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BRIEF REPORT
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Hepatic venous plexuses on the right border of the caudate lobe against the right liver in a liver cast

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Abstract: Identifying the right border of the caudate lobe against the right liver is clinically important; however, this remains challenging. As the paracaval portion (PC) of the caudate lobe is adjacent to segment 8 of the right liver, we dissected a liver cast made from epoxy resin and colored dye to define the right border of the PC against segment 8. On the right border of the PC, two major venous plexuses appearing as bouquet-shaped branches joined the inferior vena cava and the middle hepatic vein, forming short hepatic veins, whereas the venous plexuses in segment 8 joined the right hepatic and the vein inferior vena cava. These venous plexuses in PC and segment 8 created a zigzag boundary plane, which coincided with the boundary found between the caudate lobe and the right liver. Moreover, no longitudinal venous branch was found between the PC and segment 8 in the liver cast.

***Keywords*:** liver cast, caudate lobe, paracaval portion

1. Introduction

The caudate lobe is located deep in the liver and is a clinically important segment. The resection of liver tumors in the caudate lobe remains challenging in the era of laparoscopic (*1*) or robotic hepatectomy (*2*), and concomitant resection of the caudate lobe is required in the curative treatment of perihilar cholangiocarcinoma (*3*). The resection of the paracaval portion (PC) of the caudate lobe is among high-level hepatectomies according to the criteria defined by the Japanese Society of Hepato-Biliary-Pancreatic Surgery (*4,5*).

Although the left border of the caudate lobe is easily detected as the Spiegel lobe, identifying its right border remains challenging. This has been a great concern for liver surgeons when performing isolated resection of the caudate lobe. Takayama attempted to find the right border of the caudate lobe using a counter-staining technique, *i.e.*, injecting dye into the posterior portal vein (*6*); however, this is an indirect and uncertain identification method.

We have previously demonstrated the distribution of the PC of the liver on hepatic casts (*7-11*) and defined portal branches of the caudate lobe as dorsal branches from the main trunk or 1st order branch of the portal vein. The caudate lobe was divided into the following three portions according to portal segmentation: *i*) Spiegel; *ii*) PC; and *iii*) caudate process (*7-9*). In the present paper, we describe for the first time the venous plexuses on the right border of the caudate lobe in a liver cast.

2. Materials and Methods

A liver cast was made after injecting colored epoxy resin into the portal vein (blue), hepatic artery (red) and the bile duct (yellow). The present study examined three subjects. The specimens were fixed in water to preserve the natural hepatic shapes, as they would be in the body. Liver tissue was corroded completely using potassium hydroxide.

After fixation, we dissected the liver cast using a pair of forceps with fine tips and extracted the small Glissonean and venous branches, gently piece by piece (Figure 1). The right portal vein was divided at the proximal site of bifurcation of the anterior and posterior portal branches (Figure 2). After meticulous dissection, the portal and hepatic venous branches in the PC of the caudate lobe and segment 8 of the liver were observed.

The present study was approved by the National Center for Global Health and Medicine Research Ethics Committee/Institutional Review Board (approval number: NCGM-G-004020-00).

3. Results and Discussion

The Glissonean and hepatic venous branches in the PC were completely dissected from those in segment 8 (Figure 3). The PC of the caudate lobe was surrounded by the triangle made from the inferior vena cava (IVC), middle hepatic vein (MHV), and right branch of the portal vein (Figure 4).

Each venous branch was approximately 100μm in size, and numerous tiny papillary branches created two bouquet-shaped venous plexuses (Figure 4). The two major venous plexuses joined the MHV and IVC, respectively. On the opposite side of the right liver, the other two major venous plexuses were found in segment

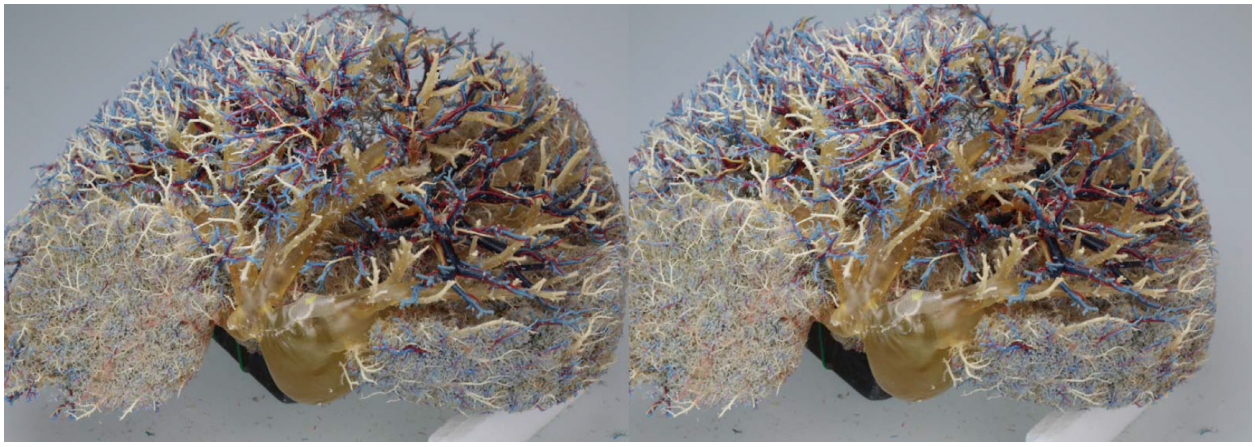

Figure 1. Cranial view of the liver cast from a ventral position.

Figure 2. Cranial view of the liver cast focusing on the root of the middle (white asterisk) and right (yellow asterisk) hepatic veins. The paracaval portion of the caudate lobe is located behind the middle hepatic vein.

Figure 3. Caudal view of the liver cast after dividing the right liver. The right liver is connected to the inferior vena cava through the venous plexuses in segment 8 (black arrowhead).

8 of the right liver (Figure 5). They joined the right hepatic vein (RHV) and IVC, respectively. The boundary between the caudate lobe and right liver coincided with the boundary between these venous plexuses in the PC and segment 8 of the liver, creating a zigzag boundary plane (Figure 6). No longitudinal intersegmental vein was observed between the PC and segment 8. These venous plexuses were found in the remaining two liver casts and no longitudinal intersegmental vein was noted between the PC and segment 8 in these two liver casts.

In the present case study, the two venous plexuses found in the PC of the liver joined the IVC as short hepatic veins and MHV. The venous plexuses in segment 8 joined the IVC and RHV, respectively. Additionally, we found that the border between the caudate lobe and right liver coincided with the boundary between the venous plexuses in the PC and segment 8, creating a zigzag irregular boundary plane. No thick longitudinal vein was noted between the PC and segment 8 of the liver, as previously shown by Maki *et al.* (*12*). In addition, these meticulous venous plexuses can never be detected on a recent CT scan or three-dimensional tomographic scans.

There have been several arguments about the right border of the caudate lobe of the liver. Kogure *et al*. advocated that the caudate process hepatic vein (CPHV) entering the IVC ran in the segmental plane between the caudate process and right liver (*13*). However, liver surgeons do not recognize the CPHA as the intersegmental vein between the caudate process and right liver. Maki *et al*. reported that the paracaval vein ran just along the boundary between the PC and right liver in 30 out of 63 (48%) participants based on analysis of the three-dimensional (3D) CT images (*12*). The paracaval vein was a branch of the RHV; however, no sagittal branch was found in the present cast. This difference will be caused by the difference of the methods of the study between liver casts and 3D-CT. On liver casts, very tiny hepatic venous branches can be seen inside the liver, while these tiny branches cannot be detected without dissecting and cutting other branches. On the other hand, on 3D-CT analysis, most thick venous branches were

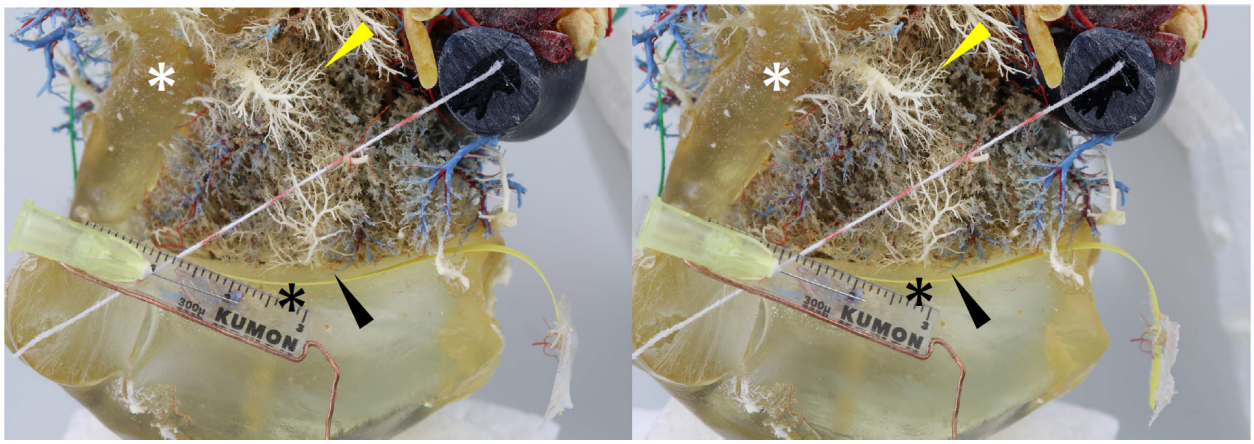

Figure 4. The right border of the paracaval portion of the caudate lobe. One venous plexus (yellow arrowhead) joins the middle hepatic vein (white asterisk), whereas another venous plexus (black arrowhead) joins the inferior vena cava (black asterisk).

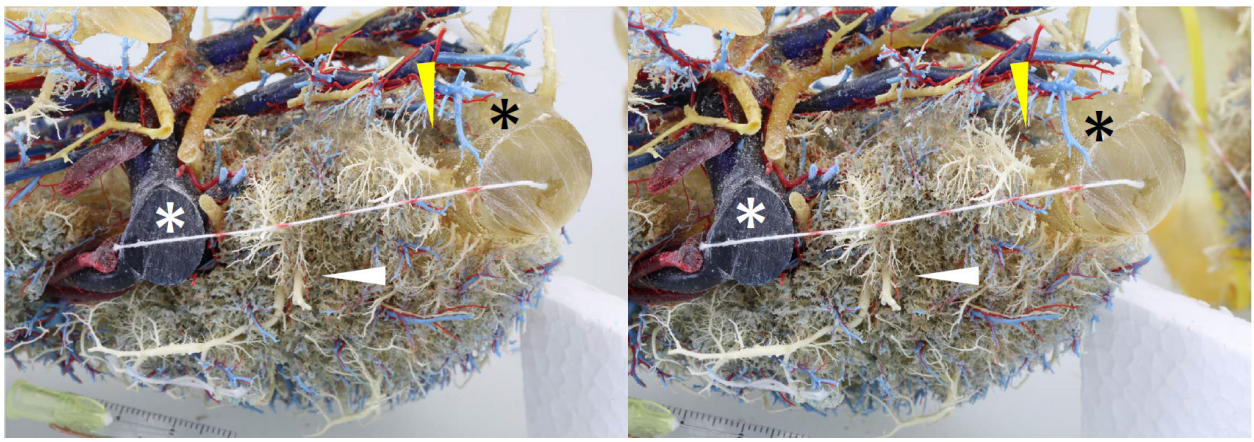

Figure 5. The left border of the right liver. Two venous plexuses are seen: one plexus (yellow arrowhead) joins the right hepatic vein (black asterisk) and another plexus (white arrowhead) joins the inferior vena cava that has been divided on the root of the short hepatic vein.

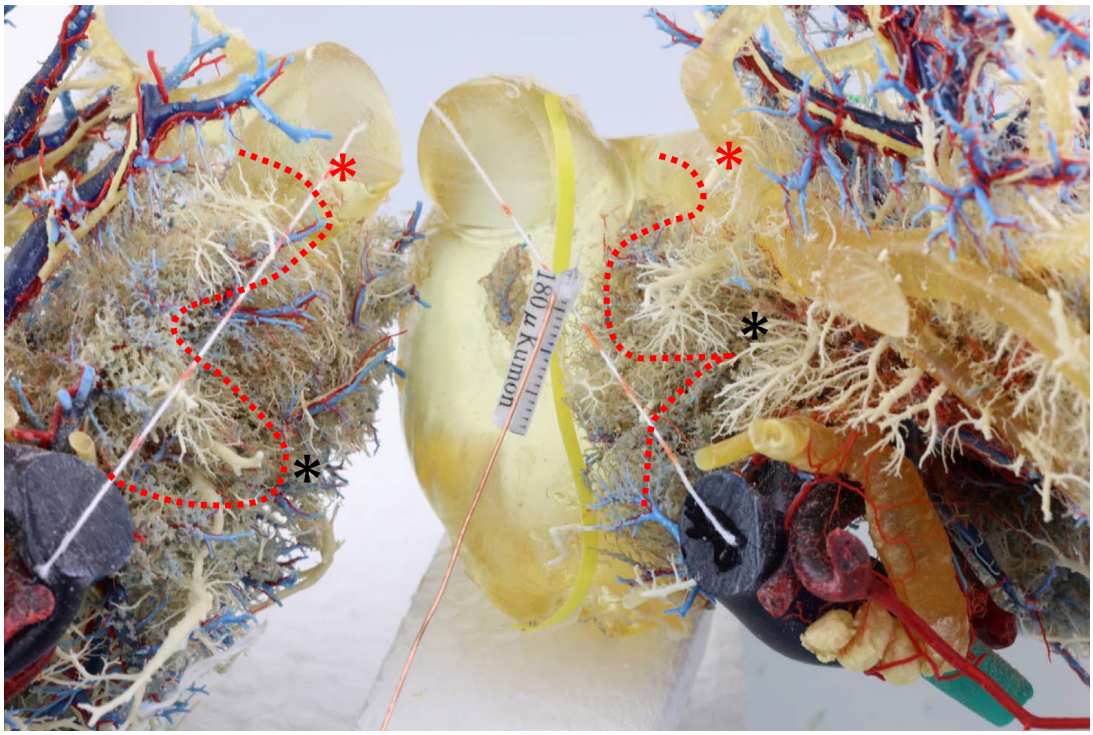

Figure 6. Caudal view of the cast after dividing the right liver and the boundary between the right liver and paracaval portion of the caudate lobe. The red dotted line shows the boundary between segment 8 in the right liver and paracaval portion in the caudate lobe. The red and black asterisks show the spots between the two livers that were connected to each other.

visualized, while the tiny venous plexus will never be shown. Each method has advantages and disadvantages to demonstrate all of the hepatic venous branches.

Takayama *et al.* clinically demonstrated the right border of the caudate lobe by injecting a dye into the posterior portal branch, as a counter-staining method (*6*). This appears to be a very clever method of visualizing the right border of the caudate lobe; however, there is a possibility that the non-stained area includes proximal branches of the posterior section. Thus, the caudate area defined by using this method was larger than that decided by using the Kumon's definition. We previously injected indocyanine green solution into the portal venous branch in PC, and found the boundary of the PC of the caudate lobe using fluorescent images using right hemihepatectomy (*14*). This will be a definite but technically demanding method to identify the boundary.

In the present cast, venous drainage of the caudate lobe joined the IVC or MHV as a venous plexus, *i.e.*, tiny venous capillary branches creating bouquet-shaped branches. This venous system can never be visualized using a 3D CT. Gadžijev's atlas also showed these venous branches in his atlas book (*15*), but they were not as clear as the present photos. In addition, he did not mention the right boundary of the caudate lobe in association with the venous plexus. Although we have examined a very small number of samples, we predict that the main venous drainage of the PC will be toward the IVC or MHV, and there will be no thick hepatic venous branch, dividing the PC and segment 8 or 7 of the liver, as previously reported (*12,13*).

The drawback of the present study is that the findings are clearly obtained from only one hepatic cast. However, dissecting the other two casts, we also found the venous plexuses, but no longitudinal venous branches were found between the PC and segment 8. This may be attributed to the fact that quality of these casts was not sufficient for visualizing the venous plexuses. In future studies, we will further increase the number of casts examined for proper investigation.

In conclusion, bouquet-shaped venous plexuses were found at the right border of the caudate lobe and left border of the right liver. These venous plexuses will never appear on the current 3D-CT and can be found only in a study using liver casts.

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

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