Surgical Endoscopy (2019) 33:3851–3857
https://doi.org/10.1007/s00464-019-06877-w

DYNAMIC MANUSCRIPT

Pure laparoscopic right posterior sectionectomy using the caudate lobe-first approach

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Received: 27 December 2018 / Accepted: 28 May 2019 / Published online: 10 June 2019

Abstract

Background In our process of standardizing laparoscopic right-sided anatomical hepatectomy, we found several advantages of the caudate lobe-first approach. We herein describe our standardized procedure of laparoscopic right posterior sectionectomy (Lap-RPS) using this approach.

Methods Between January 2011 and January 2018, 31 patients underwent pure Lap-RPS in our hospital. The mean patient age was 68 years (range 47–85 years), and the number of male patients was more than that of female patients (64.5%). Of 31 patients, 20 had metastatic liver tumor, 7 had hepatocellular carcinoma, 3 had intrahepatic cholangiocellular carcinoma, and 1 had hemangioma. All 31 patients had Child–Pugh class A liver function. The surgical technique was recorded on video. Cumulative sum (CUSUM) analyses were applied to assess the learning curve.

Results The mean operative time was 420 min (range 263–639 min), and the mean amount of blood loss was 304 g (range 10–900 g). No procedure was converted to open surgery. Postoperative bleeding, bile leakage, hepatic failure, and mortality did not occur. CUSUM analyses showed a decrease in the operative time and blood loss after using the caudate lobe-first approach.

Conclusion Our standardized procedure of Lap-RPS using the caudate lobe-first approach is not only feasible but also expected to provide an advantage for laparoscopic anatomical hepatectomy.

Keywords Laparoscopic right posterior sectionectomy · Caudate lobe-first approach

We have gradually standardized the various procedures for laparoscopic hepatectomy since the introduction of the pure laparoscopic approach for patients who underwent hepatectomy in February 2008 [1–7]. In the process of standardization, we found several advantages of the laparoscopic approach obtained from utilizing a unique laparoscopic caudodorsal view [3, 6, 7]. Among them, the caudate lobe-first approach, whose theoretical concept has been previously described in our report on laparoscopic right hemihepatectomy [7], is remarkably beneficial for right hemihepatectomy and right posterior sectionectomy (RPS). We herein describe our recent standardized procedure of laparoscopic RPS (Lap-RPS) using the caudate lobe-first approach and report the results of 31 patients who underwent Lap-RPS in our institution.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00464-019-06877-w) contains supplementary material, which is available to authorized users.

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Methods

Between January 2011 and January 2018, 45 patients underwent RPS in Tokyo Metropolitan Cancer and Infectious Diseases Center Komagome Hospital. Of the 45 patients, 31 underwent Lap-RPS. Lap-RPS can be performed in all patients indicated for open RPS, except in those with tumors abutting the hepatic hilum or root of the hepatic vein trunk and those requiring biliary or vascular reconstruction. In this series, open RPS was performed in four patients with tumors abutting the root of the hepatic vein trunk or inferior vena cava (IVC). Furthermore, it was performed in ten patients who required additional multiple (more than 4) partial hepatectomies or anatomical segmentectomy because the estimated operative time was too long. Of the 31 patients, 10 underwent extended RPS, wherein the right posterior section and the dorsal part of the right anterior section were resected with the right hepatic vein trunk. Additional hepatectomies of the other portions for multiple tumors were performed in nine patients, and laparoscopic adrenal gland resection and laparoscopic right hemicolectomy were performed in 2 patients. The mean patient age was 68 years (range 47–85 years), and the number of male patients was more than that of female patients (64.5%). Of 31 patients, 7 had hepatocellular carcinoma, 3 had intrahepatic cholangiocellular carcinoma, 20 had metastatic liver tumors, and 1 had hemangioma (Table 1). All 31 patients had Child–Pugh class A liver function. The procedure was performed by the main surgeon, who was an expert surgeon (GH), in 27 patients, and by trainee surgeons (KM or OY), who were assisted by GH, in 4 patients. The caudate lobe-first approach was used starting with the 19th patient.

Cumulative sum control chart (CUSUM) analysis was applied to evaluate the progression and evolution of the learning curve of the Lap-RPS by using operative time and blood loss as markers. All the procedures performed were ordered chronologically. The breakpoint that identified the periods in the CUSUM curve was estimated by applying a second-order polynomial. All statistical analyses were performed using JMP pro® software version 12.2 (SAS Institute Inc., Cary, NC, USA).

This study was approved by the ethics board of Tokyo Metropolitan Cancer and Infectious Diseases Center Komagome Hospital (approval no. 2172).

Surgical technique

The patient was placed in a supine position, with only the upper body twisted to the left. A trocar for the scope was placed at the umbilicus, and the other four trocars for the instruments were placed beneath the right costal arch (Fig. 1). Pneumoperitoneum was established at 10 mmHg. Infusion was restricted as much as possible. Ventilation pressure was maintained within normal range [8]. A tourniquet system to occlude hepatic inflow was prepared through the left hypochondrium, and the Pringle maneuver was initiated when the field could not be kept dry [9].

The right lobe was mobilized before the liver dissection, except when the anterior approach was required for various reasons, including a huge tumor or firm adhesion to the diaphragm. In either case, before initiating liver dissection, the caudate lobe was detached from the IVC, transecting the short hepatic veins, in the unique laparoscopic caudodorsal magnified view. After a part of the caudal side of the IVC was exposed by detaching the caudate lobe, the caudate lobe was divided from the back parallel with the rightmost line of the IVC, over which all Glissonean branches (one pedicle or a few branches) of the right posterior section theoretically cross (Fig. 2). The caudate lobe was divided vertically between the right Glissonean pedicle and IVC toward the cranial side, and then the dorsal aspect of the posterior Glissonean pedicle was exposed. To divide the liver parenchyma, we mainly used the CUSA EXcel system (Integra LifeSciences Corporation, Plainsboro, NJ, USA) with thermal coagulation using the low-voltage electrical cautery mode of VIO (Erbe Elektromedizin GmbH, Tübingen, Germany) at the tip of the CUSA EXcel.

The further cranial portion of the caudate lobe was detached from the IVC and divided from the back parallel with the rightmost line of the IVC. At the Rouviére sulcus, the cranioventral aspect of the root of the posterior Glissonean pedicle was exposed by blunt dissection between the pedicle surface and liver parenchyma. If finding a good dissection plane was difficult, the liver parenchyma between the anterior and posterior Glissonean pedicles was removed using CUSA EXcel. Subsequently, the posterior Glissonean pedicle was isolated easily, not leaving any branch of the right posterior section behind, because half of the dorsal side of the posterior Glissonean pedicle had already been exposed (Fig. 3). By clamping or ligating the posterior Glissonean pedicle, the borderline between the right posterior and anterior sections was identified as a demarcation line caused by ischemia of the right posterior section. The liver parenchyma of the ventral side of the hepatic hilum was separated by exposing the right hepatic vein (RHV) in the center of the cutting plane, and a wide space was created around the posterior Glissonean pedicle. Subsequently, the posterior Glissonean pedicle was transected using a linear stapler. One of the most important points is to dissect the liver parenchyma from the caudal side toward the cranial side, similar to opening a book (Video 1).

After transection of the posterior Glissonean pedicle, the root of the RHV was exposed by further dissection of the caudate lobe, and the main trunk of the RHV was continuously exposed toward the periphery, which had already been exposed on the ventral side (Fig. 4). Between the exposed main trunk of the RHV and the demarcation line on the liver surface, the liver parenchyma on the cranial side was divided, transecting the hepatic vein branches joining into the RHV from the right posterior section (Video 2).

In the extended RPS, the root of the anterior Glissonean pedicle was also exposed continuously from the posterior Glissonean pedicle. After transection of the posterior

Table 1 Patients characteristics and operation results

Case	Age	Sex	Diagnosis	Procedure of RPS	CLFA	Additional procedure	Operative time (min)	Blood loss (g)	Complication	POHS (days)	Main surgeon
1	57	F	Met	Pure		Hx (S8)	488	90		7	GH
2	69	M	CCC	Pure		Hx (S8)	460	380		11	GH
3	62	M	Met	Pure		Hx (S5)	472	190	Peroneal nerve palsy	8	GH
4	67	M	HCC	Pure		Rt AdG resection	512	616		8	GH
5	66	F	Met	Pure			352	350		7	GH
6	65	M	Met	Pure		Hx (S5)	519	250	Plumonary embolism	21	GH
7	74	M	HCC	Pure			317	900		11	GH
8	81	M	HCC	Extended			409	150		9	KM
9	69	F	HCC	Pure			506	260		9	KM
10	73	M	Met	Extended			374	200		5	GH
11	82	F	Met	Extended			317	250		17	KM
12	63	M	HCC	Pure			503	750		10	GH
13	85	F	Met	Extended		Rt hemicolectomy	459	380		13	GH
14	74	F	Met	Pure			334	110		8	GH
15	47	M	Met	Extended		Hx (S2, S3)	364	580		7	GH
16	66	M	Met	Pure		Hx (S2, S3)	639	490		13	GH
17	76	M	HCC	Extended			513	250		8	GH
18	49	F	Hem	Pure			371	200		7	GH
19	63	M	CCC	Pure	Done		566	290		10	GH
20	71	M	Met	Extended	Done		374	330		10	GH
21	51	M	Met	Pure	Done		470	100		11	GH
22	64	M	Met	Pure	Done		410	500		11	GH
23	71	F	Met	Extended	Done		315	100		10	GH
24	69	M	Met	Pure	Done	Hx (S4, S5)	443	450		8	GH
25	70	M	Met	Pure	Done		439	300		10	GH
26	72	M	CCC	Pure	Done		383	120		11	GH
27	72	M	Met	Pure	Done	Hx (S4, S5)	438	380		9	GH
28	69	M	Met	Pure	Done		263	100		14	GH
29	71	F	Met	Extended	Done		278	150		12	GH
30	72	F	HCC	Pure	Done		332	200		9	OY
31	53	F	Met	Extended	Done	Hx (S2×2)	408	10		6	GH
Mean	68						420	304		10	

F female, *M* male, *Met* metastatic tumor, *HCC* hepatocellular carcinoma, *Hem* hemangioma, *RPS* right posterior sectionectomy, *CLFA* caudate lobe first approach, *Hx* hepatectomy, *Rt* right, *AdG* adrenal grand, *POHS* post operative hospital stay, *GH* G Honda (expert), *MK* M Kurata (trainee surgeon), *OY* Y Ome (trainee surgeon)

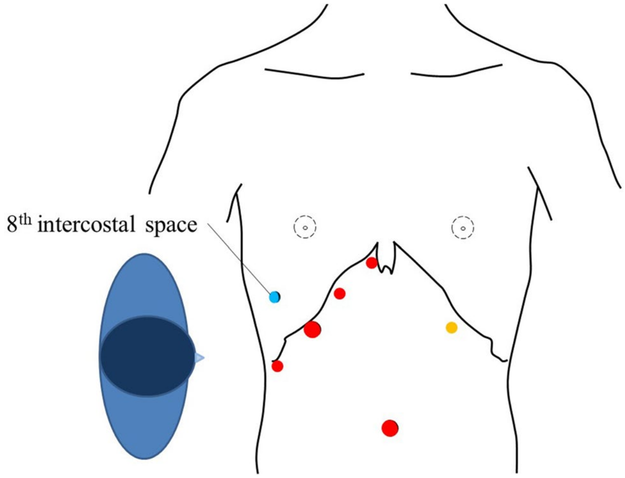

Fig. 1 Trocar placement. A trocar for the scope is placed at the umbilicus, and the other four trocars for the instruments are placed beneath the right costal arch. A tourniquet system for the Pringle maneuver is prepared through the left hypochondrium. In most cases, a 5-mm trocar equipped with a balloon stopper (Kii Access System Advanced Fixation, Applied Medical Resources Corporation) is placed at the eighth intercostal space on the right posterior axillary line. The main surgeon stands on the patient's right side

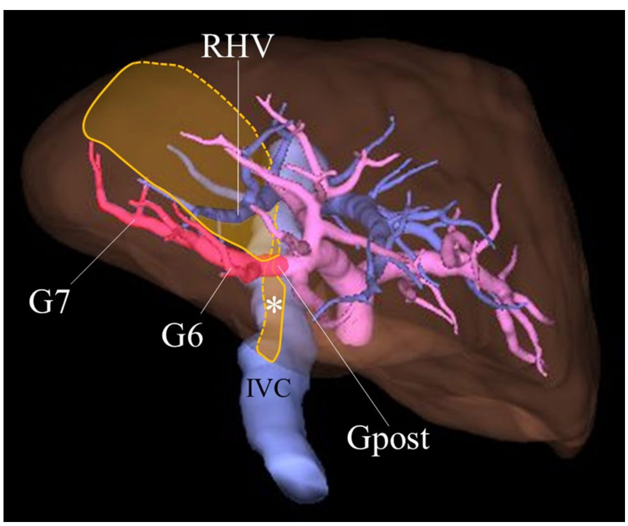

Fig. 2 The right posterior Glissonean pedicle (Gpost) that crosses over an appropriate cutting plane of the right posterior sectionectomy (yellow plane surrounded by yellow dotted line). Because all Glissonean branches (one pedicle or a couple of branches) of the right posterior section cross over the border between the right posterior section and caudate lobe, they can all be exposed from the back by dividing the caudate lobe parallel to the rightmost line of the IVC (*). RHV, right hepatic vein; G6, Glissonean branch of segment 6; G7, Glissonean brunch of segment 7; IVC, inferior vena cava (Color figure online)

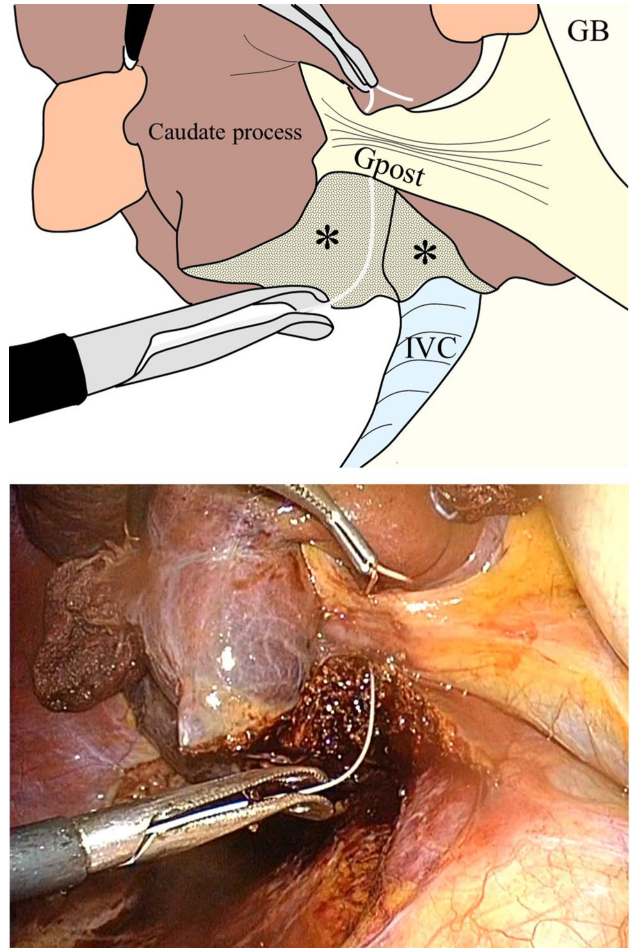

Fig. 3 Isolation of the posterior Glissonean pedicle (Gpost) using the caudate lobe-first approach. The Gpost can be isolated easily after exposing the half dorsal side of the Gpost by dividing the caudate lobe from the back parallel to the rightmost line of the inferior vena cava (IVC). *Cutting surfaces of divided caudate lobe on the rightmost line of the IVC. Gpost, right posterior Glissonean pedicle; GB, gallbladder

Glissonean pedicle, the main trunk of the anterior Glissonean pedicle was continuously exposed toward the periphery, and only the dorsal-sided branches were tusing the caudate lobe-first approachransected, dissecting the liver parenchyma between the dorsal and ventral parts of the right anterior section toward the crotch between the RHV and middle hepatic vein. Finally, the RHV was transected.

The resected right posterior section was enclosed in a plastic bag and removed through the incision in the lower abdomen. A closed suction drain was placed at the right subphrenic space in all cases.

Results

The mean operative time and blood loss were 420 min (range 263–639 min) and 304 g (range 10–900 g), respectively. None of the patients in this series received blood

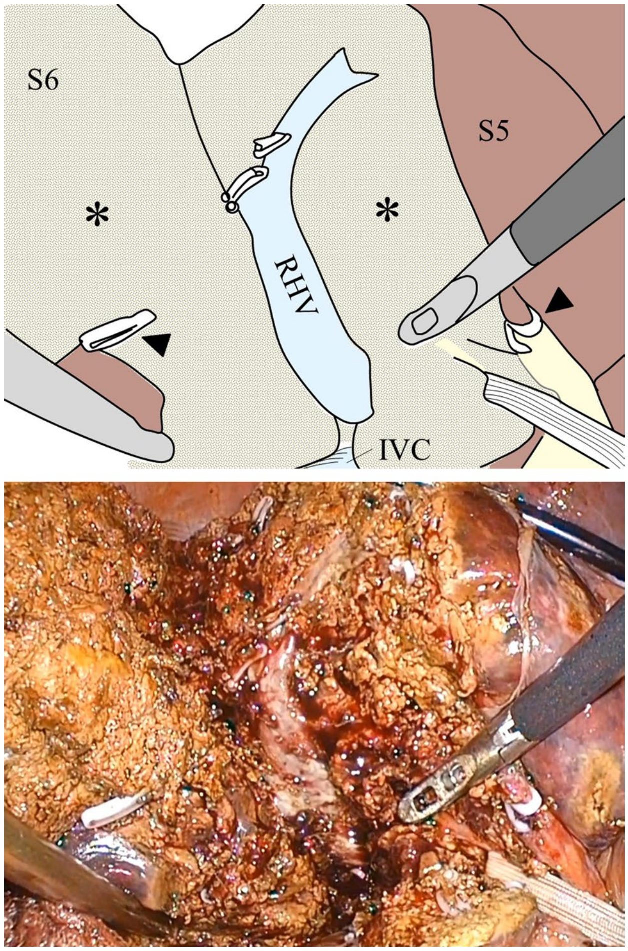

Fig. 4 The exposed main trunk of the right hepatic vein (RHV). The posterior Glissonean pedicle has been already cut (black arrow heads indicating both stumps). The liver parenchyma has been divided at the border between the right posterior and anterior sectors, similar to opening a book. *Cutting surfaces of the liver parenchyma; S5, Segment 5; S6, Segment 6; IVC, inferior vena cava; black arrow heads, stumps of the right posterior Glissonean pedicle, which has been clipped and divided

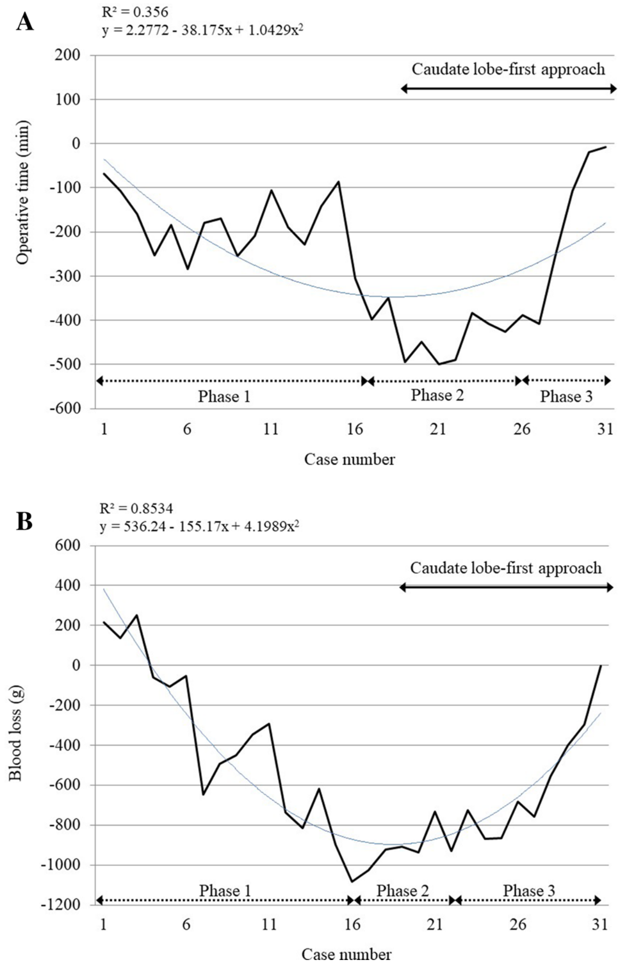

Fig. 5 **A** The risk-adjusted CUSUM curve of the operative time. **B** The risk-adjusted CUSUM curve of blood loss. Both CUSUM curves were plotted against the number of patients, and the blue lines present the curve of the best fit for the plots. The caudate lobe-first approach was used starting with the 19th patient

transfusions. No procedure was converted to open surgery. With regard to postoperative complications, 1 patient had peroneal nerve palsy, and another had pulmonary embolism. Postoperative bleeding, hepatic failure, and mortality did not occur (Table 1).

Based on CUSUM analysis, the operative time was divided into three phases: phase 1 (initial 17 patients, Initial phase), phase 2 (from the 18th to 26th patients, Plateau phase), and phase 3 (final 5 patients, Stable phase). This curve was modeled as a second-order polynomial (parabola), with the following equation: CUSUM (min) = 2.277197 − 38.175253 × number of patients + 1.042851 × number of patients^2. This had a high R^2 of 0.356. The break point of this model was at the 18th patient (Fig. 5A). Blood loss also was divided into three phases: phase 1 (initial 16 patients, Initial phase), phase 2 (from the 17th to 21st patients, Plateau phase), and phase 3 (final 10 patients, Stable phase). This curve was modeled using a similar method with the following equation: 536.2376 − 155.166666 × number of patients + 4.198857 × number of patients^2. This had a very high R^2 of 0.853. The break point of this model was at the 19th patient who was the first patient who underwent Lap-RPS using the caudate lobe-first approach (Fig. 5B).

Discussion

Laparoscopic major hepatectomy is performed only by expert teams because of the technical difficulty and lack of standardization, and laparoscopic major hepatectomy was concluded to be an innovative procedure and was still in an exploration or learning phase during the second International Consensus Conference [10]. During the last decade when laparoscopic hepatectomy rapidly evolved, several expert teams suggested the feasibility of laparoscopic major hepatectomy. Compared with laparoscopic liver resection (LLR) and open liver resection, right hemihepatectomy and left medial sectionectomy, as well as RPS, were associated with significantly less blood loss in the matched LLR group, and right and left hemihepatectomies were associated with significantly shorter hospital stays in the matched LLR group [11]. However, as Kawaguchi et al. has reported [12], Lap-RPS can result in a high amount of blood loss, high conversion rate, and high bile leakage rate. This may be due to the following: (1) most of the procedures, including transection of the short hepatic veins around the IVC during mobilization of the right lobe, are performed at the deeper site in the right subphrenic space; (2) encircling all right posterior Glissonean branches from the hepatic hilum side is difficult (or takes time) because of the variety of their branching pattern; and (3) precisely dividing the liver parenchyma and maintaining an appropriate cutting plane along the intersegment are difficult [13, 14].

As we have described in the previous report on our standardized procedure for laparoscopic right hemihepatectomy [7], the caudate lobe-first approach can make Lap-RPS easier and safer by handling these three problems. During transection of the short hepatic veins between the liver and IVC, the short hepatic vein is often too short to safely transect or too thick to safely isolate if approaching from only the lateral side. However, it can be handled more easily and safely by approaching them bilaterally by dividing the caudate lobe gradually from the caudal side. In addition, the difficulty of encircling all right posterior Glissonean branches is solved by the caudate lobe-first approach. All Glissonean branches (one pedicle or a few branches) of the right posterior section cross-over the border between the right posterior section and the caudate lobe; therefore, theoretically, they can all be exposed from the posterior by the caudate lobe-first approach and can be effectively encircled. Before initiating the caudate lobe-first approach, we had experienced confusion several times regarding the Glissonean branches of the right posterior section because of anatomical variations. However, by identifying them on 3D-CT images preoperatively and using the caudate lobe-first approach, we were able to approach all origins of Glissonean branches of the right posterior section in all cases. Moreover, the difficulty of maintaining an appropriate cutting plane is solved by the caudate lobe-first approach. The longitudinal right-most line of the IVC, which has been exposed in advance by the caudate lobe-first approach, is presented at the bottom of the operative field as a landmark. Therefore, the correct direction to divide the liver parenchyma, while maintaining an appropriate cutting plane, can be identified anytime during parenchymal dissection. Additionally, the root of the RHV can be exposed in the early stage by dividing the caudate lobe first, and then, after transection of the right posterior Glissonean pedicle, the main trunk of the RHV, which is the landmark in the center of the cutting plane, can be continuously exposed from the back. Furthermore, the caudate lobe-first approach provides one more technical benefit to maintain an appropriate cutting plane. Anatomically, the origins of the Glissonean branches and hepatic veins are located on the dorsal side of the liver, and they branch similar to a tree, extending toward the peripheral (ventral) side [7]. The hepatic vein trunk runs in the intersegmental plane, which is the border between the sections, and, theoretically, no Glissonean branch runs in that plane. Therefore, split injury at the confluences of the hepatic vein branches, which cause severe bleeding, can be prevented by exposing the hepatic vein trunk from the root side toward the periphery after first approaching the root side as much as possible [1]. Once the entire length of the main trunk of the RHV is exposed, the remnant liver parenchyma can be divided swiftly between the main trunk of the RHV and the demarcation line on the liver surface, maintaining an appropriate cutting plane.

The cutting plane of the extended RPS, in which the RHV is not exposed, is different from that of the normal RPS. However, maintaining an appropriate cutting plane is not difficult in the extended RPS because anatomical hepatectomy is performed by transecting the Glissonean branches of the dorsal parts in order from the root side of the anterior Glissonean pedicle. During anatomical hepatectomy, initiating parenchymal division at the root of the Glissonean tree, which bears the resected part of the liver, and continuing it toward the periphery with the vertical movement of the instrument make dissection along the intersegmental plane easier [1–7]. At any rate, the caudate lobe-first approach, which makes isolation and transection of the posterior Glissonean pedicle and maintaining an appropriate cutting plane easier, was useful in both the normal and extended RPSs.

In this series, patients who underwent normal RPS and those who underwent extended RPS were mixed, and additional procedures, such as partial hepatectomy or resection of the other organs, were performed simultaneously in nine patients. Therefore, the simple comparison of operative time and blood loss using CUSUM analysis has some limitations. However, both parameters started to decrease around the time when we brought in the caudate lobe-first approach (18th or 19th patient). This suggests that the caudate lobe-first approach was one of the factors for the learning curve of our Lap-RPS experiences, and our Lap-RPS procedure has been properly standardized utilizing the advantages of laparoscopic approach.

In conclusion, our standardized procedure of Lap-RPS using the caudate lobe-first approach is not only feasible but also expected to provide an advantage for laparoscopic anatomical hepatectomy.

Author contribution YH, GH: study design; MK, YH, MD, JY, and YO: data acquisition and analysis; YH and GH: draft and revision of the manuscript; GH: critical revisions, final approval, and accountability of the study.

Compliance with ethical standards

Disclosures Goro Honda has received lecture payments from Johnson & Johnson. Yuki Homma, Masanao Kurata, Yusuke Ome, Manami Doi and Jun Yamamoto have no conflicts of interest or financial ties to disclose.

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