Can we delineate preoperatively the right and ventral margins of caudate lobe of the liver?

Xue-Yin Shen¹, Hee-Jung Wang¹, Bong-Wan Kim¹, Sung-Yeon Hong¹, Mi-Na Kim¹, Xu-Guang Hu²

¹Division of Liver Transplantation and Hepatobiliary Surgery, Department of Surgery, Ajou University School of Medicine, Suwon, Korea
²Department of Hepatobiliary Surgery, Jiangxi Cancer Hospital, Jiangxi, China

INTRODUCTION

Because hilar cholangiocarcinomas may send metastases to the caudate lobe via minute bile duct branches [1], total caudate lobectomy, along with hepatic resection, is necessary [2,3]. Although the importance of the caudate lobe is being increasingly accepted and a copious amount of research carried out, the anatomy of the caudate lobe lacks consensus.

Couinaud [4] suggested a clinically useful anatomy of the liver, but the concept of caudate lobe anatomy has been changing since then. In 1954, Couinaud defined the caudate lobe as segment I according to its portal ramification. This portion of the liver corresponds to the Spiegel lobe in the Kumon classification, which is currently used worldwide. Kumon classified the caudate lobe into 3 parts: Spiegel's lobe, the paracaval portion, and the caudate process portion [5]. Many researchers have agreed with the Kumon classification, and it is being used clinically.

For the right margin of the caudate lobe, Kogure et al. [6] advocated that the hepatic vein is the boundary between the
caudate process and the right liver, but it is more important to find the right margin of the paracaval portion when searching for the right border of the caudate lobe. The paracaval portion is located inside the liver parenchyma, in neighboring segments 7 and 8, making it difficult to identify the margin. Kitagawa, of the Murakami group, initially thought that the right hepatic vein (RHV) was the most important landmark of the right margin of the paracaval portion. Later, however, he accepted the concept of the right paracaval plane [7]. Recently, Maki et al. [8] found that the paracaval vein of a branch of the RHV is the boundary between the caudate lobe and segments 7 and 8.

The ventral margin of the caudate lobe was believed to correspond to the route of the middle hepatic vein (MHV). Couinaud [9] opposed this idea, however, and thought that the margin was situated in the vicinity of the confluence of the middle and RHV drainage area into the inferior vena cava (IVC). Later, Kwon et al. [10] reported the existence of the precaudate plane.

The current study focuses on identifying the right and ventral margins of the caudate lobe, which is poorly recognized in the surgical field. So far, there are no reports on the right and ventral margins of the caudate lobe that can be applied clinically. As caudate anatomy has been analyzed by Synapse 3D software (Fujifilm, Tokyo, Japan) to visualize the 3-dimensional (3D) anatomy of the caudate lobe, we set out to delineate the right and ventral margins of the caudate lobe preoperatively using the same system.

**METHODS**

**Synapse 3D**

Contrast-enhanced helical CT examinations of the liver were conducted. After obtaining abdominal multidetector CT images (1-mm slices), 3D image reconstruction was carried out using Synapse 3D. A Digital Imaging and Communication in Medicine file of raw 1-mm CT images was transferred to the Synapse 3D software. After selecting the parenchyma of the whole liver, we traced the portal vein and hepatic vein branches. The caudate lobe was visualized after reconstruction. Although only 15 of 94 cases had portal branches in the caudate lobe, we could delineate the parenchyma of the caudate lobe by electronically clicking on them. Thereafter, we compared it with the parenchyma that remained after staining by clicking on the second-order branches of the portal veins. The directly
stained caudate parenchyma was the same as the indirectly stained caudate parenchyma. In 79 subjects in whom there were no portal branches of the caudate lobe visualized, we could delineate the caudate parenchyma by Takayama’s counterstaining technique (Fig. 1) [11]. The hepatic portal system can be easily identified by hiding the parenchyma of the liver, hepatic veins, hepatic arteries, and bile ducts. When the corresponding parenchyma of the left portal vein, the right anterior portal vein, and the right posterior portal vein is removed, the image of the caudate lobe will be revealed.

We accepted that the RHV-IVC plane is the most reliable landmark of the right margin of the caudate lobe, which contains the RHV from the root + 3 cm and the right border of the IVC. For the ventral margin, the MHV-RHV plane could be regarded as the landmark comprising the MHV from the root + 3 cm and RHV from the root + 3 cm. Where the roots of the MHV and RHV overlapped was considered the MHV-RHV plane (Fig. 2). This study was approved by the Institutional Review Board of Ajou University Hospital (approval number: AJIRB-MED-MDB-19-108).

## RESULTS

The characteristics of the caudate lobe in 94 cases are shown in Table 1. For the right margin, 17 subjects (18%) exceeded the RHV-IVC plane by a mean of 10.2 mm (range, 2.4–27.2 mm). Among them, 11 were <10 mm, 3 were 10–20 mm, and 3 were >20 mm (Fig. 3A, B). For the ventral margin, 28 subjects (30%) exceeded the MHV-RHV plane by a mean of 17.4 mm (range, 2.4–49.1 mm). 

| Characteristic | Right margin | Ventral margin |
|---------------|--------------|----------------|
| No. of cases exceeding the margin | 17 (18) | 28 (30) |
| <10 mm | 11 (12) | 12 (13) |
| 10–20 mm | 3 (3) | 5 (5) |
| >20 mm | 3 (3) | 11 (12) |
| Mean distance exceeding the margin (mm) | 10.2 | 17.4 |
| Range exceeding the margin (mm) | 2.4–27.2 | 1.2–49.1 |

Values are presented as number (%) unless otherwise indicated.

*Fig. 2.* The methods to define the right and ventral margins are shown. (A) IVC and RHV can be identified after hiding the hepatic parenchyma other than the caudate lobe. (B) RHV-IVC plane can be seen (translucent brown) by connecting the RHV from the root + 3 cm and the right border of the IVC. (C) RHV-IVC plane can be seen (yellow) by connecting the RHV from the root + 3 cm and the right border of the IVC. (D) MHV and RHV can be identified after hiding the hepatic parenchyma. (E) MHV-RHV plane can be seen (translucent yellow) by connecting the MHV from the root + 3 cm and RHV from the root + 3 cm. (F) MHV-RHV plane can be seen (yellow) by connecting the MHV from the root + 3 cm and RHV from the root + 3 cm. IVC, inferior vena cava; RHV, right hepatic vein; MHV, middle hepatic vein.
1.2–49.1 mm). Among them, 12 were <10 mm, 5 were 10–20 mm, and 11 were >20 mm (Fig. 3C, D). In all, 10 subjects were found to exceed both the MHV-RHV and RHV-IVC planes.

**DISCUSSION**

Hilar cholangiocarcinoma is known to invade the parenchyma and bile duct of the caudate lobe rapidly during early stages of the disease. In the literature, microscopic tumor involvement in caudate lobe branches was found in 42% of patients at the time of surgery [1]. Thus, caudate anatomy is of great importance when performing total caudate lobectomy in patients with hilar cholangiocarcinoma. Prognosis reportedly improved in cholangiocarcinoma patients when caudate lobectomy was performed [12]. In cases of caudate lobe tumor, isolated caudate lobectomy can be performed, as introduced by Lerut et al. [13] in 1990. Surgery included partial or total caudate lobectomy. Partial caudate lobectomy was performed by resecting Spiegel’s lobe or the caudate process only, each of which was easily identified intraoperatively [14]. In other previous research, total isolated caudate lobectomy was performed by approaching the caudate lobe from the right side of the liver, using the right posterior Glisson pedicle as the anterior border plane of the caudate lobe and reaching the dorsal plane by transecting the parenchyma between the MHV and RHV. There was no mention of the right margin of the caudate lobe [15,16]. Although it is known that the anatomy of the caudate lobe is important when performing total caudate lobectomy, the exact locations of the right and ventral margins remain obscure.

It is difficult for us to define the right margin of the caudate lobe of the liver because the paracaval portion is located anterior to the IVC, to the right of the ligamentum venosum, and cranial to the hilar plate. The right and ventral margins were not identifiable from the exterior as their locations vary [17]. Couinaud [18] suggested that the right portion of the caudate lobe was a neighbor of segments 7 and 8, lying adjacent to the end point of the RHV. Kitagawa et al. [7] firstly thought that the RHV is the most important landmark of the right margin of the paracaval portion. Later, however, they suggested the concept of the right paracaval plane. These investigators suggested that the right paracaval plane may serve as an imaginary right margin of the caudate lobe. In fact, the right margin of the paracaval portion was located on the left side of the right paracaval plane.
in 65.4% (36 of 55) of cases. Therefore, if hepatic resection was carried out in this plane, total caudate lobectomy was complete with 60% anatomical reliability; if carried out at 10 mm to the right of this plane, 80% reliability was guaranteed; and if performed at 30 mm to the right of this plane, there was 100% reliability. This report was a milestone in the search for a definition of the right margin of the caudate lobe—which is poorly visualized from the exterior. Nevertheless, the concept had little effect on identifying the right margin during surgery. Recently, Maki et al. [8] identified the paracaval vein as the landmark for establishing the boundary between the caudate lobe and segments 7 and 8. The paracaval vein, however, cannot be found by intraoperative ultrasonography. In the current study, 17 cases (18%) exceeded the RHV-IVC plane. As landmarks, the RHV and IVC are easily found in the surgical field as well as with intraoperative ultrasonography.

The need to identify the individualized right margin of the caudate lobe is indisputable. The use of Synapse 3D is more likely to enable surgeons to perform total caudate lobectomy based on each patient’s unique liver anatomy.

Regarding the ventral margin of the caudate lobe, in 2002 Kwon et al. [10] reported the existence of a precaudate plane. This plane, which they described as flat or slightly curved, was a continuum of the ligamentum venosum and the ventral margin of the hilar plate. According to this report, the ventral margin of the caudate lobe was restricted within the dorsal side of the liver. As landmarks, the RHV and IVC are easily found in the surgical field as well as with intraoperative ultrasonography.

In conclusion, regarding the right margin, 18% exceeded the RHV-IVC plane, whereas 30% exceeded the MHV-RHV plane for the ventral margin. Evaluating the anatomy of the caudate lobe using Synapse 3D preoperatively could be helpful in achieving more precise anatomical resection of the caudate lobe.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Mizumoto R, Kawarada Y, Suzuki H. Surgical treatment of hilar carcinoma of the bile duct. Surg Gynecol Obstet 1986; 162:153-8.
2. Malhi H, Gores GJ. Cholangiocarcinoma: modern advances in understanding a deadly old disease. J Hepatol 2006;45:856-67.
3. Baton O, Azoulay D, Adam DV, Castaing D. Major hepatectomy for hilar cholangiocarcinoma type 3 and 4: prognostic factors and longterm outcomes. J Am Coll Surg 2007;204:250-60.
4. Couinaud C. Liver lobes and segments: notes on the anatomical architecture and surgery of the liver. Presse Med 1954;62: 709-12.
5. Kumon M. Anatomy of the caudate lobe with special reference to portal vein and bile duct. Acta Hepatol Jpn 1985;26:1193-9.
6. Kogure K, Kuwano H, Yorifuji H, Ishikawa H, Takata K, Makuuchi M. The caudate processus hepatic vein: a boundary hepatic vein between the caudate lobe and the right liver. Ann Surg 2008;247:288-93.
7. Kitagawa S, Murakami G, Hata F, Hirata K. Configuration of the right portion of the caudate lobe with special reference to identification of its right margin. Clin Anat 2000;13:321-40.
8. Maki H, Sakamoto Y, Kawaguchi Y, Aikami T, Nakano N, Kaneko J, Arita J, et al. Anatomical boundary between the caudate lobe of the liver and adjacent segments based on three-dimensional analysis for precise
resections. J Gastrointest Surg 2018;22:1709-14.
9. Couinaud C. Surgical anatomy of the liver revisited. Paris: C. Couinaud; 1989.
10. Kwon D, Murakami G, Hata F, Wang HJ, Chung MS, Hirata K. Location of the ventral margin of the paracaval portion of the caudate lobe of the human liver with special reference to the configuration of hepatic portal vein branches. Clin Anat 2002;15:387-401.
11. Takayama T, Tanaka T, Higaki T, Katou K, Teshima Y, Makuuchi M. High dorsal resection of the liver. J Am Coll Surg 1994;179:72-5.
12. Nimura Y, Hayakawa N, Kamiya J, Kondo S, Shionoya S. Hepatic segmentectomy with caudate lobe resection for bile duct carcinoma of the hepatic hilus. World J Surg 1990;14:535-43.
13. Lerut J, Gruwez JA, Blumgart LH. Resection of the caudate lobe of the liver. Surg Gynecol Obstet 1990;171:160-2.
14. Cheung TT. Technical notes on pure laparoscopic isolated caudate lobectomy for patient with liver cancer. Transl Gastroenterol Hepatol 2016;1:56.
15. Oh D, Kwon CH, Na BG, Lee KW, Cho WT, Lee SH, et al. Surgical techniques for totally laparoscopic caudate lobectomy. J Laparoendosc Adv Surg Tech A 2016;26:689-92.
16. Lee W, Han HS, Yoon YS, Cho JY, Choi Y, Shin HK, et al. Laparoscopic resection of hilar cholangiocarcinoma. Ann Surg Treat Res 2015;89:228-32.
17. Murakami G, Hata F. Human liver caudate lobe and liver segment. Anat Sci Int 2002;77:211-24.
18. Couinaud C. The paracaval segment of the liver. J Hep Bil Pancr Surg 1994;1:145-51.