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ORIGINAL SCIENTIFIC REPORT

Short-Term Outcomes of Totally Laparoscopic Central Hepatectomy and Right Anterior Sectionectomy for Centrally Located Tumors: A Case-Matched Study with Propensity Score Matching

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Abstract

Background Recent advances in technology and accumulation of surgical experience have expanded the indications for laparoscopic liver resection (LLR). However, compared to open liver resection (OLR), the feasibility of laparoscopic anatomical liver resection for centrally located tumor (CLT) has not been clearly established. The aim of our study was to assess the feasibility and safety of laparoscopic anatomical major liver resection for CLT.

Methods From April 2011 to March 2016, 20 cases of anatomical LLR and 86 cases of OLR for CLTs such as central hepatectomy (CH) and right anterior sectionectomy (RAS) were performed at a single institution. We performed one-to-one propensity score matching and analyzed short-term outcomes between the LLR ($n = 20$) and OLR ($n = 20$) groups.

Results Among 20 cases in the LLR group, two cases underwent open conversion due to common bile duct injury and anatomical distortion, respectively. There were no statistically significant difference between the LLR and OLR groups regarding clamping time of the Pringle maneuver ($p = 0.502$), blood loss ($p = 0.746$), surgical margin ($p = 0.198$), or length of hospital stay ($p = 0.110$). However, surgical time was significantly longer in the LLR group than in the OLR group (388 vs 268 min; $p < 0.001$). There were no significant differences between the two groups with regard to morbidity rate or mean comprehensive complication index ($p = 0.716$ and $p = 0.819$, respectively).

Conclusion Total anatomical LLR can be performed safely in selected CLT patients by experienced surgeons. Laparoscopic CH or RAS appears feasible with non-inferior perioperative outcomes compared to OLR.

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Introduction

Since the first reported laparoscopic liver resection (LLR) was performed in 1992 [1], LLR has became increasingly accepted by surgeons. Laparoscopic left lateral sectionectomy has become a standard surgical procedure for treating tumors located in segment 2 or 3 [2–4]. Moreover, LLR is considered an acceptable alternative treatment to open liver resection (OLR) for malignant and benign liver tumors [5]. However, the safety and feasibility of laparoscopic anatomical liver resection for centrally located tumors (CLTs; segments 4, 5, and 8) requiring central hepatectomy (CH) or right anterior sectionectomy (RAS) have not been established yet.

Although there have been some reports of totally laparoscopic anatomical mesohepatectomy, they were case reports presenting limited outcomes of anatomical liver resection [6, 7]. Other reports did not provide comparative analysis between laparoscopic and open approaches [8, 9]. In this article, we report our experience with totally laparoscopic anatomical liver resection in a single-institution series of patients with CLTs of the liver. The purpose of this study was to assess the feasibility and safety of laparoscopic CH and RAS by comparing short-term perioperative outcomes of LLR and OLR for CLTs.

Methods

Study design and population

We retrospectively assessed the data of all patients who underwent anatomical liver resection for CLT such as CH or RAS at a single institution between April 2011 and March 2016. A total of 132 patients underwent surgical resection for CLTs over a 5-year period. Those patients who were diagnosed with metastatic liver disease requiring simultaneous operation ($n = 9$), non-anatomical resection ($n = 6$), and redo-hepatectomy ($n = 11$) were excluded from the study. The remaining 106 patients were divided into two groups according to the type of operation: LLR ($n = 20$) and OLR ($n = 86$). Two cases that were converted to open surgery were included in the LLR group for analysis based on an intention to treat approach. Since there were unbalanced covariates, we used one-to-one propensity score matching (PSM) to ensure that laparoscopic and open groups were comparable. Finally, 40 patients were enrolled in this study: the LLR group ($n = 20$) and the OLR group ($n = 20$). This study was approved by the institutional review board of our institution.

Preoperative evaluation

The diagnosis of CLT was based on computed tomography of the abdomen. Patient status was discussed at a weekly multidisciplinary meeting. Attendees included hepatobiliary surgeons, hepatologists, interventional radiologists, and radiation oncologists. Generally, liver resection was considered for patients with preserved liver function of Child–Turcotte–Pugh class A and American society of anesthesiologist grade <III [10]. The decision to use a laparoscopic approach was made by the surgeon. During the period of study, LLR was performed by a single surgeon, and the indications were tumors located more than 5 mm from major vascular or biliary structures.

Surgical procedures

The patient was laid on a table in the French position with the surgeon standing between the patient's legs. Usually, five trocars were used in this operation as shown in Fig. 1. A 12-mm flexible camera trocar was placed through the umbilical port. Pneumoperitoneum was maintained at 11 mmHg. Intraoperative ultrasonography was routinely performed to identify the course of the right and middle hepatic vein and evaluate the resection margin of the tumor. An advanced bipolar device (LigaSure™, Covidien, Mansfield, MA) and ultrasonic shear (Harmonic, Ethicon Endo Surgery, Inc., Johnson & Johnson Medical SPA, Somerville, NJ and Sonicision™, Covidien) were used. The method of parenchymal transection changed at our institution over this period of time. Either instruments and/or Cavitronal Ultrasonic Surgical Aspirator (CUSA, Valleylab, Boulder, CO) was used for parenchymal transection. All anatomical liver resections were performed using a Glissonian approach [11].

The operation began with dissection of the round and falciform ligament until the suprahepatic inferior vena cava (IVC) was exposed, and the groove between the right hepatic vein and the middle hepatic vein was identified. Dissection between the liver and the right anterior Glissonian pedicle was done via blunt dissection using bipolar forceps (Medtronic, Minneapolis, MN) and an endoscopic suction irrigator. After the right anterior pedicle was exposed, it was not divided, but temporarily clamped with a laparoscopic bulldog clamp (Aesculap, Center Valley, PA) as previously described in temporary inflow control of the Glisson (TICGL) technique, shown in Fig. 2a [12]. The

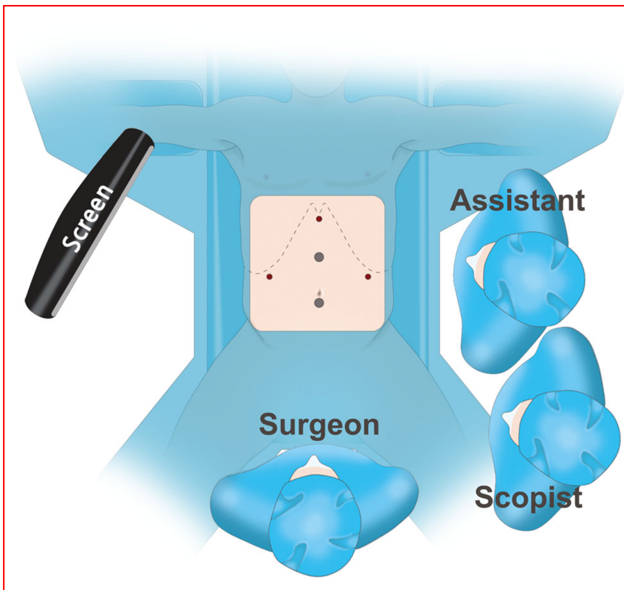

Fig. 1 Operative diagram showing the positioning of the patient ('French' position) and the surgical team

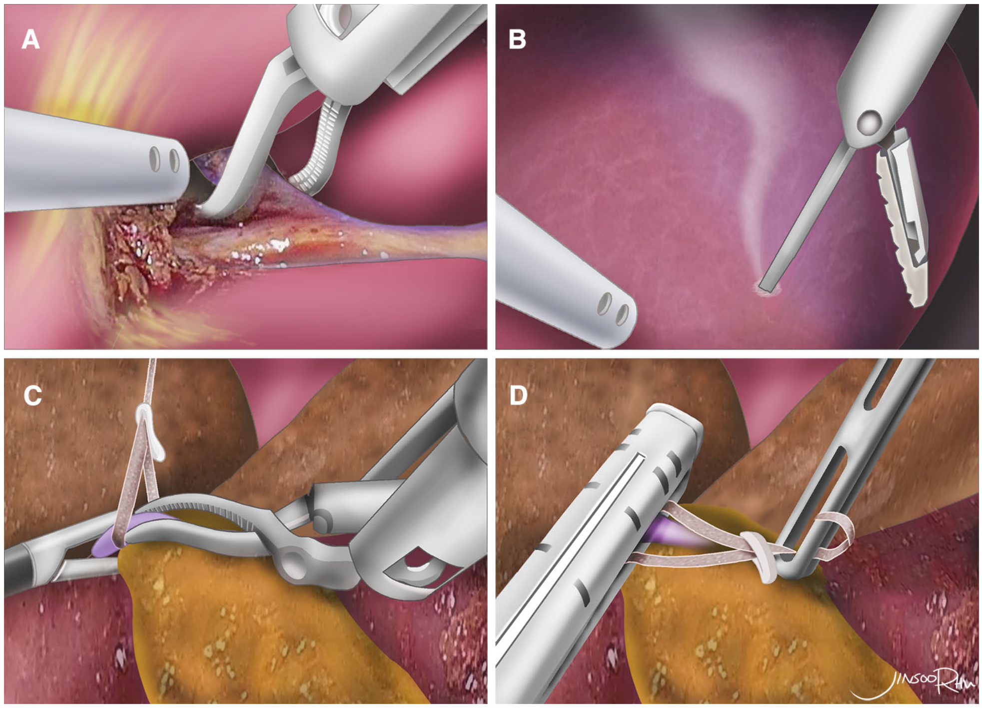

Fig. 2 Temporary inflow control of Glisson (TICGL) technique in laparoscopic *right* anterior sectionectomy [12]. **a** The *right* anterior Glisson was temporarily controlled using a bulldog clamp. **b** Demarcation and transection of the *right* intersectional plane. **c** Isolation of the *right* anterior Glisson using nylon tape and retrieval of the bulldog clamp. **d** Retraction using nylon tape and division of the *right* anterior Glisson using an endoscopic staple

demarcation line for parenchymal dissection was verified and marked using cauterization (Fig. 2b).

In the cases of difficult clamping of the right anterior Glisson, the whole right Glissonian pedicle was initially clamped to verify the margin of the plane between the right and left lobe. Since the right Glisson is fully exposed after division of this plane, the right anterior branch can be identified much easier.

For RAS, parenchymal transection was carried out along Cantlie's line. In cases of excessive bleeding during this stage of parenchymal transection, the Pringle maneuver was applied. After more than 2/3rd of the parenchymal transection was done along this plane, the remainder of the parenchymal transection was carried out along the demarcated line between the right anterior and posterior sections. Transection of the parenchyma was performed until the right anterior pedicle was fully exposed. Subsequently, tape was used to encircle the pedicle. The bulldog clamp was removed, and staples were inserted using a vascular endoscopic stapler (EndoGIA™ Tan, Covidien, Mansfield, MA and Echelon™ White, Ethicon Endo Surgery, Inc., Johnson & Johnson Medical SPA, Somerville, NJ).

It is important to retract remnant Glissonian pedicles with tape caudally and into the left, and to apply the stapler as distally as possible in order to prevent stricture of the remnant structures, as shown in Fig. 2d. The remaining parenchyma was then transected with special attention to the hepatic veins branches, since heavy bleeding might occur at this stage due to branch injury. A specimen was retrieved through the Pfannenstiel incision. The cut surfaces of the liver were checked. Bleeding and bile leakages were controlled meticulously. Subsequently, hemostatic tissue sealant was applied and then a Jackson–Pratt drain was inserted at the site of liver resection.

The process of applying the bulldog clamp throughout parenchymal transection and stapling after the right anterior section pedicle was fully exposed and is a technique referred to as the temporary inflow control of the Glisson (TICGL) technique. This slight twist on the procedure allows the surgeon to: (1) perform parenchymal transection under inflow control, thus decreasing bleeding, (2) easily encircle the Glissonian pedicle after it is fully exposed, and (3) perform stapling safely.

For CH, the general procedures including the TICGL technique are similar to RAS with minor differences. The transection plane was 5 mm to the right of the falciform ligament, and the Glissonian pedicles supplying segment 4 were dissected and divided sequentially along the resection plane. Most of the branches only required double clipping. However, if the branch was thought to be too large, a stapler was used. Following the completion of liver transection, the middle hepatic vein was divided using a vascular endoscopic stapler (EndoGIA^{TM} Tan or Echelon^{TM} White).

Study criteria

The main objective of our study was to compare intraoperative outcomes including surgical time, mean blood loss, transfusion rate, and postoperative outcomes including laboratory tests, complication rate, the comprehensive complication index (CCI), length of hospital stay, and mortality between the LLR and OLR groups. Postoperative morbidity was assessed at 90 postoperative days and graded according to Clavien–Dindo classification [13]. The CCI was obtained using a CCI calculator available online (www.assessurgery.com). Postoperative mortality was defined as death within 90 days after liver resection [14]. Definition and grading of bile leakage and liver failure after hepatectomy were described according to the International Study Group of Liver Surgery guidelines [15]. Major vascular proximity was defined as tumor abutting within 1 cm of the expected transection plane of the right anterior portal vein, and within 5 mm of the inferior vena cava and right or middle major hepatic vein in the case of RAS and of the left hepatic vein in the case of CH [16]. Subcapsular tumor was defined as a lesion located <1 cm from the liver edge [17]. In terms of intrahepatic location, 'deep' tumors were defined as those with major vascular proximity or that were not subcapsular. Otherwise, the tumor was considered 'superficial.'

Statistical analysis

Prior to descriptive statistics, Kolmogorov–Smirnov test and Shapiro–Wilk test were used to evaluate normality since the sample size of the LLR group was below 30 patients. Continuous data were presented as median and range. Categorical data were described in numbers and percentages. Statistical analysis was conducted using independent-samples T test or Mann–Whitney test for continuous values and Chi-squared test or Fisher's exact test for categorical values, especially when expected cell frequencies were below 5. In order to adjust for the difference in patient characteristics between the two groups and to decrease possible selection bias, 1:1 PSM was applied using multiple logistic regression with the nearest-neighbor matching method. Propensity scores were created using baseline characteristics (age, sex, body mass index [BMI], history of previous abdominal surgery, hepatitis B-related etiology, Child–Turcotte–Pugh [CTP] score, preoperative laboratory test, underlying liver cirrhosis, type of surgical procedure, and the American Society of Anesthesiologists [ASA] score), tumor characteristics (malignancy, size, site, major vascular proximity, and subcapsular tumor). A p value of <0.05 was considered statistically significant. Data handling and analysis were performed using the Statistical Package for Social Science for Windows^{TM} release 22.0 (SPSS Inc., Chicago, IL).

Results

Demographic data and our experience with LLR for CLTs

Baseline characteristics of the two groups of patients before and after PSM are summarized in Table 1 according to surgery type. After PSM, all baseline characteristics were similar between the LLR and OLR groups. Histologic diagnosis and surgical type of the LLR group are listed chronologically in Table 2. Ten cases of laparoscopic CH and RAS were performed, respectively. There were no statistically significant differences in mean surgical time between CH and RAS (CH: 411 min; RAS: 406 min, $p = 0.897$). However, median surgical time in seven cases of superficial tumor was shorter than it was in 13 cases with deep tumor, which represented a statistically significant difference (329 vs 452 min; $p = 0.019$). The pathologic diagnosis of these 20 cases was hepatocellular carcinoma in 17 cases and benign tumor in three cases. Nine cases occurred in a background of cirrhotic liver. The open conversion rate was 10%. Patient nos. 9 and 11 were converted to open surgery due to injury of the common bile duct and anatomical distortion, respectively.

Operative details and postoperative outcomes of LLR versus OLR groups after PSM

Table 3 summarizes the operative details and postoperative outcomes of propensity-matched groups. Surgical time was significantly longer in the LLR group (median, 388 min; range, 246–661 min) compared to the OLR group (median, 268 min; range, 98–412 min, $p < 0.001$, Table 3). There were no significant differences between the LLR and OLR groups with regard to the Pringle maneuver ($p = 0.176$), clamping time ($p = 0.502$), blood loss ($p = 0.746$), and surgical margin ($p = 0.198$). There was no patient with R1 margin which is mostly defined as below 1 mm width in both groups. Two (10%) and one (5%) cases in the LLR and OLR groups, respectively, required blood transfusion. The median duration of postoperative hospitalization in the LLR group was shorter than the OLR group, but this did not represent a statistically significant difference (LLR group: 8 days, range 5–24 days; OLR group: 10 days, range 5–24 days, $p = 0.110$). There were no significant

Table 1 Patient characteristics before and after propensity score matching

Characteristics	Entire cohort		*P* value	Propensity-matched cohort		*P* value
	LLR (*N* = 20)	OLR (*N* = 86)		LLR (*N* = 20)	OLR (*N* = 20)	
Age, median (range)	57 (29–77)	58 (27–79)	0.449	57 (29–77)	58 (27–75)	0.645
Sex (male/female)	12:8	69:17	0.078	12:8	13:7	1.000
BMI (kg/m^2), median (range)	24.4 (19.9–27.0)	24. (18.6–34.2)	0.191	24.4 (19.9–27.0)	23.5 (20.0–27.0)	0.976
Previous abdominal operations, *n* (%)	3 (15%)	15 (17%)	1.000	3 (15%)	3 (15%)	1.000
Hepatitis B related, *n* (%)	17 (85%)	63 (73%)	0.390	17 (85%)	19 (95%)	0.605[‡]
CTP score (5:6)	20:0	81:5	0.581	20:0	20:0	N/A
Laboratory test, median (range)						
Albumin (g/dL)	4.5 (3.8–5.1)	4.4 (3.2–5.2)	0.239	4.5 (3.8–5.1)	4.4 (4.2–5.1)	0.836
Total bilirubin (mg/dL)	0.6 (0.2–1.0)	0.6 (0.3–2.4)	0.076	0.6 (0.2–1.0)	0.5 (0.3–1.0)	0.572
AST (IU/L)	24 (14–60)	30 (13–143)	0.110	24 (14–60)	26 (15–57)	0.657
ALT (IU/L)	27 (9–59)	30 (9–181)	0.165	27 (9–59)	25(12–86)	0.511
PT (INR)	1.02 (0.95–1.18)	1.02 (0.9–1.2)	0.494	1.02 (0.95–1.18)	1.03 (0.97–1.17)	0.922
Platelets (×1000/μL)	168 (91–358)	163 (50–710)	0.714	168 (91–358)	166 (50–324)	0.937
ICG 15 min (%)	10.7 (0.9–26.8)	10.9 (2.0–30.0)	0.874	10.7 (0.9–26.8)	11.5 (2.0–21.5)	0.978
Underlying liver cirrhosis, *n* (%)	9 (45%)	33 (38%)	0.618	9 (45%)	8 (45%)	1.000
Malignancy, *n* (%)	17 (85%)	82 (95%)	0.122	17 (85%)	18 (90%)	1.000[‡]
Tumor size (mm), median (range)	26 (6–140)	38 (10–140)	0.285	26 (6–140)	27 (10–82)	0.621
Tumor site (S4/S5/S8)	3:3:14	9:24:53	0.530	3:3:14	2:3:15	1.000[‡]
Major vascular proximity[c], *n* (%)	13 (65%)	46 (54%)	0.456	13 (65%)	12(60%)	1.000
Subcapsular tumor[a], *n* (%)	11 (55%)	54 (63%)	0.612	11 (55%)	10 (50%)	1.000
Surgical procedure (CH/RAS)	10:10	53:33	0.449	10:10	10:10	1.000
ASA score (1:2:3)	6:13:1	11:69:1	0.148	6:13:1	3:17:0	0.273[b]

ALT alanine aminotransferase, *ASA* The American Society of Anesthesiologists, *AST* aspartate aminotransferase, *BMI* body mass index, *CH* central hepatectomy, *CTP* Child–Turcotte–Pugh, *ICG* indocyanine green, *INR* international normalized ratio, *PT* prothrombin time, *RAS* right anterior sectionectomy

[a] Subcapsular tumor was defined as a lesion located <1 cm from the liver edge

[b] Fisher exact test

[c] Major vascular proximity was defined as the tumor abutting within 1 cm of the expected transection plane of the right anterior portal vein, and within 5 mm of the inferior vena cava and right or middle major hepatic vein in the case of right anterior sectionectomy, or the left hepatic vein in the case of central hepatectomy

differences in mortality rate (30 vs 20%; $p = 0.716$) or mean CCI (4.5 vs 3.9; $p = 0.819$) between the LLR and OLR group. There was no 90-day postoperative mortality in either group. As shown in Table 4, there was no patient with extended use of patient-controlled analgesia (PCA) in the LLR group. The median duration of PCA ($p = 0.002$) and intravenous (IV) opioid ($p = 0.035$) in the LLR group was significantly shorter than in the OLR group.

Discussion

Although the acceptable indications for LLR have been expanded, the location of tumors remains a major challenge when applying totally anatomical LLR. Currently, consensual indications of LLR with respect to the tumor site are lesions located peripherally in liver segments 2–6 [2]. However, CLTs remain a major obstacle in applying a laparoscopic approach because of the technical difficulties and long operation time. We sought to determine whether this procedure was feasible when performed by experienced surgeons.

Several studies have evaluated the feasibility of laparoscopic approach for CLTs [6–9]. However, they were not comparative studies between laparoscopic and open approaches. Only one study compared laparoscopic and open liver resection [18]. However, various operation types have been reported according to the location of tumor. Comparatively, we selected a homogenous group of patients who underwent CH or RAS for tumors located in segments 4, 5, and 8.

The median surgical time for LLR was longer than that for OLR, but similar to the results of laparoscopic left lateral sectionectomy [19]. Abdominal closure time was usually shorter in LLR because of the small incision.

Table 2 Chronological data of 20 patients who underwent laparoscopic anatomical liver resection for centrally located tumors

No.	Age/sex	Diagnosis	Site	Size (mm)	Vessels close to the tumor	Depth from liver surface (mm)	ICG 15 (%)	Intrahepatic location[b]	Type of LLR	Pringle maneuver	Surgical time
1	29/F	FNH	S8	55	RAPV	0	N/A	Deep	CH	Yes	359
2	61/M	HCC	S8	19	RAPV, MHV	44	12.7	Deep	CH	No	448
3	63/F	HCC	S4	18	None	0	14.8	Superficial	CH	No	398
4	48/M	HCC	S8	11	RAPV, MHV	24	10.3	Deep	RAS	Yes	568
5	53/M	HCC	S8	35	RAPV	11	14.0	Deep	RAS	No	347
6	51/F	HCC	S8	17	RAPV, MHV	23	8.3	Deep	CH	No	302
7	67/F	HCC	S8	19	RAPV	28	0.9	Deep	RAS	No	525
8	54/M	HCC	S8	25	None	0	7.9	Superficial	CH	Yes	321
9[a]	37/M	HCC	S8	9	MHV	37	10.7	Deep	CH	Yes	398
10	59/F	HCC	S8	26	None	7	26.8	Superficial	RAS	No	286
11[a]	69/M	Biliary cystadenoma	S4	105	MPV, MHV	6	7.4	Deep	CH	Yes	661
12	57/M	HCC	S8	47	MHV	0	19.4	Deep	CH	Yes	632
13	52/M	HCC	S8	25	None	0	8.6	Superficial	RAS	Yes	387
14	64/F	HCC	S5	30	None	0	8.7	Superficial	CH	Yes	388
15	67/M	HCC	S5	27	None	0	12.6	Superficial	RAS	No	246
16	77/F	HCC	S8	38	None	0	7.9	Superficial	CH	No	277
17	57/M	HCC	S8	25	RAPV, MHV	30	11.1	Deep	CH	Yes	469
18	42/M	HCC	S5	6	RAPV	28	12.9	Deep	RAS	Yes	469
19	60/M	HCC	S8	66	MHV	42	10.8	Deep	CH	Yes	378
20	54/F	Cavernous hemangioma	S4	140	MHV	0	4.9	Deep	CH	Yes	318

CH central hepatectomy, *F* female, *FNH* focal nodular hyperplasia, *HCC* hepatocellular carcinoma, *LLR* laparoscopic liver resection, *M* male, *MHV* middle hepatic vein, *MPV* main portal vein, *N/A* not assessed, *RAPV* right anterior portal vein, *RAS* right anterior sectionectomy

[a] These two cases were converted to laparotomy. Cases 9 and 12 were converted to open surgery due to injury of the common bile duct and anatomical distortion, respectively

[b] 'Deep' tumor was defined as tumor with major vascular proximity or that was not subcapsular. Otherwise, the tumor was considered 'superficial'

However, parenchymal transection was slower in LLR compared to OLR due to technical difficulties. In left lateral sectionectomy, the time required for parenchymal transection was usually shorter compared to the duration of the operation. Both RAS and CH are the types of liver resection that require the largest area of parenchymal transection. These two parenchymal transection planes are the main cause of the longer total operation time observed for LLR for CLTs [9]. However, our study only reported a preliminary experience of LLR for CLTs. The cohort consisted of all consecutive RASs and CHs since the beginning of the laparoscopic program at our institution. Based on the results of laparoscopic left lateral sectionectomy, it is hypothesized that accumulation of experience can reduce operation time. Moreover, if the Pringle maneuver is applied more frequently, the operation time may be decreased [20]. In our study, the Pringle maneuver was applied less frequently in the LLR, compared to OLR, but this did not represent a statistically significant difference. Blood loss and transfusion rates may also decrease with further experience. However, due to the complexity of the operation, overall liver-related morbidities such as bile leakage will not be easy to reduce.

Intrahepatic location of CLTs can affect operation time. In our study, the median surgical time of LLR for superficial tumors was significantly shorter than that of deep tumors (321 vs 448 min; $p = 0.019$). If we adopt stricter indications of LLR for CLTs on the basis of intrahepatic location, LLR operation time may be decreased, to a level comparable to OLR.

The TICGL technique provides an easy, safe, and quick way of performing anatomical liver resection. It allows the surgeon to: (1) perform parenchymal transection under inflow control to decrease blood loss, (2) easily encircle the Glissonian pedicle, which is done after the pedicle is fully exposed, and (3) perform stapling safely [12]. This technique has been used since mid-2012 (patient no. 3 in Table 2) at our center. We analyzed the operation time of 8 patients (no. 2 vs no. 3, 5, 6, 7, 10, 15, and 16 in Table 2) according to use of the TICGL technique without the

Table 3 Operative details and postoperative outcomes of propensity-matched patients who underwent LLR and OLR

	LLR (*N* = 20)	OLR (*N* = 20)	*P* value
Surgical time (min), median (range)	388 (246–661)	268 (98–412)	<0.001
Patient who underwent Pringle maneuver, *n* (%)	11 (55%)	16 (80%)	0.176
Clamping time (min), median (range)	33 (0–106)	40 (0–71)	0.502
Blood loss (mL), median (range)	350 (100–1300)	400 (50–3300)	0.746
Blood transfusion, *n* (%)	2 (10%)	1 (5%)	1.000[b]
Surgical margin (mm), median (range)	7 (0.1–40)	6.5 (0.1–23)	0.198
Hospital stay (days), median (range)	8 (5–24)	10 (5–24)	0.110
Laboratory test, peak (range)			
Total bilirubin (mg/dL)	1.8 (0.7–7.5)	1.6 (0.9–4.7)	0.399
AST (IU/L)	402 (196–1161)	348 (171–3175)	0.508
ALT (IU/L)	390 (194–1316)	393 (187–1648)	0.765
PT (INR)	1.42 (1.16–2.80)	1.39 (1.11–2.53)	0.944
Patients with morbidity, *n* (%)	6 (30%)	4 (20%)	0.716
C-D grade (I:II:IIIa:IIIb:IVa:IVb)	2:1:3:0:0	2:0:1:1:0	0.735[b]
CCI, mean (range)	4.5 (0–26.2)	3.9 (0–33.7)	0.819
Postoperative complications, events (%)	6 (30%)	4 (20%)	0.549[b]
Wound complication	0	2 (10%)	
Ascites	1 (5%)	0	
Transient liver failure[a]	1 (5%)	0	
Partial portal vein thrombosis	1 (5%)	0	
Bile leakage	3 (15%)	2 (10%)	

ALT alanine aminotransferase, *AST* aspartate aminotransferase, *CCI* comprehensive complication index, *C-D* Clavien–Dindo, *INR* international normalized ratio, *LLR* laparoscopic liver resection, *OLR* open liver resection, *PT* prothrombin time

[a] Transient liver failure was characterized by an increased international normalized ratio and concomitant hyperbilirubinemia (according to the normal limits of the local laboratory) on or after postoperative day 5

[b] Fisher exact test

Table 4 Postoperative analgesia of propensity-matched patients who underwent LLR and OLR

	LLR (*N* = 20)	OLR (*N* = 20)	*P* value
PCA, *n* (%)	19 (95%)	20 (100%)	1.000[a]
Extended use of PCA, *n* (%)	0 (0%)	8 (40%)	0.003[a]
Duration of PCA (days), median (range)	3 (0–3)	3 (3–9)	0.002
IV opioid, *n* (%)	5 (25%)	11 (55%)	0.105
Duration of IV opioid (days), median (range)	0 (0–7)	1 (0–24)	0.035
Oral opioid, *n* (%)	18 (90%)	19 (95%)	1.000[a]
Duration of IV opioid (days), median (range)	8 (0–16)	9.5 (0–24)	0.076
Other pain killer, *n* (%)	9 (45%)	8 (40%)	1.000
Duration of other pain killer (days), median (range)	0 (0–13)	0 (0–27)	0.360

IV intravenous, *PCA* patient-controlled analgesia

[a] Fisher exact test

Pringle maneuver. Before applying TICGL, the operation time of patient no. 2 was 448 min. The mean operative time after applying TICGL was 340 min. By applying the TICGL technique routinely, in addition to accumulation of surgical experiences, RAS and/or CH may be completed within 5 h, which may allow more surgeons to perform this technically demanding operation. Additionally, no patients in the LLR group experienced postoperative bile duct stricture, reflecting the safety of this technique.

One important previously reported benefit of LLR is the shorter hospital stay compared to OLR. This result is in concordance with other reported studies on different types of liver resection [14, 21, 22]. However, our propensity-matched study did not demonstrate that the same results could be duplicated in liver resections of CLTs. The median hospital stay in the LLR group was 8 days, which appears to be rather long. Hospital stay is dependent on the medical system of each country. Because of the low admission cost in Korea, most of the patients who underwent major operations were reluctant to be discharged within 7 postoperative days. In addition, routine postoperative CT was taken on day 7 to confirm possible unexpected complications. More recently, our patients have been discharged on postoperative day 5 without routine postoperative CT. In the LLR group of our study, the mean hospital stay of 14 patients who had no morbidities was 8 days. If our recent clinical pathway had been applied earlier, the median hospital stay of the LLR group would have been decreased.

Another benefit of LLR was that the intensity of postoperative pain was less than OLR. Significant reduction of IV analgesia following surgery is important to achieve enhanced recovery after surgery (ERAS) protocol and to reduce length of hospital stay. In our center, IV PCA was routinely given to patients with major liver resection. And if patients request extended use of PCA, we permitted extension use of PCA for two times. No patients in the LLR group had extended use of PCA, and duration of PCA in the LLR group was significantly shorter than in the OLR group in our study.

This study has several limitations. First, the sample size of the LLR group was smaller than that of the OLR group, which was the main drawback of this study. More studies with a larger sample size are necessary to confirm our results. In addition, our study focused on short-term outcomes in order to evaluate the operative feasibility. Further studies are needed to assess long-term outcomes and to demonstrate the oncological safety of the laparoscopic approach, including overall and disease-free survival in patients with malignant tumors. Moreover, LLR was performed by a single surgeon, whereas OLR was performed by several surgeons. This limitation can act as selection bias of postoperative outcomes.

Conclusion

According to a difficulty scoring system for LLR [23], RAS and CH should be performed by laparoscopic surgeons with extensive experience who are able to successfully perform easy and intermediate difficulty surgeries without much difficulty. Therefore, our findings may not be generalizable to all laparoscopic liver surgeons, but LLR as difficult as RAS and CH can be performed with comparable results to OLR by experienced surgeons.

Compliance with ethical standards

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

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