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Right hemihepatectomy preserving the fluorescently visible paracaval portion of the caudate lobe

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Abstract: The paracaval portion (PC) of the caudate lobe is a small area of the liver located in front of the inferior vena cava. Conventional right hemihepatectomy (RH) along the Rex–Cantlie line involves resection of not only the anterior and posterior sections but also the PC behind the middle hepatic vein (MHV). However, to preserve the future liver remnant volume as much as possible, PC-preserving RH may be beneficial in selected patients. We injected an indocyanine green (ICG) solution in the PC portal branch under intraoperative ultrasonography (IOUS) guidance and performed an RH preserving the fluorescently visible PC in a patient with liver metastasis. The patient was a 47-year-old male with a 24 ×10 cm metastatic hepatic tumor from sigmoid colon cancer. CT volumetry revealed that the left hemiliver excluding the caudate lobe was 55%, and the caudate lobe was 5.3%. Before hepatic transection, the ICG solution was injected into the PC portal branch under IOUS guidance. During hepatic transection, the PC was identified as a fluorescent area behind the MHV using a near-infrared imaging system. Thus, the anatomical right-side boundary of the caudate lobe was clearly found. Following RH, the PC was preserved as a fluorescently visible area. The patient had an uneventful recovery. RH preserving the fluorescently visible PC of the liver is a feasible procedure.

***Keywords*:** caudate lobe, colorectal liver metastasis, indocyanine green, paracaval portion, right hemihepatectomy

Introduction

Right hemihepatectomy (RH) of the liver is a standard procedure to remove an anatomically right-sided hemiliver. In 1949, Honjo performed the first RH (*1,2*) followed by Lotart–Jacob in 1951 (*3*), where the right hemiliver was resected concomitant with the right hepatic artery, portal vein, and hepatic veins regardless of the preservation of the middle hepatic vein (MHV). Conventional standard RH along the Rex–Cantlie line exposing the MHV on the transection plane (*4*) has been first presented by Hasegawa (*5,6*). According to Kumon's classification, the dorsal area of the MHV corresponds to the paracaval portion (PC) of the caudate lobe (*7,8*), and the conventional RH involves resection of the PC of the caudate lobe. Recently, Kumon *et al*. described the right-side boundary of the caudate lobe based on portal segmentation using liver casts (*9*). However, visualizing the right-side boundary of the caudate lobe during parenchymal transection has been considered challenging.

This is the first report of intraoperative identification and preservation of the fluorescently visible PC of the caudate lobe during RH.

Case characteristics

The patient was a 47-year-old man with a 24 × 10 cm synchronous liver metastasis occupying the right lobe of the liver from sigmoid colon cancer (Figure 1A). Although the colon cancer was a circumferential type 2 lesion, the patency of the bowel was well preserved. Therefore, considering the rapid progression of the hepatic tumor, the liver-first approach was performed. Preoperative CT volumetry revealed that the left hemiliver (S2–4) and the total caudate lobe were 55% and 5.3% of the total liver volume, respectively. The indocyanine green (ICG) retention rate at 15 min was 5.8%, suggesting normal liver function. On gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid (Gd–EOB–DTPA)-enhanced magnetic resonance imaging, a thick PC branch occupying a small lesion behind the MHV was noted in accordance with cranial branches from the anterior and posterior portal veins (Figure 1B–1E). These findings suggested that if the right-side boundary of the PC could be identified during liver resection, PC-preserving RH may be feasible to preserve the liver parenchyma as much as possible.

Surgical technique

Liver mobilization was performed after laparotomy with thoracotomy. Following right hepatic artery ligation,

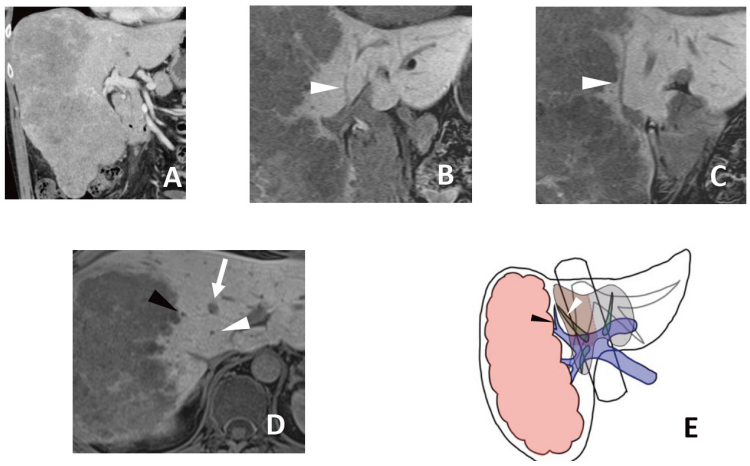

Figure 1. Radiological findings. (A) Preoperative contrast-enhanced CT imaging in the coronal section. The tumor occupies the right lobe. **(B)** Preoperative Gd–EOB–DTPA-enhanced magnetic resonance imaging in the hepatobiliary phase. The PC branch (arrowhead) from the hilar bifurcation area is observed in the coronal section. **(C)** Cranial branch from the anterior portal vein (arrowhead) is observed in the coronal section. **(D)** PC branch (white arrowhead), cranial branch from the anterior portal vein (black arrowhead), and MHV (arrow) are observed in the axial section. **(E)** Schema of the anatomy of the patient. The PC branch (white arrowhead) corresponds to the PC (brown area) of the caudate lobe. The cranial branch from the anterior portal vein (black arrowhead) corresponds to the cranial region of the anterior sector adjacent to the PC of the caudate lobe. Gd–EOB–DTPA, gadolinium–ethoxybenzyl–diethylenetriamine pentaacetic acid; PC, paracaval; MHV, middle hepatic vein.

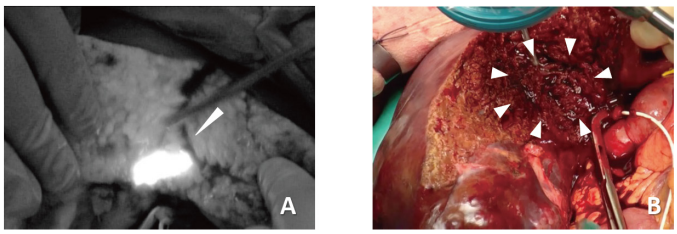

Figure 2. Operative findings. (A) Behind the MHV (arrowhead), a small fluorescence area is visualized, which corresponds to the stained PC of the caudate lobe. **(B)** PC (arrowhead) existed behind the MHV and above the hepatic hilum in the cut surface. MHV, middle hepatic vein; PC, paracaval.

the right portal vein was ligated and divided on the distal side of the PC portal branch bifurcation, which was confirmed using intraoperative ultrasonography (IOUS). An indigo carmine plus ICG solution (0.25-mg ICG and 5-mg indigo carmine) was injected into the PC portal branch under IOUS guidance. However, no fluorescence area except for fluorescing tumor due to preoperative venous ICG injection for liver function test was observed on the liver surface using a near-infrared image system (PDE NEO; Hamamatsu Photonics, Hamamatsu, Japan). The right hepatic duct was divided following intraoperative cholangiography.

Hepatic transection was performed along the Rex–Cantlie line using the clamp crushing method under Pringle's maneuver. The main trunk of the MHV was exposed to the cut surface and preserved in the left hemiliver. Behind the MHV, a small fluorescence area was visualized, which corresponded to the stained PC of the caudate lobe (Figure 2A and 2B). The fluorescently visible PC was preserved with the left hemiliver, and RH was completed.

The operative time was 6 h and 45 min, and the estimated blood loss was 140 mL. On day 7, a self-expandable metallic stent (Niti-S stent, Taewoong Medical, Seoul, Korea) was placed in the sigmoid colon to treat circumferential colon cancer-associated obstructive colitis. On day 16, the patient was discharged without any significant morbidity. Laparoscopic sigmoidectomy was successfully performed 36 days following hepatectomy. The patient received systemic chemotherapy for the treatment of multiple liver metastases detected 7 months following hepatectomy.

Discussion

By injecting dye into the PC portal branch under IOUS guidance, it was possible to identify the right-side boundary of the PC and preserve the PC of the liver.

In 1949, Honjo first performed RH. In 1950, he described his RH in Japanese (*1*) and in 1955 in English. He did not intentionally expose the MHV to avoid bleeding (*2*). In 1951, Lotart–Jacob performed RH combined with MHV resection and published it in 1952 (*3*). In 1982, Bismuth described RH with a middle division of the MHV (*10*). In 1975, published in Japanese, Hasegawa proposed RH exposing the MHV along the intersegmental plane between the right and left hemilivers (*5*). In 1980, his idea was introduced as the

"cherry fruits theory" or "banana theory" in French (*6*). Since then, RH exposing the MHV on the cut surface to its root has been considered an anatomically precise RH; however, there have been no arguments regarding right caudate lobe resection during RH. To preserve the future liver remnant volume and minimize the risks of posthepatectomy liver failure, it may be acceptable to preserve the whole caudate lobe during RH.

The anatomical boundary of the caudate lobe has been controversial. Couinaud defined the caudate lobe as a dorsal liver based on the spatial position against the major hepatic veins and inferior vena cava. He classified the caudate lobe into segments I and IX or other variations (*11-13*), however, in 2000, he finally abandoned his idea (*14*) and accepted the definition proposed by Kumon (*8*). Kumon defined the caudate branches as dorsal branches ramified from the first-order branch or main trunk of the portal vein (*8,15*). Regarding the right-side boundary of the caudate process, using a cadaver liver, Kogure proposed that the hepatic vein of the caudate process can be the landmark between the right liver and caudate lobe (*16*). Maki *et al*. reported that the PC branches reached the right subphrenic surface of the liver in one-third of cases (*17*). In this case, the PC area could not be fluorescently visualized before hepatic transection. In a clinical setting, the right-side boundary of the PC will be important for determining the hepatic transection line during caudate lobectomy; RH; anatomical resection of the anterior section and segments 6, 7, and 8; or extended left hemihepatectomy with caudate resection for perihilar cancer.

Takayama determined the right-side boundary of the caudate lobe using the counter-staining technique by injecting dye into the posterior portal vein before isolated caudate lobectomy (*18*), which is similar to the negative staining technique during recent laparoscopic anatomical hepatectomy using ICG fluorescence imaging (*19*). However, in negative staining, the caudate lobe may be overestimated, because some branches may present at the root of the posterior portal vein, and the area supplied by these branches will be recognized as the caudate lobe. In the present case, we directly inject dyes into the PC to stain the PC and right-side boundary of the caudate lobe. We must concede that the PC branch may be excessively thin to precisely inject the dye solution at all times. Preoperative identification of the PC branch by imaging study will be important. This technique may be used to identify the anatomical area of PC during caudate lobectomy; RH; anatomical resection of the anterior section and segments 6, 7, and 8; or extended left hemihepatectomy with caudate resection for perihilar cancer.

In conclusion, RH preserving the PC of the liver is a feasible procedure by identifying the PC using ICG fluorescence imaging. This technique can be applied in other anatomical hepatectomy procedures to identify the caudate lobe boundary.

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

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