



Right intersectional transection plane based on portal inflow in left trisectionectomy

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Abstract

Purpose Left trisectionectomy (LT) extending to the segment I with bile duct resection for perihilar cholangiocarcinoma (PHC) is a technically demanding procedure with high morbidity. Liver transection during LT is generally conducted to expose the right hepatic vein (RHV) on the remnant side. In clinical practice, we have often encountered a discrepancy between the theoretical RHV-oriented plane and the actual right intersectional plane.

Methods To enable anatomical LT safely, the three-dimensional right intersectional transection plane based on portal inflow was investigated using multidetector-row computed tomography, and it was compared to the theoretical RHV-oriented plane in 100 patients with hepatobiliary disease.

Results The posterior portion of RHV just below the diaphragm was supplied by the dorsal portal branches of segment VIII in 85 cases of 100 (85.0%). The median volume of this portion was 82 mL (25–169 mL). On the other hand, the anterior region of the peripheral RHV was supplied by a few small ventral portal branches of segment VI in 24 of 90 cases (26.7%). The median volume of this portion was 53 mL (20–104 mL). In ten cases with a large inferior RHV, the RHV trunk was relatively short and did not reach the caudal part of the liver.

Conclusions The portal inflow-oriented right intersectional plane does not coincide with the RHV-oriented plane in most cases. The cranial part of the actual transection plane becomes hollow, whereas the caudal part is protruded in relation to the RHV. Hepatobiliary surgeons should recognize this complicated transection plane to avoid postoperative complications when performing LT for PHC.

Keywords Right intersectional plane · Left trisectionectomy · Perihilar cholangiocarcinoma

Introduction

Left trisectionectomy (LT) (resection of hepatic segments II, III, IV, V, and VIII) has been selected more often than left hemihepatectomy for perihilar cholangiocarcinoma (PHC) with left-sided predominance in high-volume centers [8, 16, 17, 24, 26, 30], although LT extending to segment I with bile duct resection is a technically demanding procedure [12,

13]. To date, LT was indicated not only for hepatobiliary malignancies such as cholangiocarcinoma, hepatocellular carcinoma, metastatic liver tumors, sarcoma, and primary neuroendocrine tumor [18], but also for benign disease such as hepatolithiasis [9].

The incidence of postoperative complications, especially biliary fistula, intra-abdominal abscess and liver failure following LT, has been reported to be higher than in other standard surgical procedures, such as left hemihepatectomy, right hepatectomy and right trisectionectomy [5, 6]. Several issues can be considered to explain why LT is such a challenging procedure [10]. The first is the complexity of recognizing the right intersectional plane. The second is the variety of three-dimensional positional relationships of the right posterior sectional bile duct or the right posterior hepatic artery to the right portal vein. The third is the relatively small future remnant liver volume following LT.

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The anatomical classification of the liver proposed by Couinaud [3, 4] and Bismuth [1, 2] is widely accepted as representing surgically relevant anatomy [14, 15, 29]. It is generally known that the liver is divided longitudinally into right and left hemilivers along the middle hepatic vein (MHV). The right hemiliver is further divided into anterior and posterior sections along the right hepatic vein (RHV). That is, a flat plane containing the hepatic venous trunk can be regarded as a landmark for the corresponding intersectional plane. Several authors have shown that the main longitudinal intersectional plane (main portal scissura), known as the Rex-Cantlie line, is an almost flat plane that contains the MHV trunk in most cases [23, 27]. However, as to right intersectional plane (right portal scissura), we have often encountered a discrepancy between the theoretical RHV-oriented plane and the actual right intersectional transection plane, when performing LT in clinical practice.

Generally, anatomical liver transection should be performed so as to leave the whole portal perfusion portion and minimize the non-perfused ischemic portion of the liver. In patients undergoing extended hepatectomy, such as LT, providing maximal liver functional volume is crucial to avoid postoperative liver failure [25]. On the other hand, if large volume of the ischemic/infarcted portion of the liver is excised, infectious complications may often occur after surgery, particularly in patients with preoperative biliary drainage [7, 19, 20] (Fig. 1a, b).

Liver transection during LT was usually performed at the RHV-oriented right intersectional plane because the RHV is the only landmark of the right intersectional plane. Originally, it was thought that liver transection during LT should be performed at the proper right portal scissura (the actual right intersectional plane based on the PV inflow) to avoid postoperative infectious complications. However, postoperative infectious complications that might be caused

by the ischemic/infarcted portion of the remnant liver often developed following LT that transected the liver at the RHV-oriented plane. Therefore, we hypothesized that the RHV-oriented right intersectional plane does not coincide with the portal inflow-oriented right intersectional plane.

In this study, the actual three-dimensional (3D) shape of the right intersectional plane was investigated based on the portal inflow (portal inflow-oriented plane) using a workstation based on the multidetector-row computed tomography (MDCT) scan data. Furthermore, the relation between the actual portal inflow-oriented plane and the theoretical RHV-oriented plane was evaluated in 100 patients with hepatobiliary diseases at Chiba University Hospital.

Patients and methods

To investigate the 3D right intersectional plane based on the portal inflow to the right posterior section, MDCT scan data were retrospectively reviewed in 100 patients (64 men, 36 women) with hepatobiliary diseases, including 41 patients with PHC, 29 patients with distal bile duct cancer and 30 patients with gallbladder stones at Chiba University Hospital. All 100 patients had no previous hepatic surgery. Patients with distal bile duct cancer who underwent surgery at our institution were included in this study as a control group with normal anatomy and malignant disease. Similarly, patients with gallbladder stones who underwent surgery at our institution were also included in this study as a control group with normal anatomy and benign disease. However, patients with liver tumors such as colorectal liver metastases or hepatocellular carcinoma were excluded from this study as controls, because it is difficult to perform volumetric analysis of liver segments due to the presence or

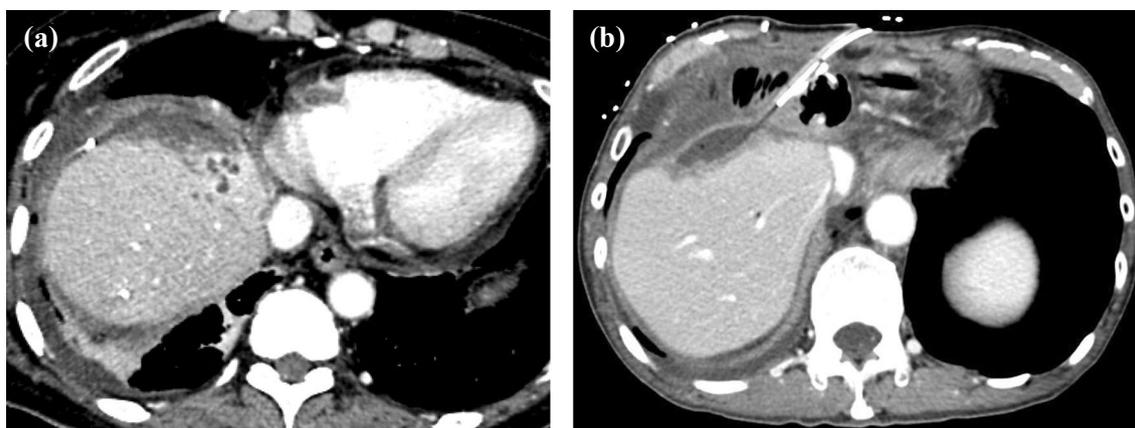


Fig. 1 Multidetector-row computed tomography **a, b** shows the infarcted liver with infection is observed close to the liver transection surface just below the right diaphragm after left trisectionectomy for perihilar cholangiocarcinoma

vascular invasion of the tumor. Of 41 patients with PHC, 9 underwent LT.

All MDCT examinations were done using a scanner with 64 rows of detectors (Acquisition 64; Toshiba Medical Systems, Tokyo, Japan), as previously described [22]. After a series of scans without a contrast agent was performed throughout the liver and biliary tree, 100–150 mL of non-ionic contrast material with an iodine content of 300 mg/mL was administered via the antecubital vein at a rate of 0.07–0.08 ml/kg/s for 30 s with a power injector before the second, third, and fourth helical scans (early arterial, late arterial, and portal phases) were obtained (26, 45, and 68 s after contrast injection, respectively). For 3D image analysis of the 3D right intersectional transection plane, the Synapse Vincent medical imaging system (Fuji Film, Tokyo, Japan) was used.

This study was conducted in the following two steps. As a first step, virtual 3D shapes of the right posterior sectional liver, based either on the portal inflow-oriented plane or the RHV-oriented plane (Fig. 2), were constructed using MDCT scan data of the portal and late phases by the automatic algorithm of the software in each case. As a second step, volumetric analysis of the dissociated portions of the liver between the portal inflow-oriented plane and the RHV-oriented plane was performed in each case.

Results

The posterior portion of the RHV just below the diaphragm was not supplied by the right posterior portal vein (PV) in 85 of 100 patients (85%); it was supplied by the dorsal portal branches of segment VIII. The median volume of this portion of the liver ($n=85$) was 82 mL (range 25–169 mL).

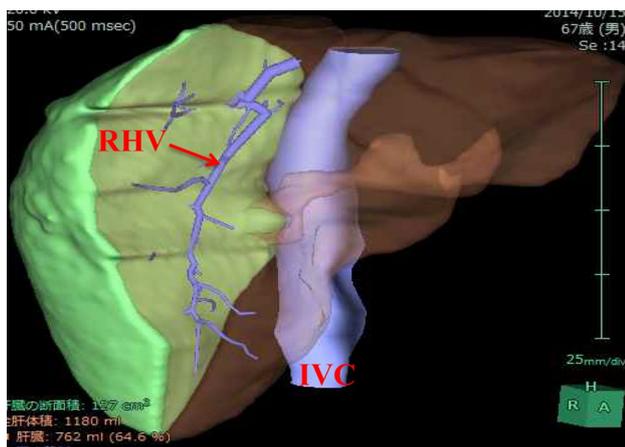


Fig. 2 Reconstructed right hepatic vein (RHV)-oriented liver transection plane in left trisectonectomy for perihilar cholangiocarcinoma. IVC, inferior vena cava

Accordingly, the cranial part of the actual right intersectional plane was hollowed to a certain extent in comparison with the RHV-oriented plane (Fig. 3) in 85% of the cases examined.

On the other hand, the ventral branches of segment VI, mostly the first/second branch of the right posterior PV trunk (Fig. 4a), supplied the ventral portion of the caudal RHV in 23 of 90 (25.5%) patients. The median volume of this portion of the liver ($n=23$) was 53 mL (range 20–104 mL). The caudal part of the actual right intersectional plane was, therefore, protruded when compared to the RHV-oriented plane (Fig. 4b) in 25% of the cases. Furthermore, ten patients (10%) had a large inferior RHV that drained segment VI. In all of these patients, the RHV trunk was relatively small and short, and did not reach the caudal portion of the right liver (Fig. 5).

Discussion

In clinical practice, we have often encountered the dissociation between the actual right intersectional plane and the RHV-oriented plane when performing LT [23]. Therefore, in this study, we investigated the 3D shape of the right intersectional plane based on the PV inflow and further compared it to the theoretical RHV-oriented plane.

The present results clearly demonstrated that the PV inflow-oriented right intersectional plane did not coincide with the RHV-oriented plane in most cases. The right subphrenic region posterior to the RHV was occupied by the dorsally protruded segment VIII in 85% of the cases. Accordingly, liver transection at cranial part should be performed in the upward direction from demarcation line,

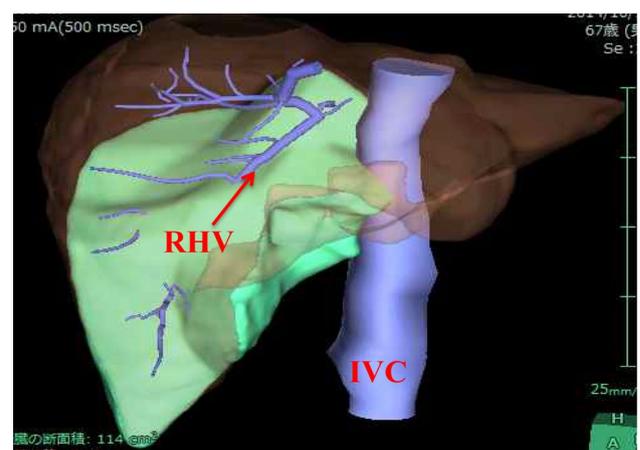


Fig. 3 Reconstructed portal inflow-oriented liver transection plane in left trisectonectomy for perihilar cholangiocarcinoma. The cranial part of the actual transection plane becomes hollow in comparison with the right hepatic vein (RHV)-oriented plane. IVC inferior vena cava

Fig. 4 **a** Multidetector-row computed tomography shows the ventral branch (P6a) of the right posterior portal vein supplies a part of the liver ventral to the peripheral right hepatic vein (RHV). **b** Portal inflow-oriented right intersectional plane in left trisectionectomy. The caudal part of the portal inflow-oriented right intersectional plane is protruded in comparison with the RHV-oriented plane. S6a, ventral portion of segment VI

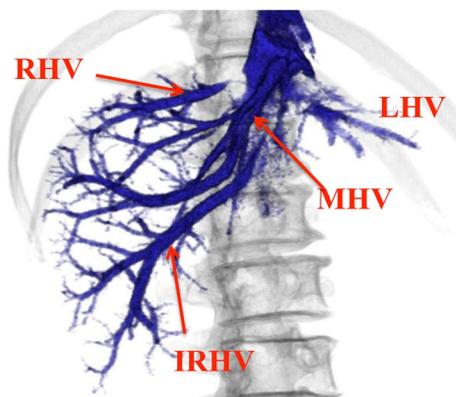
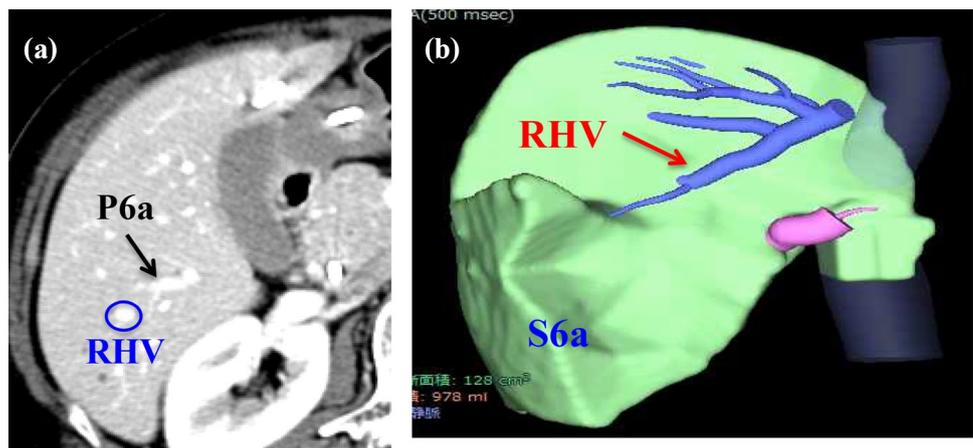


Fig. 5 The three-dimensional reconstructed hepatic vein: In cases with a large inferior right hepatic vein (IRHV) that drains segment VI, the right hepatic vein (RHV) trunk is relatively small and short, and does not reach the caudal portion of the right liver. *MHV* middle hepatic vein, *LHV* left hepatic vein

which can be seen on the surface of the right liver intraoperatively, to the RHV trunk for conducting anatomical LT.

On the other hand, the anterior region of the peripheral RHV was supplied by a few small ventral PV branches of segment VI in 26.7% of the cases. For these cases, liver transection at caudal part should be conducted in the downward direction from demarcation line on the surface of the right liver to the right edge of the inferior vena cava. Moreover, when a large inferior RHV was present, the RHV trunk was relatively short and did not reach the caudal part of the right intersectional plane. Taken together, the full length of the RHV trunk did not exist on the right intersectional plane in most cases [21].

Actually, the cranial part of the right intersectional plane was often hollowed in comparison with the RHV-oriented plane, whereas the caudal part was protruded in some cases. These results were in accordance with the previous report by Shindoh et al., which showed that the right

intersectional plane was not always flat but was sometimes uneven, especially in the subphrenic region of the right lobe of the liver [24]. Therefore, when we perform parenchymal transection just along the RHV in LT, it may lead to unnecessary preservation of the ischemic portion of segment VIII just below the right diaphragm and/or excessive resection of the ventral portion of the segment VI.

The remnant liver after LT may be as small as 30–40% of the whole liver volume even after portal embolization [11]. Therefore, providing maximal liver volume to sustain liver function is very important [28]. At the same time, preventing infectious complications such as biliary fistula and its related hepatic/intra-abdominal abscess is also important [10]. These infectious complications may be associated with the preoperative biliary drainage, and may further lead to sepsis and subsequent liver failure in cases with a small liver remnant after surgery [10]. Accordingly, identification of the appropriate right intersectional transection plane based on the portal inflow may be crucial for conducting anatomically safe LT [26].

In conclusion, the portal inflow-oriented right intersectional plane does not coincide with the RHV-oriented plane in most cases. The cranial part of the actual transection plane becomes hollow, whereas the caudal part is protruded in relation to the RHV. To perform an anatomically safe LT, hepatic/biliary surgeons should pay attention to the actual right intersectional plane based on the PV inflow to avoid postoperative complications. The virtual right intersectional sectional transectional plane constructed by 3D image-processing software before surgery may be very helpful for identifying the margin of the right intersectional transection plane in LT.

Author contributions IH: data collection or management and manuscript writing/editing; MO: data analysis; HY: data collection or management; KF: data collection or management; MM: data analysis; HS: protocol/project development and manuscript writing/editing. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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