Journal of Gastrointestinal Surgery (2019) 23:2314–2321
https://doi.org/10.1007/s11605-019-04276-z

MULTIMEDIA ARTICLE

Laparoscopic Repeat Hepatic Resection for the Management of Liver Tumors

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Received: 21 February 2019 / Accepted: 17 May 2019 / Published online: 16 July 2019

Abstract

Background Laparoscopic hepatic resection has been developed as a minimally invasive surgery; however, laparoscopic repeat minor hepatic resection (LRH) carries a higher risk of damage to other organs because of postoperative changes to and losses of anatomical landmarks. The current standard approach at many facilities has been to perform open repeat minor hepatic resection (ORH). This paper describes the surgical outcomes, procedure safety, and utility of ORH versus LRH, as well as the laparoscopic techniques used in LRH.

Methods Between February 2010 and May 2018, the data of 142 patients who underwent LRH or ORH at a single institution were retrospectively reviewed. Surgical outcomes, procedure safety, and procedure utility data were analyzed.

Results Forty-five patients underwent LHR and 97 patients underwent ORH. The conversion rate from LHR to OHR was 13.3%. After propensity score matching (PSM), the estimated blood loss was significantly lower in the LRH group than in the ORH group (50 mL vs. 350 mL; $P < 0.001$). The LRH group had an 8.1% complication rate, while the ORH group had a complication rate of 24.3% ($P = 0.044$). The postoperative length of stay was significantly shorter in the LHR group than in the OHR group (9 days vs. 11 days) ($P = 0.024$).

Conclusion LRH can be performed safely using various surgical devices. More favorable results are achieved with LRH than with ORH in terms of surgical outcomes including intraoperative bleeding, postoperative complications, and postoperative lengths of stay.

Keywords Laparoscopic repeat hepatic resection · Surgical outcomes · Liver tumor

Introduction

There are currently various methods available to treat liver tumors such as metastatic liver cancer and hepatocellular carcinoma. These methods include hepatic resection, chemotherapy, local paracentesis therapy (i.e., radiofrequency ablation), hepatic artery chemoembolization, and liver transplantation.[1, 2] It is not uncommon for cumulative surgical treatments to become necessary in the treatment plan. There are a number of studies that have reported the efficacy of repeat hepatic resection for recurrent liver tumors following an initial liver resection. However, most of these reports discuss repeat hepatic resection via open laparotomy methods. There are few reports of laparoscopic repeat hepatic resection.

In the past 20 years, laparoscopic surgical techniques have improved exponentially and have become widely accepted among gastrointestinal surgeons because they are minimally invasive and offer a potential replacement for conventional open surgery.[3, 4] Today, various types of hepatic resections are being performed laparoscopically, including partial

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11605-019-04276-z) contains supplementary material, which is available to authorized users.

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hepatic resection for tumors.[5] Many current reports have compared the surgical outcomes after laparoscopic partial hepatic resection with those of open partial hepatic resection in the treatment of liver tumors. The findings indicate that laparoscopic partial hepatic resection provides more favorable short-term outcomes because it is minimally invasive, well-tolerated, and is associated with less perioperative bleeding, low surgical site infection (SSI) rates, and shorter hospital stays after surgery.[3, 6] These results are thought to be due to the improvements in the surgical procedures of laparoscopic hepatic resection, resulting from advances in laparoscopic surgical instruments. However, these reports are limited to initial hepatic resection under laparoscopic assistance, with currently no clear positioning and evidence established for laparoscopic repeat minor hepatic resection (LRH).

In this study, we evaluated the surgical outcomes and techniques of the increasingly utilized LRH method compared with open minor hepatic resection (ORH).

Materials and Methods

Patient Population and Selection

LRH was introduced to our hospital in 1998 and we gradually addressed standardization of the surgical procedure. The LRH procedures were established in 2010 after the accumulation of a number of cases. This study included patients who underwent LRH after 2010 when standardization had been established.

Between February 3, 2010, and May 23, 2018, we conducted repeat minor hepatic resection for liver tumors on 142 consecutive patients at Osaka Medical College Hospital in Takatsuki City, Japan. All patients were fully informed of the study design according to the Ethics Committee on Clinical Investigation of Osaka Medical College Hospital (No. 1828 and 1997) and provided written informed consent. A tumor size less than 7 cm (independent of tumor number and location) was the main criterion for performing LRH. Not more than 5 resection site of hepatic resection were an indication for LRH. Patients with portal or hepatic vein involvement and invasion to adjacent organs are not considered candidates for LRH. Moreover, LRH was not considered for candidates when any complications occurred after initial hepatic resection.

The criteria for conversion from LRH to ORH included the following: (1) liver stumps of both preserved and resected sides could not be expanded adequately, (2) intraoperative bleeding could not be controlled, (3) blood loss exceeded 500 mL, (4) total time for the Pringle maneuver (hepatic blood flow occlusion) exceeded 120 min, and (5) intraoperative bile leakage could not be controlled. The patients who required conversion from LRH to ORH were analyzed as part of the LRH group.

Surgical Procedure

In this series, all patients underwent potentially curative hepatic resections with complete removal of gross tumor masses and visualization of negative margins macroscopically. All procedures were performed by three experienced hepatobiliary surgeons (YI, FH, KU) during the study period.

All procedures were performed with the patient under general anesthesia. The detailed laparoscopic surgical techniques routinely used in our department have been described in previous reports.[1–3, 6–8] Briefly, for patients undergoing laparoscopic resections for tumors involving the right hepatic lobe, the patients were placed in the left lateral recumbent position. For patients undergoing laparoscopic resections for tumors involving the left hepatic lobe, the patients were placed in the supine position. With an abdominal ultrasound, we assessed the tumor for the presence of abdominal wall adhesions, after which the first trocar was placed at a site that was deemed to be free of adhesions (Supplementary Video 1). After the introduction of a 12-mm umbilical or other port using an open technique, continuous carbon dioxide (CO_2) pneumoperitoneum was induced at a pressure limit of 12 mmHg and flow of 6 L/min to decrease the risk of gas embolism. Four 5- to 12-mm trocars and a 30-degree laparoscope (1588 AIM; Stryker Japan K.K., Tokyo, Japan) were inserted. For patients undergoing laparoscopic resection for a cephalad tumor involving the right hepatic lobe (segment VII and VIII), an intercostal port was inserted if necessary.

After identifying any adhesions of the hepatic vein root, diaphragm, or hepatic portal region, we would begin to mobilize the liver. The lateral hepatic attachment and the triangular ligament were divided using a Surgical Tissue Management System (Thunderbeat; Olympus Inc., Tokyo, Japan) after the round and falciform ligaments were dissected. This dissection was typically carried up to the diaphragm, allowing for a more effective mobilization of the liver. In mobilizing the liver, we took care to preserve the liver membrane as much as possible so that even if some of the anatomy was lost due to adhesions, the liver membrane could be preserved, and other organs such as the intestinal tract and diaphragm would not be damaged.

Next, the liver was evaluated via intraoperative laparoscopic ultrasonography (Prosound α7; Hitachi Aloka Medical, Ltd., Tokyo, Japan) in all cases. In addition to intraoperative ultrasonography, laparoscopic indocyanine green (ICG)-fluorescence imaging was also used to facilitate tumor identification. Following thermocoagulation procedures and in cases of small tumors or a cirrhotic liver, identification of hepatic tumors using ultrasonography alone is often difficult. With ICG-fluorescence imaging, tumors on the liver surface in particular become fluorescent green, and thus, the tumor site(s) is easily identified.

Next, we performed an extracorporeal Pringle maneuver, by occluding the blood flow with a vascular occlusion tube (Vessel-Clude; Argon Medical Devices Inc., USA) from outside the body after any adhesions of the hepatic hilar region were identified. Intermittent clamping was applied according to 15-min clamp, 5-min release cycles.

By changing the port that housed the laparoscope, the surgeon formed a triangle with the laparoscope in the center. This adjustment placed the surgeon, the target area, and the laparoscopic monitor in a straight line, and maintained the co-axial position. Central venous pressure (CVP) was maintained at 2–5 mmHg during the parenchymal transection. The parenchymal transection was performed using the Cavitron Ultrasonic Surgical Aspirator (Integra CUSA Excel Plus; Integra Neurosciences Ltd., Andover, UK) and the Thunderbeat device under an extracorporeal Pringle maneuver. Small vessels were ligated or coagulated using a soft-coagulation system. Intraparenchymal bleeding of the major vessels was controlled with clips, whereas biliary and vascular radicle divisions were made using clips or stapling devices. Next, the laparoscopic Pringle maneuver was performed. The resected, undivided specimen was placed in a plastic retrieval bag and removed through the slightly enlarged periumbilical incision (Supplementary Video 2).

Preoperative, Surgical, and Pathological Factors

The data analyzed included preoperative factors, surgical factors, and pathological factors. The preoperative factors investigated were age, sex, body mass index (BMI), viral hepatitis infection status, pathology, total bilirubin, albumin, prothrombin time (PT), platelet count, and the Child-Pugh classification. Surgical factors included the conversion rate, duration of surgery, intraoperative blood loss, and blood transfusion requirements. Minor hepatic resection was defined as the resection of 2 or fewer liver segments according to the Brisbane 2000 system.[9] Pathological factors included the size of the largest tumor, the total number of tumors, and surgical margin status. “R” classification denoted the absence or presence of postoperative residual tumor.[10] An R0 resection refers to excision of the tumor in one piece without violating the tumor plane. R0 resection also referred to the achievement of negative margins after sequential re-excision of the involved margins. An R1 resection involves a microscopically positive margin anywhere, and an R2 resection involves macroscopically positive margin(s) with a visible tumor.

Postoperative Evaluation

The following parameters were evaluated after surgery: transfusion rate, pathological margins, postoperative complications, 30-day mortality, and length of hospital stay. Morbidity was graded according to the Clavien classification system.[11, 12] SSIs were defined according to the CDC’s National Nosocomial Infection Surveillance (NNIS) system criteria.[13]

Statistical Analysis

To minimize the influence of potential confounders on selection bias, propensity scores were generated using binary logistic regression which included the following variables: age, sex, BMI, viral hepatitis infection status, pathology, total bilirubin, albumin, PT, platelet count, Child-Pugh classification, tumor number, largest tumor size, tumor location, and number of hepatic resections. The choice of these variables was based on the univariate analysis results and/or the known influence of specific factors on the selection of the intervention type. Independent variables entered into the propensity model included the patients’ preoperative data. One-to-one matching between the groups was accomplished using the nearest-neighbor matching method, which was performed without replacement and using a caliper width of 0.2 standard deviations of the logit of the estimated propensity score. After propensity score matching (PSM), the 2 matched groups were handled as unpaired independent groups. Continuous variables are expressed as medians ± standard deviation (SD). The univariate analysis results were compared using the Student’s t, χ^2, Mann-Whitney U, Wilcoxon signed-rank, or Fisher’s exact tests, as appropriate. Factors that were found to be significant in the univariate analysis were subjected to a multivariate logistic regression analysis to determine the adjusted odds ratios (aORs). $P < 0.05$ values were considered significant. All statistical analyses were performed using JMP version 12 (SAS Institute, Inc., Cary, NC, USA).

Results

Patient Demographics

In the LRH group, the laparoscopic procedure was successfully completed in 39 patients. However, 6 patients (13.3%) required conversion to ORH because of bleeding from a hepatic vein branch and adhesions that could not be removed laparoscopically. According to PSM, 37 of the 45 patients in the LRH group were matched with 37 of the 97 patients in the ORH group. The baseline characteristics of the matched study population (74 patients) are summarized in Table 1. There were no significant differences in the demographic or operative characteristics between the groups.

Surgical outcomes are reported in Table 2. Before PSM, of the cases in which repeat hepatic resection was performed laparoscopically, the Pringle maneuver was performed in 11 of 45 patients (24.4%), and of the repeat open resections, the Pringle maneuver was performed in 38 of 97 patients (39.2%) ($P = 0.086$). After PSM, no significant difference was observed between the two groups (24.3% vs. 32.4%, $P = 0.439$).

Table 1 Patient demographic data

	Before PSM			After PSM		
	LRH	ORH	*P* value	LRH	ORH	*P* value
Number	45	97		37	37	
Conversion	6 (13.3%)	NA	NA	6 (16.2%)	NA	NA
Age (years)	68 (45–86)	67 (41–83)	0.320	69 (45–86)	69 (42–81)	0.650
Sex (M/F)	32/13	62/35	0.399	25/12	23/12	0.626
Body mass index (kg/m^2)	22.8 (15.4–29.9)	22.6 (15.9–31.5)	0.560	22.8 (17.4–29.9)	23.4 (17.2–31.3)	0.854
Viral hepatitis infection	25/20	36/61	0.039*	19/18	20/17	0.816
HCC/CCC vs. others	24/21	37/60	0.089	18/19	19/18	0.816
Total bilirubin (mg/dL)	0.6 (0.3–1.4)	0.6 (0.2–1.9)	0.488	0.6 (0.3–1.4)	0.7 (0.3–1.3)	0.929
Albumin (g/dL)	4.1 (3.0–4.9)	4.1 (2.8–4.8)	0.484	4.2 (3.0–4.9)	4.2 (2.8–4.8)	0.650
Prothrombin time (%)	106 (45–129)	105 (26–146)	0.423	105 (45–129)	107 (26–146)	0.202
Platelet count (×10^4/μL)	16.6 (6.6–36.0)	17.5 (5.5–35.4)	0.773	16.5 (6.6–36.0)	16.5 (5.5–33.3)	0.753
Child's grading (A/B)	44/1	95/2	0.951	37/0	37/0	1.000
Number of tumors	1 (1–3)	1 (1–12)	0.010*	1 (1–3)	1 (1–4)	1.000
Size of largest tumor (cm)	2.1 (0.8–5.2)	2.7 (0.5–18.5)	0.008*	2.2 (0.8–5.2)	2.2 (0.5–4.3)	0.844
Tumor location (%)			0.548			0.838
I	2 (4.4%)	4 (4.1%)		2 (5.4%)	2 (5.4%)	
II	5 (11.1%)	8 (8.3%)		5 (13.5%)	4 (10.8%)	
III	10 (22.2%)	9 (9.4%)		9 (24.3%)	4 (10.8%)	
IV	7 (15.6%)	25 (26.0%)		6 (16.2%)	7 (18.9%)	
V	5 (11.1%)	13 (13.5%)		2 (5.4%)	4 (10.8%)	
VI	5 (11.1%)	10 (10.4%)		4 (10.8%)	4 (10.8%)	
VII	6 (13.3%)	13 (13.5%)		5 (13.5%)	8 (21.6%)	
VIII	5 (11.1%)	14 (14.6%)		4 (10.8%)	4 (10.8%)	
Number of hepatic resections	1 (1–5)	1 (1–9)	0.208	1 (1–5)	1 (1–4)	0.392

HCC hepatocellular carcinoma, *CCC* cholangiocellular carcinoma, *PSM* propensity score matching, *LRH* laparoscopic repeat hepatectomy, *ORH* open repeat hepatectomy

*$p < 0.05$

After PSM, the median estimated blood loss was significantly lower in the LRH group (50 mL; range 0–2250 mL) than in the ORH group (350 mL; range 0–1790 mL) ($P < 0.001$).

The LRH group had an 8.1% complication rate, whereas the ORH group had a complication rate of 24.3% ($P = 0.044$). Early-stage complications following surgical treatment, including the incidences of SSIs and remote site infections within 30 days after surgery, were compared. The incidences of superficial incisional, deep incisional, and deep space/organ SSIs were not different between the two groups ($P = 0.556$, 1.000, and 0.304, respectively). Moreover, there were no significant differences between the two groups with respect to the incidence of postoperative bile leakage and respiratory complications, including respiratory infections and pleural effusions ($P = 0.077$, $P = 1.000$).

There were 3 inpatient deaths (3.1%) due to post-hepatic liver failure (PHLF) in two patients and postoperative hemorrhage in one. After PSM, the LRH group had no inpatient deaths, while the ORH group had a mortality rate of 5.4%, although this difference was not significant ($P = 0.152$).

The postoperative medical treatment was similar for the two groups and included intravenous electrolyte and balanced fluid solutions. Oral fluid intake commenced on postoperative day 2. The median length of postoperative intravenous medication administration was 5 days in the both groups. However, the median postoperative length of hospital stay was 9 days (range 5–29 days) in the LRH group and 11 days (range 6–82 days) in the ORH group ($P = 0.024$).

Postoperative aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels peaked on day 1 and had almost normalized on day 7. Postoperative serum albumin, white blood cell (WBC) counts, C-reactive protein (CRP) levels, PTs, and platelet counts peaked on day 2 and then gradually normalized. Postoperatively, serum albumin, AST, ALT, WBC counts, and CRP levels, especially on the peak day, were significantly lower in the LRH group than in the ORH group ($P < 0.001$, 0.001, 0.003, < 0.001, and < 0.001, respectively).

Table 2 Surgical procedures and results

	Before PSM			After PSM		
	LRH	ORH	*P* value	LRH	ORH	*P* value
Number	45	97		37	37	
Conversion	6 (13.3%)	NA	NA	6 (16.2%)	NA	NA
Operative time (min)	200 (43–417)	211 (30–610)	0.081	211 (43–417)	207 (30–440)	0.826
Blood loss (mL)	50 (0–2250)	450 (0–10,970)	0.025*	50 (0–2250)	350 (0–1790)	< 0.001*
Blood transfusion (%)	7 (15.6%)	25 (25.8%)	0.175	7 (18.9%)	8 (24.3%)	0.572
Surgical margin (mm)	5 (0–18)	2 (0–30)	0.060	3 (0–18)	2 (0–13)	0.068
Curative resection, R0 (%)	38 (84.4%)	77 (79.4%)	0.670	32 (86.5%)	29 (78.4%)	0.477
Postoperative complications (%)	3 (6.7%)	25 (25.8%)	0.008*	3 (8.1%)	9 (24.3%)	0.044*
Superficial incisional SSIs	1 (2.2%)	5 (5.2%)	0.413	1 (2.7%)	2 (5.4%)	0.556
Deep incisional SSIs	1 (2.2%)	2 (2.1%)	0.958	1 (2.7%)	1 (2.7%)	1.000
Organ/space SSIs	1 (2.2%)	11 (11.3%)	0.067	1 (2.7%)	3 (8.1%)	0.304
Postoperative bile leakage	0 (0%)	11 (11.3%)	0.019*	0 (0%)	3 (8.1%)	0.077
PHLF	0 (0%)	2 (2.1%)	0.332	0 (0%)	2 (5.4%)	0.152
A	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
B	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
C	0 (0%)	2 (2.1%)		0 (0%)	2 (5.4%)	
Respiratory complications	3 (6.7%)	7 (7.2%)	0.905	3 (8.1%)	3 (8.1%)	1.000
Mortality (%)	0 (0%)	3 (3.1%)	0.233	0 (0%)	2 (5.4%)	0.152
Postoperative length of hospital stay (days)	9 (5–29)	12 (0–98)	0.010*	9 (5–29)	11 (6–82)	0.024*

LRH laparoscopic repeat hepatectomy, *ORH* open repeat hepatectomy, *NA* not applicable, *PSM* propensity score matching, *R0* excision of tumor in one piece without violating the tumor plane, also refers to the achievement of negative margins after sequential re-excision of involved margins, *SSI* surgical site infection, *PHLF* post-hepatectomy liver failure

Risk Factors for Conversion from LRH to ORH

Perioperative factors were compared between patients with and without conversion to ORH. Nineteen factors including age, sex, BMI, diabetes mellitus, viral hepatitis infection, pathology, total bilirubin, albumin, PT, platelet count, the Child-Pugh classification, tumor number, largest tumor size, tumor location, number of hepatic resection sites, hepatic resection method, the Pringle maneuver, operative time, and blood loss were examined.

Estimated blood loss was the only factor that was significantly greater in patients with conversion to ORH than in those without conversion (1113 ± 149 mL vs. 35 ± 59 mL, respectively; $P < 0.001$). The receiver operating characteristic (ROC) curve analysis indicated that the optimal cutoff value for operative blood loss was 160.0 mL, yielding 100.0% sensitivity and 89.5% specificity for conversion to ORH (Table 3).

There was no significant association between whether the original hepatic resection was open or laparoscopic, or whether there was conversion from laparoscopic to open surgery in the repeat hepatic resection ($P = 0.292$). There was also no association between whether the original hepatic resection was in the right or the left liver lobe and the subsequent ORH conversion ($P = 0.292$). There was no association between whether the initial and repeat hepatic resections were in the same lobe or in different lobes ($P = 0.482$). In the aforementioned situations, there was no statistical significance; however, in cases in which the Pringle maneuver was performed, no cases were converted to ORH ($P = 0.135$).

Discussion

For recurrences following hepatic resection, the method of treatment is often decided based on the same criteria that are used to determine the initial treatment method. Among patients with good liver function, there are increasingly more cases of repeat hepatic resection being selected. Because of adhesions that can often occur after the first surgery, repeat hepatic resection has a higher risk of damage to blood vessels and other organs including the biliary tract, intestinal tract, and diaphragm, given that anatomical markers are often lost. For that reason, to sufficiently make use of tactile sensation, the current standard approach at many facilities has been ORH. However, our study findings indicate that LRH can be performed safely, and more favorable results are achieved than with ORH with respect to intraoperative bleeding,

Table 3 Risk factors for conversion from laparoscopic to open repeat hepatic resection

Initial hepatic resection		Conversion to open surgery		*P* value
		(+)	(−)	
Method	Laparoscopy	4	17	0.292
	Open	2	22	
Location	Right lobe	4	17	0.292
	Left lobe	2	22	
Side from initial to repeat resection	Same lobe side	4	20	0.482
	Opposite lobe side	2	19	
Pringle maneuver	(+)	0	11	0.135
	(−)	6	28	
Blood loss (mL)	< 160 mL	0	34	< 0.001*
	≥ 160 mL	6	5	

intraoperative transfusions, postoperative complication rates, and postoperative lengths of hospital stays.

Laparoscopic surgical instrumentation methods have developed rapidly in recent years, and the surgical techniques have improved and are becoming more standardized. However, these surgeries have previously been limited to initial laparoscopic-assisted hepatic resections, with no clear positioning and evidence established for LRH.[14–16] Thus, we investigated the outcomes of ORH versus LRH, as well as present our LRH techniques.

In the present study, PSM was used to sort the patient demographic data. Surgical outcomes, including perioperative blood loss, postoperative complications, and postoperative length of hospital stays, after LRH were more favorable than those after ORH. These results are similar to the reported surgical outcomes after initial laparoscopic hepatic resection thus far. However, the factors for conversion to open resection during initial laparoscopic hepatic resection included a poor surgical field due to intraperitoneal adhesions, inability to identify the tumor, and uncontrollable intraoperative bleeding. Since we believe that those factors will be even more important with LRH at this hospital, we use five processes and devices to increase the safety of these surgeries.

The first process is to carry out an assessment of intraperitoneal adhesions via ultrasonography prior to placement of the first trocar. As Kolecki et al. have reported,[17] if it is confirmed that there are no adhesions based on the respiratory displacement of the abdominal wall and intraperitoneal organs of two cm or more, the first trocar can be placed. Using this assessment method, we have experienced no intraperitoneal organs damage at the time of placement of the first trocar.

The second process involves the surgeon changing the laparoscope insertion port and taking a co-axial position with respect to the hepatic resection site and the laparoscopic monitor, and securing a triangular formation centered on the laparoscope. This avoids unusual positioning of the surgeon's body during LRH, which could potentially decrease the surgeon's ability to recognize cavities due to unforeseen adhesions. It also facilitates better control of the left and right clamps in the direction of the organs. This means that the resected side and the dissected surface of the preserved side are sufficiently secured. Thus, operability is improved, blind maneuvering is avoided, and fewer opportunities are afforded for the clamps to be in a tangential direction to the dissected surface.

The third process involves a determination of previous surgery–involved detachment of the left lobe, which increases the likelihood that the stomach and duodenum may have adhesion connecting them to the remaining liver. If the previous surgery involved detachment of the right lobe, then it would be common for the diaphragm, colon, retroperitoneum, and adrenal gland to have adhesions to the remaining liver. In mobilizing the liver, we then must take care to preserve the liver membrane as much as possible, so that even those anatomical landmarks lost due to adhesions are preserved and other organs are not damaged.

The fourth process involves the use of is ICG-fluorescence imaging with intraoperative ultrasonography to identify the tumor. In repeat hepatic resections, thermocoagulation is easy to perform when adhesions have been detached and the liver has been mobilized. Tumors on the liver surface then can be very poorly defined, making visual observation by ultrasonography insufficient for tumor identification. With ICG-fluorescence imaging, the tumors on the liver surface in particular will show green fluorescence, thus facilitating tumor site(s) identification.[18]

The final process involves adequate control of perioperative bleeding. In past research, the intraoperative bleeding volume has been cited as a risk factor for conversion to ORH during LRH. For venous bleeding, it is effective to increase the abdominal air pressure, lower the CVP, reduce ventilatory volume, and reduce positive end-expiratory pressure.[19] Furthermore, when detaching the liver parenchyma, we generally attempt to disrupt the hepatic blood flow to decrease intraoperative bleeding so that the surgery can be safely conducted with a dry liver dissection surface. However, whether the first hepatic resection is open or laparoscopic, taping of the hepatoduodenal ligament for the Pringle maneuver can be difficult due to adhesions in the hepatic portal area. Therefore, we clamp the blood vessels supplying blood flow to the liver by compressing the hepatoduodenal ligament with removable intestinal clamps.

Our study had some limitations. First, the total number of patients was relatively small. Additionally, there were various biases such as previous hepatic resection type, hepatic resection quality, and the retrospective nature of the control group. Although these various factors allow for the chance of a possible statistical error, the conclusions appear reliable. The potential historical bias is reduced by the design of the study resulting in an LRH group that was well-matched with the ORH group for all demographic data. The preoperative management of patients was also similar in the both groups. Moreover, to adjust for the differences in tumor size, tumor number, and magnitude of operation, the short-term results were compared. However, in the future, randomized controlled trials with a greater number of cases are needed, as are investigations through meta-analysis studies.

In conclusion, LRH can be safely performed using various surgical techniques. More favorable results are achieved with LRH than with ORH, in terms of surgical outcomes including intraoperative bleeding, intraoperative transfusions, postoperative complication rates, and postoperative length of hospital stays.

Author Contributions YI conceived the study concept and design, was involved with patient care, and drafted the manuscript. KF, MI, SK, AT, HH, WO, YT, TT, TO, SM, MY, AI, AA, KK, SF, FH, MG, KT, JO, KH, and KU were involved with formation of the study concept and design, patient care, and drafting of the manuscript. All authors have read and approved the final version of the manuscript.

Compliance with Ethical Standards

All patients were fully informed of the study design according to the Ethics Committee on Clinical Investigation of Osaka Medical College Hospital (No. 1828 and 1997) and provided written informed consent.

Conflict of Interest Drs. Y. Inoue, K. Fujii, M. Ishii, S. Kagota, A. Tomioka, H. Hamamoto, W. Osumi, Y. Tsuchimoto, T. Terasawa, T. Ogura, S. Masubuchi, M. Yamamoto, A Imoto, A Asai, K. Komeda, S. Fukunishi, F. Hirokawa, M. Goto, K. Higuchi, and K. Uchiyama declare no conflict of interests.

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