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Feasibility of laparoscopic liver resection for caudate lobe: technical strategy and comparative analysis with anteroinferior and posterosuperior segments

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Abstract
Background Although laparoscopic liver resection (LLR) is now considered a standard procedure in peripheral segments, there are few reports on laparoscopic segment 1 (Sg1) resection. The aim of this study was to assess both safety and feasibility of Sg1 LLR.
Methods From 2000 to 2014, all patients who underwent LLR were identified from a prospective database. Patients with resection of Sg1 (Sg1 group) were compared with those with resection of anteroinferior segments (AI group: segments 3, 4b, 5, 6) or posterosuperior segments (PS group: segments 4a, 7, 8), in terms of tumor characteristics, surgical treatment, and short-term outcomes.
Results There were 15, 151, and 67 patients in Sg1, AI, and PS groups. Tumor size and tumor number were similar between the three groups ($p = 0.139$, $p = 0.102$). Operative time was significantly shorter in Sg1 (150 min) and AI group (135 min) compared with PS group (180 min) ($p = 0.021$). Median blood loss was notably higher in PS group (140 ml) compared with Sg1 group (75 ml) and AI group (10 ml) ($p = 0.001$). No mortality was observed in all groups. Postoperative complication rate was 20.0 % with Sg1 group, 14.6 % with AI group, and 20.9 % with PS group ($p = 0.060$). The rate of major complication was significantly higher in Sg1 group (13.3 %) and PS group (11.9 %) compared with AI group (4.0 %) ($p = 0.042$). Resection margins were clear in all Sg1 and PS group patients, whereas two (1.3 %) patients in AI group had R1 margins ($p = 0.586$).
Conclusion The laparoscopic approach of isolated resection located in the caudate lobe is a feasible and curative surgical option in selected patients.

Keywords Laparoscopic liver resection · Caudate lobe · Anteroinferior lesion · Posterosuperior lesion · Caudal approach

The caudate lobe (Couinaud's segment 1: Sg1) is a small liver segment consisting of three parts: Spiegel's lobe, paracaval portion, and caudate process. Sg1 is anatomically unique in that it is situated posteriorly in the liver and directly over the inferior vena cava (IVC), which makes this lobe not directly visible and less accessible for surgeons. In addition, Sg1 contains several thin hepatic veins draining directly into IVC, which increases the risk of bleeding in dissecting the attachment between Sg1 and IVC [1]. Due to these anatomical characteristics, local excision of Sg1 is technically demanding and requires different surgical strategies for each individual case [2].

Despite diffusion of laparoscopic liver resection (LLR), there have been a few reports on laparoscopic Sg1 resection [3, 4]. The aim of this study was to assess the safety and feasibility of the procedure by comparing its outcomes

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to those after laparoscopic resection of anteroinferior and posterosuperior segment.

Materials and methods

Study population

From January 2000 to December 2014, all patients who underwent LLR at author's institution were identified from a prospective database, and their data were retrospectively reviewed. Patients with resection of segment 1 (Sg1 group) were compared with those with resection of anteroinferior segments (AI group: segment 3, 4b, 5, 6) or posterosuperior segments (PS group: segment 4a, 7, 8), in terms of tumor characteristics, surgical treatment, and short-term outcomes. Suitability for the laparoscopic approach was based on tumor size and location, type of planned resection, and patient comorbidities. Except unusual cases with limited tumor abutment on IVC, direct involvement of IVC on preoperative imaging was considered as a contraindication to laparoscopic approach.

Preoperative evaluation

Preoperative investigations included blood and liver function tests, as well as routine cardiorespiratory evaluations. Computed tomography imaging of the thorax, abdomen, and pelvis was obtained routinely. In recent years, magnetic resonance imaging of the liver was routinely performed. No specific evaluation was required for Sg1 resection, but special attention was payed on contact between the tumor and IVC.

Surgical procedures

The surgical technique of LLR, including the positioning of the trocars, has been previously described [5, 6]. Intra-abdominal pressure was maintained at 12 mmHg. Liver resectability was routinely confirmed by intra-operative ultrasonography [7]. The gastrohepatic ligament is divided to approach segment I, preserving the accessory left hepatic artery. The hepatoduodenal ligament is dissected posteriorly, and the portal pedicles going toward segment I are identified, dissected free, and divided. The caudate lobe is mobilized from the left side and also along the anterior aspect of the IVC, dividing the short hepatic veins. The hepatic veins are usually coagulated without any clip and/or suture. The confluence of the left and middle hepatic vein with the IVC is exposed after division of the segment I hepatic vein; the duct of Arantius is cut or preserved depending on the tumor location. Then, the liver parenchyma is dissected from the caudal side toward the IVC, exposing the posterior aspect of the middle hepatic vein [8]. For all procedures, tissue dissection and hemostasis were performed using an ultrasonic dissector, such as the Harmonic scalpel (Ethicon Endo-Surgery, Inc., Cincinnati, OH) or, more recently, the Thunderbeat® (Olympus Co, Tokyo); Gayet bipolar forceps (MicroFrance CEV134, Medtronic, Minneapolis, MN) provided retraction and rescue hemostasis. All intra-operative parameters, including type and duration of vascular clamping, blood loss with subsequent intraoperative blood transfusion, and duration of surgery, were recorded. The overall surgical policy was to attempt radical anatomic or wedge resection, sparing the greatest amount of liver parenchyma feasible.

Postoperative outcomes

Postoperative complications after LLR were stratified according to the Dindo–Clavien classification, and major complications were defined as a grade $\geq$ III [9]. If a patient had two or more complications, the most severe was taken in account. Liver-specific complications were detailed as follows: Liver failure was defined according to the "50–50 criteria" on postoperative day 5 [10], ascites was defined as abdominal drainage output of >10 ml per kg per day after postoperative day 3, and biliary leakage was defined as a bilirubin concentration in the drainage fluid of more than threefold that in serum [11]. Complications and operative mortality were considered if they occurred within 90 days of surgery or at any time during the postoperative hospital stay.

Statistical analysis

Patient baseline characteristics were expressed as mean (SD) for continuous data and numbers with percentages for categorical data. Preoperative, operative, and postoperative characteristics were compared. Chi-square test was used to identify differences in categorical variables, and ANOVA was used to compare differences in categorical variables. Cumulative overall survival rates were determined using the Kaplan–Meier method and compared using the log-rank test. All statistical analyses were performed using SPSS for Windows version 21.0 (SPSS Inc.), and statistical significance was accepted at the 0.05 level.

Results

Preoperative characteristics

Of 233 patients included in this study cohort, there were 15, 151, and 67 patients in the Sg1, AI, and PS groups, respectively. Preoperative characteristics of these patients

are detailed in Table 1. The three groups did not differ significantly in terms of demographics and tumor characteristics. The rate of previous abdominal surgery was significantly higher in PS group (73.1 %) compared with Sg1 (46.6 %) and AI groups (48.3 %) ($p = 0.002$). Tumor characteristics including indication and tumor number were similar in each group, and tumor diameter was also similar in each group: Sg1 group (19.5 mm), AI group (20.0 mm), and PS group (25.0 mm), respectively ($p = 0.139$). There was no difference in the proportion of patients having previous hepatectomy (13.3 vs. 14.6 vs. 23.9 %, $p = 0.220$).

Intra-operative characteristics

The number of patients who underwent anatomical liver resection was 3 (20.0 %) in the Sg1 group, 26 (17.2 %) in the AI group, and 20 (29.9 %) in the PS group ($p = 0.590$). There was no difference in the extra-hepatic procedures performed. No patient required vascular reconstruction. Operative time was shorter in the Sg1 (150 min) and AI group (135 min) compared with PS group (180 min) ($p = 0.021$). Median blood loss was larger in the PS group (140 ml, range 0–1500 ml) compared with Sg1 group (75 ml, range 0–500 ml) and AI group (10 ml, range 0–1100 ml) ($p = 0.001$) (Table 2). There was no significant difference in use of intra-operative transfusion. Two patients required conversion in the PS group (3.0 %) and none in Sg1 and AI groups. Resection margins were clear in all Sg1 and PS group patients, whereas two (1.3 %) patients had R1 margins in AI group ($p = 0.586$).

Postoperative outcomes

There was no mortality in the three groups. Three (20.0 %) patients in Sg1 group experienced postoperative

Table 1 Preoperative characteristics

	N (%)			*p* value
	Sg1 group (*N* = 15)	AI group (*N* = 151)	PS group (*N* = 67)	
Age, year, mean ± SD	64 ± 9	59 ± 15	62 ± 13	0.624
Male gender	7 (46.6)	84 (55.6)	38 (56.7)	0.944
BMI, kg/m^2, mean ± SD	25.3 ± 4.7	25.4 ± 4.4	26.2 ± 5.0	0.700
Alcohol	3 (20.0)	33 (21.9)	12 (17.9)	0.624
Smoking	3 (20.0)	22 (14.6)	11 (16.4)	0.664
Comorbidities				
Diabetes mellitus	1 (6.6)	8 (5.3)	9 (13.4)	0.109
Hypertension	3 (20.0)	27 (17.9)	17 (25.4)	0.374
Dyslipidemia	2 (13.3)	23 (15.2)	10 (14.9)	0.760
Ischemic heart disease	0 (0)	10 (6.6)	4 (6.0)	0.632
COPD	1 (6.6)	4 (2.6)	2 (3.0)	0.601
Preoperative chemotherapy	3 (20.0)	41 (27.2)	11 (16.4)	0.236
Viral status				
HBV	0	1 (0.7)	1 (1.5)	0.776
HCV	0	2 (1.3)	1 (1.5)	0.907
Diagnosis				
CRLM	10 (66.6)	93 (61.6)	43 (64.2)	0.168
Other metastases	2 (13.3)	25 (16.6)	9 (13.4)	0.514
HCC	1 (6.6)	9 (6.0)	7 (10.4)	0.465
Cholangiocarcinoma	0 (0)	4 (2.6)	0 (0)	0.349
Benign disease	2 (13.3)	20 (13.2)	8 (11.9)	0.187
Previous abdominal surgery	7 (46.6)	73 (48.3)	49 (73.1)	0.002
Previous hepatectomy	2 (13.3)	22 (14.6)	16 (23.9)	0.220
Tumor size, mm, median (range)	19.5 (2–50)	20.0 (5–160)	25.0 (8–140)	0.139
Tumor number, median (range)	1.0 (1–2)	1.0 (1–4)	1.0 (1–4)	0.102

BMI body mass index, *COPD*, chronic obstructive pulmonary disease, *HBV* hepatitis B virus, *HCV* hepatitis C virus, *CRLM*, colorectal cancer liver metastases, *HCC* hepatocellular carcinoma

Table 2 Intra-operative characteristics

	N (%)			*p* value
	Sg1 group ($N = 15$)	AI group ($N = 151$)	PS group ($N = 67$)	
Surgical procedures				
Pure laparoscopy	13 (86.7)	123 (81.5)	59 (88.1)	0.492
Anatomical resection	3 (20.0)	26 (17.2)	20 (29.9)	0.590
Use of Pringle maneuver	0	2 (1.3)	0	0.590
Blood loss, ml, median (range)	75 (0–500)	10 (0–1100)	140 (0–1500)	0.001
Operative time, min, median (range)	150 (60–480)	135 (60–480)	180 (60–600)	0.021
Intraoperative transfusion	0	0	3 (4.5)	0.022
Conversion	0	0	2 (3.0)	0.082
Abdominal drainage	0	5 (3.3)	2 (3.0)	0.801

complications, 22 (14.6 %) of the AI group, and 14 (20.9 %) of the PS group ($p = 0.060$) (Table 3). The rate of major complication was significantly higher in the Sg1 group (13.3 %, $N = 2$) and PS group (11.9 %, $N = 8$) compared with AI group (4.0 %, $N = 6$) ($p = 0.042$). One Sg1 patient who underwent combined lymphadenectomy developed pancreatic fistula, and this patient needed reoperation for management of this complication. Three patients in AI group and one patient in PS group required reoperation for a complication in relation to simultaneous colorectal resection. Bile leakage was observed in one patient in the AI group (0.7 %) and two PS group patients (3.0 %) ($p = 0.218$), managed by abdominal drainage. Biliary stenosis was occurred in one patient in the Sg1 group (6.6 %), successfully treated by endoscopic stenting. The length of hospital stay was significantly longer in Sg1 group (8.0 ± 6.5 days) and PS group (8.3 ± 7.3 days) compared with AI group (6.7 ± 5.1 days) ($p = 0.008$).

As shown in Table 4, Sg1 resection was not identified as an independent factor associated with postoperative major morbidity unlike PS resection. Based on multivariate analysis, COPD was found to be an independent predictor for major complication.

Discussion

As a result of this unique anatomical location, caudate lobe resection is technically challenging, because it is easy to damage the bile ducts and an error in dissecting the posterior part of the caudate lobe can cause uncontrolled bleeding from the IVC [12]. However, precise anatomical knowledge of the caudate segment, improvements in perioperative care, and refined surgical technique for caudate lobectomy in open surgery have resulted in more widespread use of this procedure. Until recently, the most favorable locations for LLR have been the peripheral liver segments [13]. However, the limitations associated with the procedure have gradually diminished with the accumulation of surgical experience in LLR. Although the reports are limited, LLR has been shown to be a feasible option for lesions located in the posterior and superior segments [14–16]. In laparoscopic view, the surgical field is visualized and accessed from the caudal side to the cranial side using a laparoscope, known as the 'caudal approach.' Thus, laparoscopic approach for caudate lobe has advantage of easy access to this location compared with approach for cranial side, such as posterosuperior segments [17–19]. However, the Sg1 is close to the liver hilum, major hepatic veins, and IVC, and is still considered theoretically as a contraindication for laparoscopic approach. Indeed, parenchymal transection near these major vessels poses greater risk of injury, and once such an injury occurs, the complications may be difficult to control laparoscopically.

The present study represents the first series reporting the results of laparoscopic Sg1 resection and the analysis compared with other lesions. Indeed, this study suggests that LLR can be safely performed for Sg1 tumors without open conversion or mortality. When compared with AI and PS groups, the Sg1 group showed a similar operative time, a significant reduction in blood loss, and a similar rate of intraoperative transfusion.

Although the danger in resection of the caudate lobe may arise from massive bleeding from the anterior part of the IVC and posterior part of the middle hepatic vein, laparoscopy has the significant advantages of providing excellent view and access to these parts behind the liver by 'caudal approach' [17–19]. Indeed, the laparoscopic approach allows precise dissection upward along the IVC. At this level, short hepatic veins for Sg1 are meticulously coagulated with the bipolar forceps and then divided rather

Table 3 Comparisons between postoperative outcomes

	N (%)			*p* value
	Sg1 group ($N = 15$)	AI group ($N = 151$)	PS group ($N = 67$)	
Postoperative mortality	0	0	0	–
Overall complication[a]	3 (20.0)	22 (14.6)	14 (20.9)	0.060
Infectious complications	2 (13.3)	7 (4.6)	8 (11.9)	0.021
Major complication[a]	2 (13.3)	6 (4.0)	8 (11.9)	0.042
Overall complication				
Liver-specific complication				
Biliary leakage	0	1 (0.7)	2 (3.0)	0.336
Intra-abdominal abscess	0	4 (2.6)	5 (7.5)	0.172
Biliary stenosis	1 (6.6)	0	0	0.001
Postoperative bleeding	0	0	1 (1.5)	0.293
Pancreatic fistula	1 (6.6)	0	0	0.001
Pulmonary complication	0	1 (0.7)	1 (1.5)	0.487
Pleural effusion	0	1 (0.7)	2 (3.0)	0.344
Ileus	1 (6.6)	4 (2.6)	0	0.172
Anastomotic leakage	0	1 (0.7)	0	0.766
General complication	0	10 (6.6)	3 (4.5)	0.542
Postoperative major complication[a]				
Liver-specific complication				
Biliary leakage	0	1 (0.7)	2 (3.0)	0.336
Intra-abdominal abscess	0	2 (1.3)	3 (4.5)	0.172
Biliary stenosis	1 (6.6)	0	0	0.001
Postoperative bleeding	0	0	1 (1.5)	0.293
Pancreatic fistula	1 (6.6)	0	0	0.001
Pulmonary complication	0	0	1 (1.5)	0.293
Pleural effusion	0	0	1 (1.5)	0.293
Anastomotic leakage	0	1 (0.7)	0	0.766
Stenosis of stomach	0	1 (0.7)	0	0.766
Ileus	0	1 (0.7)	0	0.766
Reoperation	1 (6.6)	3 (2.0)	1 (1.5)	0.364
Length of hospital stay, days, mean ± SD	8.0 ± 6.5	6.7 ± 5.1	8.3 ± 7.3	0.008

[a] Postoperative complications were stratified according to the Clavien–Dindo classification, which defines major complications by grade III or more

than clipped. We believe that clips, even locked clips, could easily slip when applied on very short veins. The posterior part of the middle hepatic vein is more inaccessible. Improved laparoscopic vision (particularly via three-dimensional camera) and the flexibility of the camera further facilitate meticulous dissection of the liver parenchyma even in the narrow surgical field at the front of the IVC and behind the liver [20].

Additionally, postoperative complications were comparable in the three groups. However, we observed nonsignificant higher rates of infectious complications and reoperation after Sg1 resection. This absence of significance may be explained by the limited sample size. However, even though Sg1 resection is scarce uncommon, we observed complications could be assigned specifically to Sg1 resection; this was the case of a postoperative biliary stricture developed by a patient six weeks after caudate lobectomy and successfully treated by biliary stenting. Indeed, we have to keep in mind that biliary drainage for Sg1 includes small tributaries to the right but occurs predominantly through the left hepatic duct [21]. Postoperative morbidity after Sg1 resection is similar to those observed after PS resection and higher than those observed after AI resection. Therefore, we should consider Sg1 as arduous location for laparoscopic approach.

Table 4 Logistic regression analysis for the risk of major complication

Risk factors	Variables	Univariate analysis			Multivariate analysis		
		p value	Odds ratio	95 % CI	*p* value	Odds ratio	95 % CI
Age (years)	≤65 versus >65	0.134	2.824	0.727–10.973			
Gender	Male versus Female	0.597	0.708	0.256–1.962			
BMI (kg/m^2)	≤30 versus >30	0.803	1.333	0.139–12.758			
Preoperative complication							
Diabetes mellitus	Negative versus positive	0.808	0.773	0.096–6.209			
Hypertension	Negative versus positive	0.897	0.918	0.250–3.364			
Dyslipidemia	Negative versus positive	0.338	0.366	0.047–2.863			
Ischemic heart disease	Negative versus positive	0.999	0.000	–			
COPD	Negative versus positive	0.043	5.943	1.057–33.415	0.033	7.319	1.178–45.480
Preoperative chemotherapy	Negative versus positive	0.128	2.209	0.795–6.136			
Previous abdominal surgery	Negative versus positive	0.129	2.462	0.769–7.878			
Previous hepatectomy	Negative versus positive	0.249	0.299	0.038–2.333			
Tumor size (mm)	≤30 versus >30	0.428	0.987	0.956–1.019			
Anatomical resection	negative versus positive	0.331	1.734	0.572–5.256			
Operation time (min)	≤300 versus >300	0.414	1.003	0.996–1.009			
Blood loss (ml)	≤500 versus >500	0.055	1.001	1.000–1.003	0.221	1.001	0.999–1.003
Sg1 group	Negative versus positive	0.233	0.377	0.076–1.871			
PS group	Negative versus positive	0.063	0.378	0.136–1.054	0.076	0.334	0.100–1.122

BMI body mass index, *COPD* chronic obstructive pulmonary disease

Another concern about the application of LLR for tumors located in Sg1 is the ability to obtain a safe resection margin. Indeed, LLR for tumors close to both the hilum and the major hepatic veins are technically challenging procedures because it may be difficult to obtain adequate surgical margins, even in open liver resection [13]. The present study emphasizes that en bloc complete caudate lobectomy involving the caudate lobe is not appropriate in all cases since all 15 patients who underwent Sg1 resection had clear surgical margins. In addition, laparoscopic ultrasound should be widely used during the procedure in order to provide a precise evaluation of tumor location and its relationship with the adjacent vascular structures [7].

The limitations of the present series include both the limited number of patients who underwent Sg1 resection and the relative heterogeneity of the tumors. Additionally, patients were highly selected given only one had cirrhosis and all tumor diameters were under 3 cm. Even though it would have been ideal to compare intra- and postoperative outcomes between laparoscopic and open Sg1 resection, our institute has high volume number of LLR; the total number of Sg1 liver resection is very low. We assume that it is a limitation of this study. Furthermore, we emphasize that surgeons should have experienced technique of LLR when considering laparoscopic Sg1 resection.

In conclusion, this study suggests that the laparoscopic approach is a feasible and curative surgical option for resection of tumors located in the caudate lobe with acceptable operative time, postoperative outcomes, and tumor-free margins in selected patients.

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Compliance with ethical standards

Disclosures Kenichiro Araki, David Fuks, Takeo Nomi, Satoshi Ogiso, Ruben R Lozano, Hiroyuki Kuwano, and Brice Gayet have no conflict of interest. Brice Gayet is consultant for Olympus.

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