Editorial

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Anatomical study of the caudate lobe of the liver on hepatic casts and the dawn of isolated caudate lobectomy

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SUMMARY: Surgical resection of the caudate lobe of the liver remains the final hurdle for liver surgeons, not only in open hepatectomy but also in recent minimally invasive hepatectomy. In the dawn of liver surgery, Prof. Kumon made hepatic casts and showed the anatomy of the caudate lobe of the liver based on the portal segmentation in the National Cancer Center Hospital, Tokyo. Meanwhile, liver surgeons in the center successfully performed isolated caudate lobectomy of the liver for liver cancers one after another. Prof. Kumon is still dissecting hepatic casts to demonstrate the right border of the paracaval portion of the caudate lobe against segment VIII of the liver. An approach to right hemihepatectomy preserving the paracaval portion of the caudate lobe was developed thanks to the detailed anatomical knowledge of the liver based on hepatic casts.

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

1. Introduction

Surgical resection of the caudate lobe of the liver remains the final hurdle for liver surgeons not only in open hepatectomy (*1-3*) but also in recent minimally invasive hepatectomy (*4,5*). This is because the caudate lobe of the liver, *i.e.*, segment I in Couinaud's classification, is located deep in the liver, surrounded by the major hepatic vein, the inferior vena cava (IVC), and the hepatic hilum (*6*). One cannot see this lobe of until full mobilization of the whole liver from the IVC. Surgical resection of the caudate lobe is associated with bleeding from the short hepatic veins branching from the IVC in a minute surgical field. Thus, caudate lobe resection has been challenging for liver surgeons, since the late of 1980s, the dawn of safe liver surgery in Japan.

2. The dawn of liver surgery

In the 1980s, in the National Cancer Center Hospital, Tokyo, Prof. Hasegawa, Yamazaki, and Makuuchi started a new liver surgery for liver cancer using intraoperative ultrasonography (IOUS). They were pioneers of anatomical subsegmentectomy of the liver, exposing the landmark major hepatic veins on the transactional surface of the liver.

However, the precise location of the caudate lobe of the liver was unclear at the time. Prof. Hasegawa asked Dr. Masamitsu Kumon, a resident, to make hepatic casts to reveal the anatomy of the caudate lobe. He made 75 hepatic casts injecting colored epoxy resin, Mercox resin, silicon and so other chemicals into the portal vein (blue), hepatic artery (red) and the bile duct (yellow) of the whole liver between 1981 and 1990. The liver tissue was corroded completely using potassium hydroxide.

The completed liver cast was so exquisite (Figure 1A). Dr. Kumon dissected the tiny branches of the cast liver to reveal the anatomy of the caudate lobe. The epoxy resin was hard and fragile; therefore, meticulous dissection was necessary to excavate the caudate lobe preserving the surrounding other segments (Figure 2). Finally, he classified the caudate branches into three; the Spiegel branch, the paracaval (PC) branch and the caudate process branch. He defined the caudate branch as the dorsal branch from the main trunk of the portal vein or the first-order branch of the portal vein (Figure 1B). His first classification of the caudate lobe was published in 1985 in Japanese (*7*), and later republished in English with color photos (*8*).

3. Initial experiences of caudate lobectomy

Liver surgeons in the National Cancer Center Hospital challenged isolated total caudate lobectomy in patients

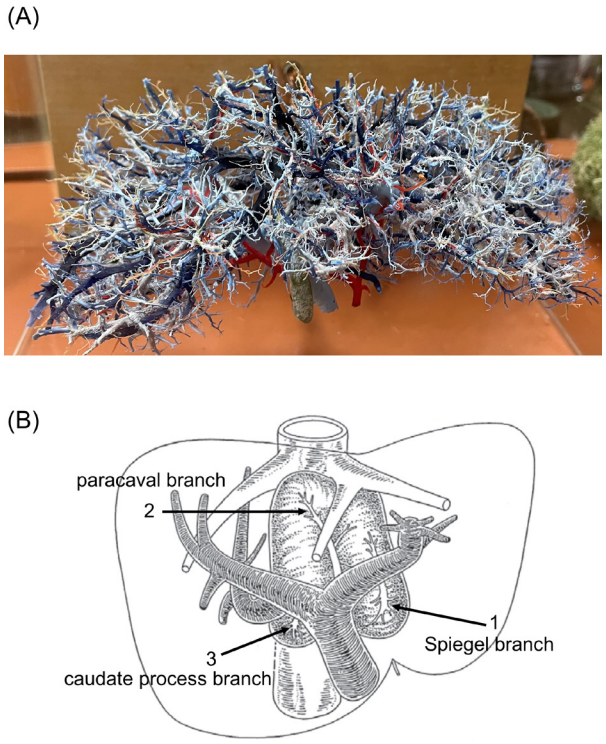

Figure 1. (A), Anterior view of the whole liver cast. (B), Definition of the three portions of the caudate lobe of the liver. (1), The Spiegel branch; (2), The paracaval branch; (3), The caudate process branch. Figure (B) adapted with modifications from *Ref. (7,8)*.

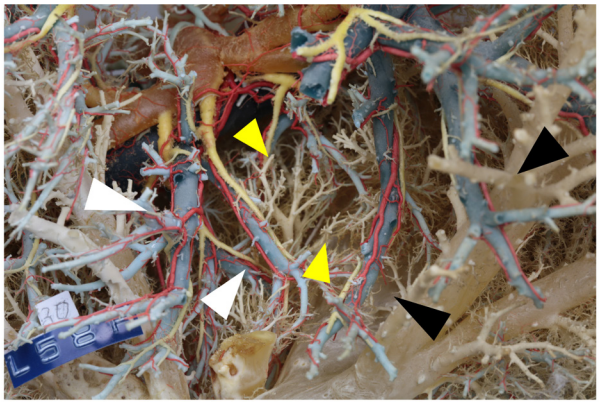

Figure 2. Cranial view of the liver cast focusing on the boundary between the paracaval portion and the segment VIII of the liver. White arrowheads indicate the portal venous branches in the paracaval portion of the caudate lobe. Black arrowheads indicate the venous branches in segment VIII. Yellow arrowheads indicate short hepatic veins between the two hepatic segments.

with hepatocellular carcinoma (HCC) in the 1990s (*1-3,9*) (Table 1). As most patients with HCC were associated with cirrhotic liver caused by the hepatitis C virus, isolated caudate lobectomy was required to prevent posthepatectomy liver failure. They successfully performed isolated caudate lobectomy using the transhepatic (*1,3,9*) or high dorsal approaches (*2*).

Sakamoto compared the short-term and long-term outcomes of surgical resection for HCC in the National Cancer Center Hospital (*10*). No survival difference was found between patients with HCC in the caudate lobe (n = 46) and in those with HCC at other sites (n = 737) of the liver. However, the resection of the paracaval portion (n = 27) was associated with longer surgical procedures (p = 0.002), more intraoperative blood loss (p = 0.02), and shorter surgical margins (p < 0.001) than the resection of the Spiegel lobe (n = 10) or caudate process (n = 19).

4. Where is the right boundary of the caudate lobe of the liver?

Prof. Kumon was born in Kochi in 1948 and went to the National Cancer Center Hospital as a surgical resident in 1979. He still dissects his hepatic casts in his laboratory. His recent primary focus is the right border of the caudate lobe of the liver because it is clinically important and has remained a mystery for a long time.

Prof. Couinaud in Paris, defined the hepatic eight segments of the liver (from segment I to VIII); however, he suffered from the definition of segment I (Figure 3) (*11*). He divided segment I into two subsegments, Ir and Il and further classified subsegment Ir into b, c, and d portions in 1989 (*12*). He reclassified subsegment Ir into segment IX in 1994 (13) and then divided segment IX into subsegments IXb and IXd in 1998 (*14*). He reclassified subsegments IXb and IXd into subsegments IX_L and IL_R in 2000 (*15*). He mentioned that segments I and IX are crossed by overlapping branches from the left and right sectors, and thus the entire dorsal liver is more correctly termed a single portal segment that has three subsegments: the Spiegel lobe, the PC portion, and the caudate process, as proposed by Kumon (*16*). Therefore, Prof. Couinaud gave the rights over the definition of the caudate lobe to Dr. Kumon.

Table 1. Reports on surgical resection of caudate lobe from National Cancer Center Hospital

Author	Year	Journal	Disease	Approaches	Number
Yamamoto J	1992	World J Surg	HCC	Transhepatic isolated caudate lobectomy	1
Takayama T	1994	J Am Coll Surg	HCC	High dorsal resection	1
Kosuge T	1994	Arch Surg	HCC	Transhepatic isolated caudate lobectomy	1
Yamamoto J	1999	World J Surg	HCC, meta	Transhepatic isolated caudate lobectomy	5
Sakamoto Y	2011	Surgery	HCC	Anatomical or non-anatomical resections	46

HCC, hepatocellular carcinoma; meta, colorectal liver metastasis.

In the original article published in 1985, Dr. Kumon found several branches from the anterior sector toward the paracaval portion, named them "PV^{8}C," and excluded them from caudate lobe branches (Figure 4A) (*7,8*). However, it is sometimes difficult to distinguish the PC branches from PV^{8}C on computed tomography (CT) images, because PC branches and PV^{8}C branches can be visualized on CT images in 33% and 45% of case, respectively (unpublished data).

Dr. Kumon found tiny, short hepatic veins toward IVC located at the boundary between the PC portion and segment VIII (Figure 4B) (*11*). He also divided the hepatic cast along the Rex-Cantlie's line and demonstrated the PC portal and biliary branches at the boundary of the PC portion of the caudate lobe and segment VIII (*17*). He found accessory branches along the IVC beside the PC branches. They were from the posterior portal vein; thus, they should be included in the posterior section.

Furthermore, he found venous plexuses in the PC and also in segment VIII of the liver. The venous plexuses joined the IVC and middle hepatic vein, while the plexuses in segment VIII joined the right hepatic vein and IVC (Figure 5) (*18*) So far, it has not been possible to reveal these venous plexuses on CT images

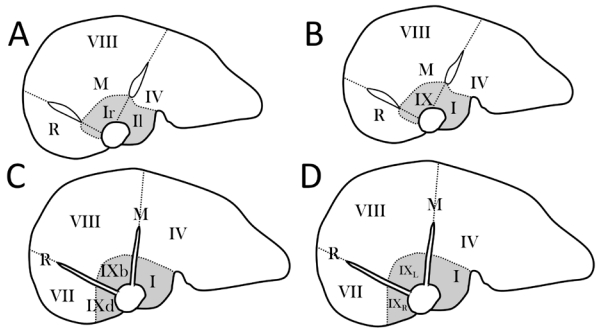

Figure 3. Serial change of the definition of the dorsal liver by Prof. Couinaud. Prof. Couinaud changed his definition on the caudate lobe of the liver in 1989 **(A)**, 1994 **(B)**, 1998 **(C)**, and 2000 **(D)**.

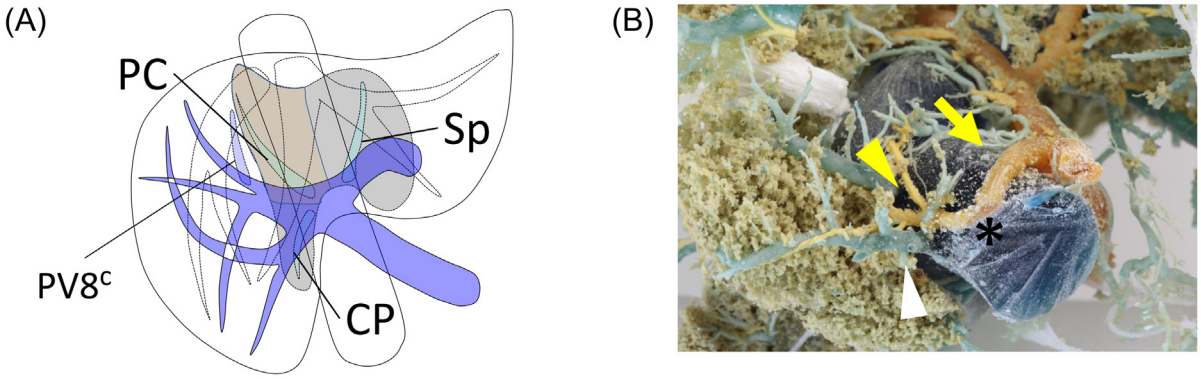

Figure 4. (A), Paracaval branch of the caudate lobe and PV8^{c}. The root of the paracaval portal branch is the right branch of the portal vein, while the root of PV8^{c} is the anterior portal vein. PC, paracaval portion; Sp, Spiegel portion; CP, caudate process. **(B), The right border of the paracaval portion of the liver.** The yellow arrow indicates the posterior bile duct, and the yellow arrowhead indicates the paracaval branch of the bile duct. The white arrowhead indicates the paracaval branch of the portal vein. The posterior bile duct is divided at the point of the asterisk.

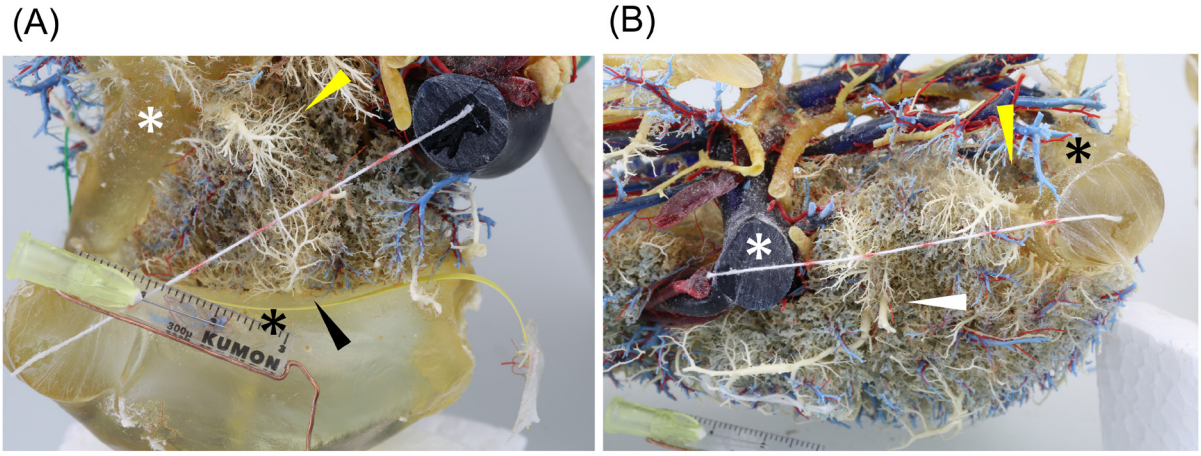

Figure 5. (A), The right border of the paracaval portion of the caudate lobe. One venous plexus (yellow arrowhead) joins the middle hepatic vein (white asterisk), whereas another venous plexus (black arrowhead) joins the inferior vena cava (black asterisk). **(B), The left border of the right liver.** Two venous plexuses are seen: one plexus (yellow arrowhead) joins the right hepatic vein (black asterisk) and the other plexus (white arrowhead) joins the inferior vena cava that has been divided at the root of the short hepatic vein.

Figure 6. Photos of the second meeting of the caudate lobe of the liver held in Kochi on July 12, 2025. Prof. Kumon (center) brought his hepatic casts to the meeting and the participants found that the casts are so fragile and the dissection of tiny branches is not easy.

or to detect them during hepatectomy. To the best of our knowledge, this study will be the first to reveal these plexuses in the PC and segment VIII.

5. Clinical application of anatomical knowledge on the caudate lobe

How can we translate the above anatomical knowledge to real-world liver surgery? Kogure *et al* first performed right hemihepatectomy preserving the PC of the caudate lobe completely (*19*). The patient was a man in his 40s with a metastatic mass from colorectal cancer measuring 24 × 10 cm in the right lobe of the liver. Preoperative CT volumetry revealed that the left hemiliver and the caudate lobe constituted 55% and 5.3%, respectively, of the total liver volume.

To preserve the future liver remnant volume, he decided to preserve the PC portion of the caudate lobe. He injected a mixture of indigo carmine and indocyanine green solution into the PC portal branch under IOUS guidance. During right hemihepatectomy, the PC portion was visualized fluorescently using a near-infrared image system. The fluorescently visible PC portion was preserved with the left hemiliver, and right hemihepatectomy was completed. To the best of our knowledge, this is the first report of isolated fluorescent visualization and preservation of the PC of the caudate lobe during right hemihepatectomy. The patient had enough functional reserve of the liver; however, this technique might be useful in patents with deteriorated hepatic function, in whom the liver parenchyma should be preserved as much as possible.

Comments

The anatomy of the liver does not change; however, the required anatomical knowledge changes with the advancement of surgical technology. Recent three-dimensional analyses of CT images do not always visualize tiny hepatic branches, which can be clearly demonstrated on the hepatic casts produced in the 1980s. We must reconsider the anatomy of the liver with the advancement of surgical techniques.

Appendix

In honor of the anatomical study of the caudate lobe on hepatic casts, the second meeting of the caudate lobe of the liver was held in Kochi, Japan on July 12, 2025. This meeting was planned by Prof. Sakamoto Y, and managed by Prof. Satoru Seo of the Department of Surgery, Kochi Medical School. The clinical and anatomical importance of the caudate lobe of the liver was discussed around Prof. Masamitsu Kumon (Figure 6).

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

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