: PCPvs reached the hepatic surface through the gap between the middle and left hepatic veins (n = 3) (Figure 1C and Figure 2C).

iv) Type 0: The PCPvs did not reach the hepatic surface (n =19) (Figure 1D and Figure 2D).

Among the 15 cases of RM and M types, the root of the PCPvs originated from the right portal vein in six cases, and the left portal vein in nine cases.

No PCPvs reached the hepatic surface behind the right hepatic vein.

Locating the cranial boundary of the caudate lobe

In the present study, we found that PCPvs reached the liver surface in 48.6% of cases through the major hepatic veins. However, no PCPvs reached the liver surface behind the right hepatic vein. This is because we defined the caudate branch as the dorsal branch from the first-order portal vein branches, and did not include branches toward the IVC from the anterior or posterior sections. However, defining PCPvs as branches from the first-order or main branch of the portal vein in the context of portal vein-based liver segmentation is essential for understanding hepatic anatomy (*9-11*). Some PCPvs passed through the gap between the middle and left hepatic veins. Considering the anatomical structures of the PC vein and its branches, liver surgeons should encounter PCPvs behind the middle hepatic vein during conventional hemihepatectomies. Alternatively, systematic segmentectomy of segment 8 should involve resection of the PCPvs when the surfaces of the IVC, middle hepatic vein and right hepatic vein are exposed on the resectional plane. We believe that it is essential for all liver surgeons to determine the distribution of the caudate lobe branches among the major hepatic veins.

It has been reported that part of the liver surface is supplied by the portal vein branches of the caudate lobe. By examining 23 liver casts, we have previously reported that in 50% of cases the PCPvs reached the hepatic surface (*9,10*). Couinaud reported that PCPvs penetrated the plane comprising the major hepatic veins in 40 casts, and that in 18 of these (45%) the PCPvs reached the hepatic surface (*7*). Maki et al. revealed that the caudate lobe can be identified on the liver surface using 3D Vincent analysis of dynamic computed tomography (CT) scan images in 30.2% of cases (*12*). In order to locate the cranial boundary of the caudate lobe, it is essential to define the PCPvs clearly.

In this study, we found that 8% of PCPvs went through the gap between the middle and left hepatic veins and 11% went through the branches of the middle hepatic vein. These branches can be exposed during hepatectomy; however, without knowledge of our current data, surgeons would not be aware that the tiny portal vein branches between the middle and left hepatic vein originated from the PC portion of the liver. These fine portal vein branches cannot always be visualized even on a precise dynamic CT scan.

A partial or total caudate lobectomy is often performed during hemihepatectomy to resect hepatic or biliary malignancies. An anatomically precise definition of the right-sided boundary of the caudate lobe is important in cases of right hemihepatectomy for liver cancer or extended left hemihepatectomy for biliary cancer. It is technically possible to preserve the liver PC portion during right hemihepatectomy (*13*). On the other hand, it is important to remove the PC portion to enhance the curability of perihilar cancer (*4,5*). Liver surgeons must accurately define the right-sided and cranial boundary of the caudate lobe to perform anatomically precise liver resections.

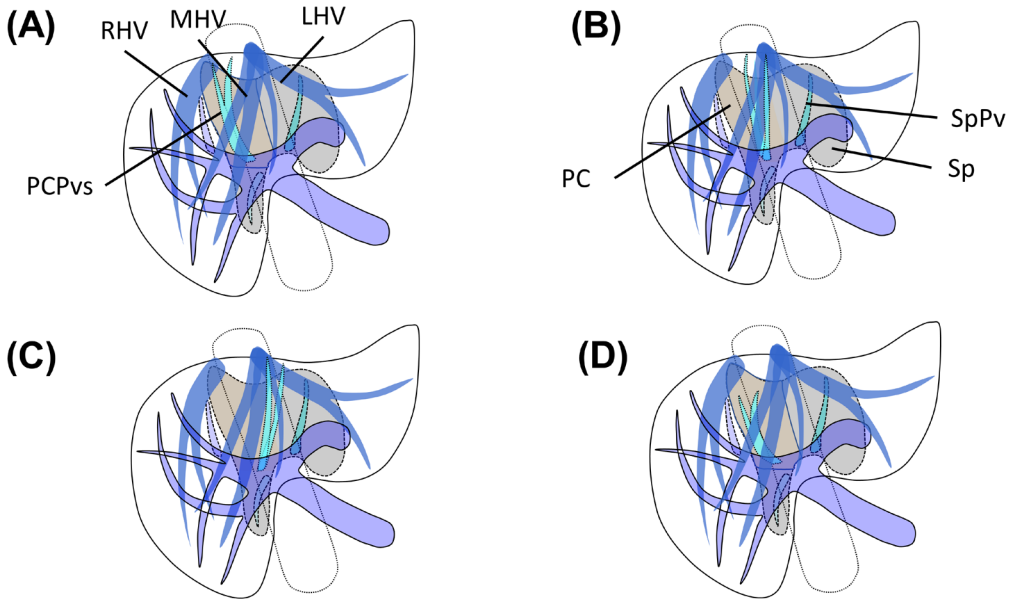

Figure 1. Four types of relationships between the PCPvs and the major hepatic veins. (A) Type RM, PCPvs reach the hepatic surface through the gap between the right and the middle hepatic veins (MHV); **(B)** Type M, PCPvs reached the hepatic surface through the branches of the MHV; **(C)** Type ML, PCPvs reached the hepatic surface through the gap between the MHV and left hepatic vein; **(D)** Type 0, PCPvs did not reach the hepatic surface. PCPvs, paracaval portal veins; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; PC, paracaval portion; Sp, Spiegel lobe; SpPv, Spiegel portal vein.

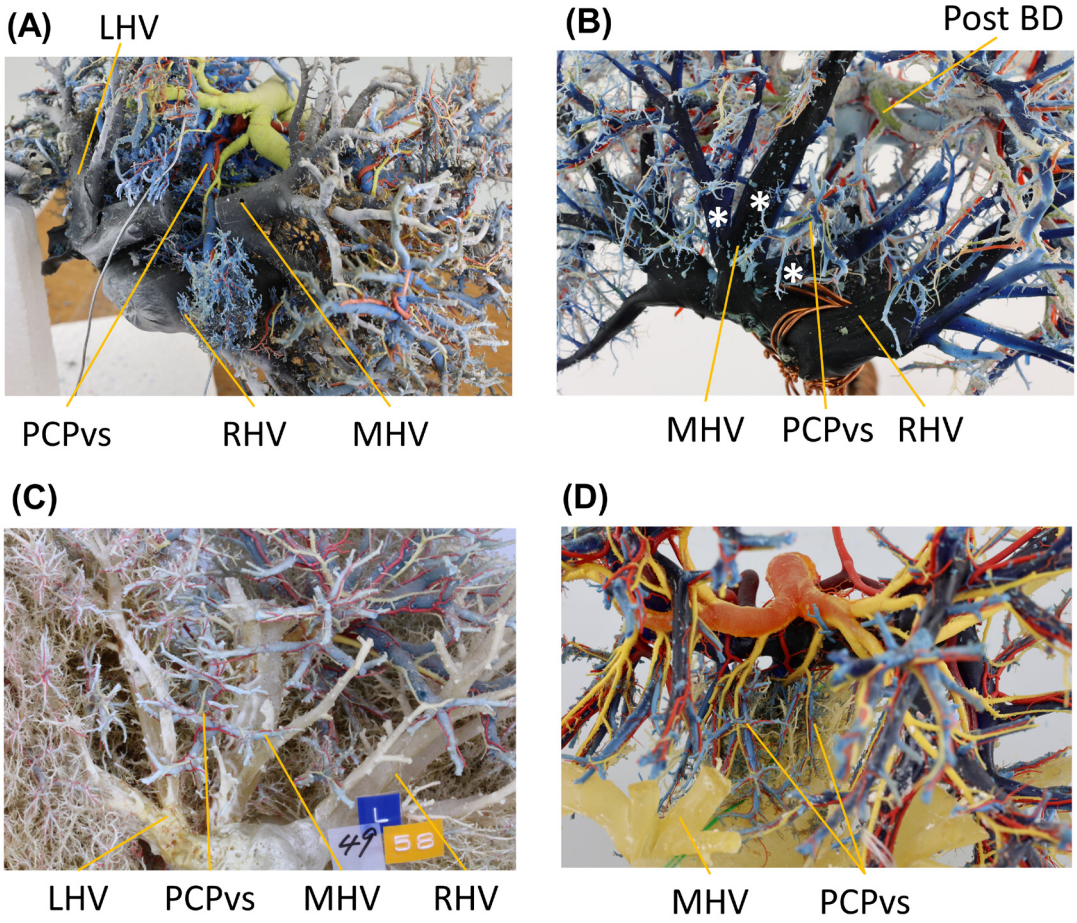

Figure 2. (A) Right-cranial view of a whole liver cast of type RM. The PCPvs extends from the left portal vein toward the liver surface behind the gap between the MHV and RHV. The MHV was divided to reveal the PCPvs clearly. **(B)** Right-cranial view of a whole liver cast of type M. The PCPvs originating from the left portal vein penetrated the plane of the MHVs and reaches the liver surface. **(C)** Right-cranial view of a whole liver cast of type ML. The penetrating PCPvs passed through the gap between the MHVs and the LHVs toward the liver surface. **(D)** Cranial view of a whole cast of Type 0. The caudate lobe was small and the PCPvs did not reach the liver surface. PCPvs, paracaval portal veins; RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; PCB, paracaval bile duct; RHD, right hepatic duct; Post BD, posterior bile duct.

In conclusion, we dissected 37 liver casts and focused on the relationship between PCPvs and the major hepatic veins. In half of the cases, the PCPvs passed through the gap between the major hepatic veins and reached the hepatic surface; however, there were no branches behind the right hepatic vein. This anatomical knowledge will be indispensable for liver surgeons in the era of minimally invasive hepatectomies.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

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