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Laparoscopic liver resection for hepatocellular carcinoma in cirrhotic patients: 10-year single-center experience

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Abstract

Background Liver resection in cirrhotic patients reported to have higher morbidity and mortality rates compared to non-cirrhotic patients. Recently, there is increased acceptance of laparoscopic approach in liver surgery. However, few reports evaluated laparoscopic liver resection (LLR) for hepatocellular carcinoma (HCC) in cirrhotic patients. The aim of this study is to evaluate our experience of LLR for HCC and to compare perioperative and long-term outcomes between patients with and without liver cirrhosis (LC).

Methods A retrospective analysis of 232 patients who underwent LLR for HCC between 2004 and 2013 was carried out. Patients were divided into two groups according to the pathological status of their liver parenchyma, in terms of presence or absence of LC.

Results LC group had 141 patients, and non-LC group had 91 patients. There were no statistically significant differences between both groups regarding operation time, blood loss, transfusion requirements, intraoperative complications, hospital stay, and postoperative complications. Long-term oncologic outcomes were comparable between both groups regarding the recurrence rates ($p = 0.067$), overall survival (OS) rates ($p = 0.908$), and disease-free survival (DFS) rates ($p = 0.197$). The 1-, 3-, 5-, and 7-year OS were 91.7, 85.5, 79.4, and 70.1 % in LC group, and 93.9, 86, 79.5, and 72.3 % in non-LC group. The 1-, 3-,5-, and 7-year DFS were 75.3, 52.4, 42.6, and 32.7 % in LC group, and 74.1, 57.6, 55.3, 50.2 % in non-LC group.

Conclusions LLR for HCC is feasible in patients with LC. Cirrhotic patients showed comparable perioperative and long-term outcomes to non-cirrhotic patients.

Keywords Hepatocellular carcinoma · Liver resection · Liver cirrhosis · Laparoscopy

Hepatocellular carcinoma (HCC) is the fifth most common cancer worldwide [1, 2]. Liver resection (LR) and transplantation remain the main stay of curative treatment of HCC. However, liver transplantation is restricted by donor shortage, high costs, and the burden of life-long immunosuppression [3, 4]. Therefore, LR remains the commonly used strategy of curative treatment for HCC patients with preserved liver functions. On the other hand, LR in the context of cirrhosis is associated with high incidence of operative difficulties, postoperative complications, and recurrence rates [5, 6].

In the recent years, there is increased acceptance of laparoscopic approach in liver surgery. Indications for laparoscopic liver resection (LLR) are expanded to include malignant tumors, and unfavorable locations as tumors in the postero-superior segments and close to major vessels [7, 8].

Recent studies showed that LLR is associated with reduced operative stress and postoperative complications [9, 10]. Therefore, LLR is expected to be more beneficial to cirrhotic patients. However, it remains a matter of debate whether LLR is appropriate for HCC, especially in cirrhotic patients.

Few reports have evaluated LLR for HCC in cirrhotic patients [11–16]. Most of these reports are limited to sub-

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capsular tumors located in antero-lateral segments [11–13]. Also, few reported long-term outcomes of LLR for HCC [13, 16].

The aim of this study is to evaluate 10-year single-center experience of LLR for HCC and compare perioperative and long-term outcomes between patients with and without liver cirrhosis.

Methods

Study design

During the period between January 2004 and December 2013, 389 patients underwent liver resection for HCC at Seoul National University Bundang Hospital (SNUBH), South Korea. Of them, 232 patients underwent LLR and were enrolled in this study.

Patients were divided into two groups according to the status of their liver parenchyma, with and without liver cirrhosis (LC). LC group had 141 patients with histologically confirmed F4 cirrhosis according to the Metavir score [17], whereas non-LC group had 91 patients. F3 stage is a pre-cirrhotic liver disease. In this study, we included only patients with overt LC (F4).

Preoperative evaluation

All patients underwent detailed laboratory evaluation including complete blood count, liver function tests, serum α-feto-protein (AFP), blood glucose, and indocyanine green (ICG) clearance. The diagnosis and staging of HCC were done by triphasic computed tomography (CT) of the abdomen. Some patients were also assessed by contrast-enhanced ultrasound (US) and magnetic resonance imaging to detect additional lesions.

For all patients, treatment strategies were discussed at multidisciplinary conferences including hepato-pancreato-biliary surgeon, hepatologists, interventional radiologists, and medical oncologists.

Generally, LR was applied for patients with preserved liver functions (i.e., sufficient future liver remnant), without signs of severe portal hypertension, without evidence of extrahepatic metastasis, and with American Society of Anesthesiologists (ASA) grade <III [18].

Surgical procedure

The types of LRs were defined according to Brisbane 2000 terminology [19]. LRs were classified into minor (≤2 segments) or major (>2 segments) according to Couinaud classification. Anatomical resections were generally more preferred if the future liver remnant is adequate, otherwise non-anatomical resections were applied.

The surgical technique was described elsewhere [8]. Generally, the patient was placed in supine or French position, and a periumbilical port was placed under direct vision. A carbon dioxide pneumo-peritoneum was created with pressure 12 mmHg, and three or four additional ports were used. General abdominal evaluation to exclude metastasis was done, and then liver evaluation was done by intraoperative US to determine tumor location, vascular relations and to exclude multiplicity of tumors. Pringle maneuver was used in some cases for non-anatomical resections. Parenchymal transection was done by combination of ultrasonic shears (harmonic scalpel; Ethicon Endo-Surgery Inc., Cincinnati, OH, USA) and Cavitron ultrasonic surgical aspirator (CUSA; Valleylab, Inc., Boulder, CO, USA). Intraoperative US was routinely used to guide the resection planes. LigaSure (ValleyLab, Inc.) was used to control small vessels, and larger vessels were secured by Hem-o-lock clips (Teleflex Medical, Research Triangle Park, NC, USA). Division of hepatic veins was done by vascular staplers. Fibrin glue sealant (Greenplast, Green Cross Corp., Seoul, Korea) was applied to the cut surface, and the specimen was placed in a retrieval bag and extracted through an enlarged port site or Pfannenstiel incision.

Postoperative care and follow-up

Postoperatively, all patients underwent daily follow-up of liver functions and abdominal CT was done routinely on fifth postoperative day (POD).

After discharge, all patients were followed up every 3 months in the first 2 years and then every 6 months afterward. Follow-up assessments included liver function tests, serum AFP, and triphasic CT scan of the abdomen.

Clinical outcomes

Postoperative morbidity was defined as events occurring during the first 60 PODs and was graded according to the Clavien–Dindo classification [20]. Postoperative biliary fistula and liver cell failure were defined according to the International Study Group of Liver Surgery (ISGLS) [21, 22].

Postoperative mortality was defined as death within 90 days after liver resection. Overall survival (OS) is calculated from the day of surgery to the day of death or last follow-up. Disease-free survival (DFS) is calculated from the day of surgery to the day of tumor recurrence or the day of death or last follow-up.

Statistical analysis

Categorical data are expressed as numbers and percentages, and continuous data are expressed as median and range or mean and standard deviation.

Fisher's exact test was used to compare categorical variables, and Mann–Whitney test was used to compare continuous variables. Survival rates were calculated by Kaplan–Meier method and were compared by log-rank test.

Data management and statistical analyses were done using IBM-SPSS statistical package (v. 20). A p value <0.05 was considered to be statistically significant.

Results

Baseline characteristics

Baseline characteristics of patients of the two groups are shown in Table 1. There were significant differences between the two groups in liver function tests, platelets count, virology status, and model for end-stage liver disease score, and ICG clearance (15 min). Non-LC group had three Child-Pugh class B patients. These patients were diagnosed as hilar cholangiocarcinoma based on preoperative radiological evaluation, but postoperatively they were diagnosed as HCC invading the bile ducts based on the pathological examination.

Surgical outcomes

Operative data of the two groups are shown in Table 2. There were no statistically significant differences between the two groups regarding tumor number, site, and presence of ascites and lymph nodes. Non-LC group showed larger median tumor size (LC, 2.5 cm; non-LC, 3 cm; $p = 0.001$).

More minor resections were done in LC group [LC, 124 (97.9 %); non-LC, 71 (78 %); $p = 0.011$]. There were no statistically significant differences between the two groups regarding operation time, blood loss, transfusion requirements, and intraoperative complications. No operative mortality occurred in both groups.

Open conversion occurred in 13 cases (9.1 %) of LC group and 10 cases of non-LC group (11 %), ($p = 0.824$). Bleeding was the most common cause of open conversion [LC, 7 (5 %); non-LC, 2 (2.2 %)].

Table 1 Baseline characteristics

	LC ($N = 141$)	Non-LC ($N = 91$)	p value
Age (years)	57 (31–87)	57 (26–79)	0.139
Sex (male:female)	100:41 (70.9:29.1 %)	56:26 (71.4:28.6 %)	0.934
BMI (kg/m^2)	24.1 (15.9–44.2)	24.3 (16.4:48.9)	0.859
Previous abdominal operations	23 (16.3 %)	18 (19.8 %)	0.508
Previous TACE	37 (26.2 %)	17 (18.7 %)	0.185
Previous RFA	12 (8.5 %)	4 (4.4 %)	0.229
Child-Pugh class			0.073
A	125 (88.7 %)	87 (95.6 %)	
B	13 (9.2 %)	3 (4.4 %)	
C	3 (2.1 %)	0	
Albumin (g/dL)	4.1 (2.8–5.2)	4.3 (2.9–4.8)	<0.001
Bilirubin (mg/dL)	0.8 (0.2–3.1)	0.7 (0.2–2.8)	0.019
INR	1.1 (0.9–1.6)	1.03 (0.8–1.8)	<0.001
SGPT (IU/L)	36 (9–308)	28 (10–330)	0.008
SGOT (IU/L)	37 (14–684)	27 (14–291)	<0.001
Platelets (×1000/mcL)	131 (45–247)	180 (71–400)	<0.001
Virology			0.001
HBV	109 (77.3 %)	58 (63.7 %)	
HCV	14 (9.9 %)	5 (5.5 %)	
Both +ve	1 (0.7 %)	0	
Both –ve	17 (12.1 %)	28 (30.8 %)	
ICG 15 min (%)	9.03 (0.1–243)	6.4 (0.2–37.9)	<0.001
MELD score	7 (6–18)	7 (6–14)	0.002
AFP (ng/mL)	15.7 (1.1–35,000)	9.1 (0.8–9210)	0.227

TACE transarterial chemoembolization, *RFA* radiofrequency ablation, *HBV* hepatitis C virus, *HCV* hepatitis C virus, *ICG* indocyanine green clearance, *MELD* model for end-stage liver disease, AFP α-feto-protein

Table 2 Operative data

	LC (*N* = 141)	Non-LC (*N* = 91)	*p* value
Number (single:multiple)	112:39 (79.4:20.6 %)	80:10 (87.9:12.1 %)	0.454
Site			0.375
Segments II–VI	92 (65.7 %)	65 (71.5 %)	
Segments I, VII, VIII	41 (28.7 %)	25 (27.4 %)	
Bilobar	8 (5.6 %)	1 (1.1 %)	
Size (cm)	2.5 (1–9)	3 (0.9–12)	**0.001**
Ascites	12 (8.5 %)	3 (3.3 %)	0.085
LN	2 (1.4 %)	No	0.357
Extent of resection (minor:major)	124:17 (87.9:12.1 %)	71:20 (78:22 %)	**0.011**
Tumorectomy	56 (39.7 %)	22 (24.2 %)	
Segmentectomy	30 (21.3 %)	14 (15.4 %)	
Bisegmentectomy	0	2 (2.2 %)	
Left lateral sectionectomy	19 (13.5 %)	20 (22 %)	
Left hepatectomy	5 (3.5 %)	4 (4.4 %)	
Right anterior sectionectomy	3 (2.1 %)	0	
Right posterior sectionectomy	14 (9.9 %)	10 (11 %)	
Right hepatectomy	9 (6.4 %)	16 (17.6 %)	
Central hepatectomy	2 (1.4 %)	0	
Combined resection	3 (2.1 %)	3 (3.3 %)	
Operative time (minutes)	245 (35–950)	255 (70–930)	0.453
Blood loss (ml)	500 (20–14,300)	400 (20–13,600)	0.177
Blood transfusion	30 (21.3 %)	23 (25.5 %)	0.481
Intraoperative complications			
Bleeding	17 (11.9 %)	11 (12.1 %)	0.994
Diaphragm injury	15 (10.6 %)	10 (11 %)	
Both	1 (0.7 %)	0	
Gas embolism	1 (0.7 %)	0	
	0	1 (1.1 %)	
Intraoperative mortality	No	No	–

LN lymph nodes

Bold values are statistically significant

Pathological outcomes

There were no statistically significant differences between groups according to tumor satellites, microvascular invasion, capsular invasion, Edmondson–Steiner grade, or pT stage, as shown in Table 3. The non-LC group had a significantly larger resection margin than did the LC group [LC, 0.8 cm (0.01–6.5); non-LC, 1.3 cm (0.1–6.8); $p = 0.019$].

Postoperative outcomes

There were no statistically significant differences between groups regarding hospital stay, postoperative complications, complication types, and grades as shown in Table 4.

Fluid collections occurred in 16 patients (11.3 %) in LC group and in six patients (6.6 %) in non-LC. In LC group, they were managed conservatively in four patients (2.8 %), US-guided tube drainage in 11 patients (7.8 %), and surgically in one patient (0.7 %). All cases of fluid collection in the non-LC group were managed using US-guided tube drainage.

Bile leakage occurred in three patients (2.1 %) in LC group which was managed by conservative measures in one patient (0.7 %), US-guided tube drainage in one patient (0.7 %), and endoscopic retrograde biliary stent in one patient (0.7 %). One patient (1.1 %) in non-LC group had bile leakage which was managed by US-guided tube drainage.

Early postoperative mortality occurred in two patients (1.4 %) in LC group due to acute respiratory distress syndrome and multi-organ failure.

Long-term outcomes

The mean follow-up period for all patients was 42.3 ± 29.6 months (39.4 ± 27.4 months in LC group and

Table 3 Pathological data

	LC ($N = 141$)	Non-LC ($N = 91$)	p value
Resection margin			
Median (cm)	0.8 (0.01–6.5)	1.3 (0.1–6.8)	**0.019**
<1: ≥ 1 cm	81:60 (57.4:42.6 %)	37:54 (40.7:59.3 %)	**0.015**
R0:R1	135:6 (95.7:4.3 %)	90:1 (98.9:1.1 %)	0.171
Satellites	12 (8.5 %)	9 (9.9 %)	0.719
Microvascular invasion	48 (34 %)	32 (35.2 %)	0.797
Capsular invasion	37 (26.2 %)	33 (36.3 %)	0.96
Edmonson–Steiner grade			
I	12 (8.5 %)	9 (9.9 %)	0.119
II	48 (59.6 %)	58 (63.7 %)	
III	36 (25.5 %)	23 (25.3 %)	
IV	9 (6.4 %)	1 (1.1 %)	
pT stage			
T1	79 (56 %)	53 (58.2 %)	0.748
T2	56 (39.7 %)	33 (36.3 %)	
T3	5 (3.5 %)	4 (4.4 %)	
T4	1 (0.7 %)	1 (1.1 %)	

Bold values are statistically significant

44.4 ± 31.6 months in non-LC group). Recurrence occurred in 70 patients (49.6 %) in LC group and 34 patients (37.4 %) in non-LC group; there was no statistically significant difference between the groups ($p = 0.067$). There were no statistically significant differences between groups in terms of recurrence pattern and recurrence treatment as shown in Table 5.

Mortality occurred in 27 patients (19.1 %) in LC group and 13 patients (14.3 %) in non-LC; there was no statistically significant difference between the two groups ($p = 0.238$).

The long-term oncological outcomes were comparable between groups regarding the rates of OS ($p = 0.908$) and DFS ($p = 0.197$). The 1-, 3-, 5-, and 7-year OS rates were 91.7, 85.5, 79.4, and 70.1 %, respectively, in the LC group, and 93.9, 86, 79.5, and 72.3 %, respectively, in the non-LC group (Fig. 1). The 1-, 3-, 5-, and 7-year DFS rates were 75.3, 52.4, 42.6, and 32.7 %, respectively, in the LC group, and 74.1, 57.6, 55.3, and 50.2 %, respectively, in the non-LC group (Fig. 2).

Discussion

HCC is associated with LC in approximately 60–90 % of cases, with chronic viral hepatitis (B and C infection) being the main risk factor [23]. Management of HCC that is associated with LC is a complex clinical condition. Selecting the appropriate treatment modality is dependent not only on tumor stage but also on the severity of the underlying liver disease. Nevertheless, LR remains the main curative treatment [24].

When considering LR in the setting of LC, it is important to consider the degree of surgical stress to the patient and the liver, as well as the oncological outcomes. LR in cirrhotic patients is associated with high rates of morbidity and mortality which is partially due to abdominal laparotomy [25].

Recently, LLR has been widely accepted and safely used as a curative treatment for patients with HCC [10]. LLR is associated with several advantages as reduced surgical stress, and blood loss, shorter hospital stay, and decreased postoperative morbidity and mortality. In addition, some studies reported good long-term oncological outcomes in HCC patients [13, 26, 27]. However, it remains unclear whether LLR for HCC is beneficial to cirrhotic patients. Initially, LC was considered a contraindication for LLR [28, 29]. Recently, with the growing surgical experience and introduction of new equipment, some studies reported good perioperative outcomes after LLR for HCC in cirrhotic patients [11, 13, 16, 30]. However, these studies were limited to minor resections of easily accessible lesions and enrolled few numbers of patients. Also, most of them lack the long-term oncological outcomes. The current study included variable-sized tumors located in all liver segments including the posterosuperior segments, and all types of liver resections including major hepatectomies, and reported the long-term oncological outcomes.

For long time, there had been a consensus that a diagnosis of Child-Pugh class C was a contraindication for

Table 4 Postoperative outcomes

	LC ($N = 141$)	Non-LC ($N = 91$)	p value
Hospital stay (days)	8 (2–101)	3 (3–97)	0.051
Complications	27 (19.1 %)	11 (12.1 %)	0.199
Complication type			
General	2 (1.4 %)	2 (2.2 %)	0.76
Surgical	13 (9.2 %)	4 (4.4 %)	
Liver related	4 (2.8 %)	2 (2.2 %)	
Mixed	8 (5.7 %)	3 (3.3 %)	
Clavien–Dindo grade			
I	9 (6.4 %)	3 (3.3 %)	0.668
IIIa	12 (8.5 %)	7 (7.7 %)	
IIIb	4 (2.8 %)	1 (1.1 %)	
V	2 (1.4 %)	0	
General complications			
Respiratory	8 (5.7 %)	3 (3.3 %)	0.408
Renal	0	1 (1.1 %)	0.214
Ileus	1 (0.7 %)	1 (1.1 %)	0.423
Systemic infection	1 (0.7 %)	0	0.423
Unknown fever	1 (0.7 %)	0	0.423
Variceal bleeding	1 (0.7 %)	0	0.423
DU bleeding	1 (0.7 %)	0	0.423
Surgical related			
Port site infection	1 (0.7 %)	0	0.423
Port hernia	1 (0.7 %)	1 (1.1 %)	0.766
Internal hemorrhage	1 (0.7 %)	1 (1.1 %)	0.766
Fluid collections	16 (11.3 %)	6 (6.6 %)	0.206
Lymphatic leakage	1 (0.7 %)	0	0.423
Liver related			
Bile leakage	3 (2.1 %)	1 (1.1 %)	0.559
Transient liver failure and ascites	7 (5 %)	2 (2.2 %)	0.25
Early mortality	2 (1.4 %)	No	0.256

DU duodenal ulcer

conventional LR [31]. Abdel-Atty et al. [32] reported safe LLR in three Child-Pugh class C patients. In the current study, LLR was performed also in three Child-Pugh class C patients. Although they underwent minor resections, they could recover after surgery without significant morbidities. These findings suggest that laparoscopy enables extension of the indications of LR to include Child-Pugh C patients who are excluded from conventional LR.

In the current study, minor liver resections were more performed in the LC group. In addition, LC group showed a smaller median tumor size and smaller resection margin. As described above, the outcome of LR is dependent not only on tumor stage, but also on the severity of the underlying liver disease [24]. The risk of morbidity after LR depends on the balance between the liver function and the operative procedure used [33]. In our group, we adopted a patient-tailored approach including parenchymal sparing procedures as wedge resection, and anatomical resections in cirrhotic patients with limited hepatic functional reserve [34, 35]. Anatomical LR was performed when the tumor was deeply located or relatively larger in size, whereas a tumorectomy was performed when the tumor was small and located superficially.

Cirrhotic patients have higher morbidity and mortality rates after conventional hepatectomy than do non-cirrhotic patients [36]. Minor open LR in cirrhotic patients is often associated with liver failure, refractory ascites, and wound-related complications [37]. In the current study, there was no statistically significant difference in the incidence of postoperative morbidity and mortality between the two groups. This provides an important finding supporting the safety and the feasibility of LLR for HCC in LC.

Posthepatectomy liver failure (PHLF) and ascites are the primary causes of high early postoperative mortality after

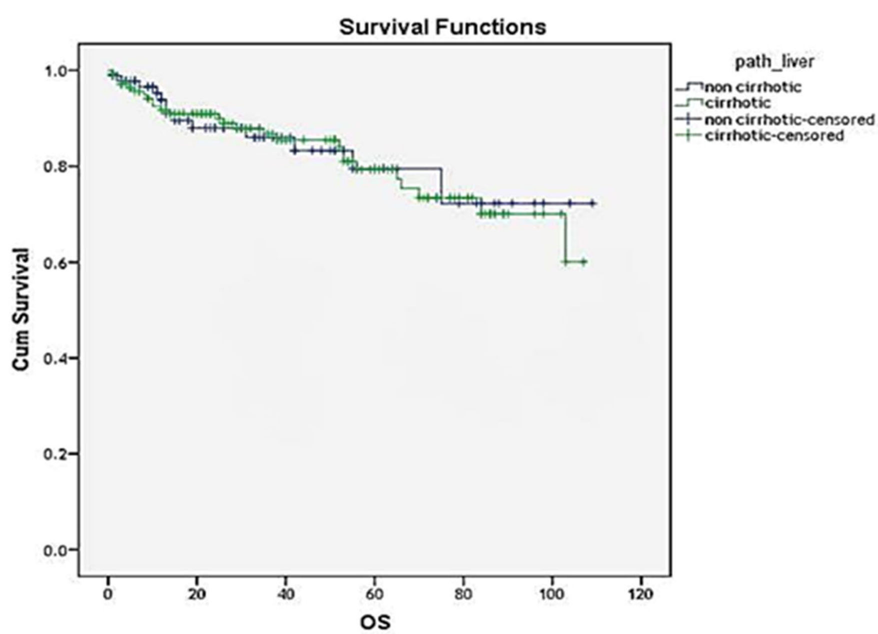
Table 5 Long-term outcomes

	LC ($N = 141$)	Non-LC ($N = 91$)	p value
Mortality	27 (19.1 %)	13 (14.3 %)	0.238
Recurrence	70 (49.6 %)	34 (37.4 %)	0.067
Mean recurrence time (months)	29.3 ± 27.6	29.1 ± 28.3	0.86
Recurrence pattern			0.735
Intrahepatic	59 (41.8 %)	25 (27.5 %)	
Extrahepatic	2 (1.4 %)	1 (1.1 %)	
Both	8 (5.7 %)	8 (8.8 %)	
Recurrence treatment			0.635
Redo	7 (5 %)	2 (2.2 %)	
TACE	14 (9.9 %)	11 (12.1 %)	
RFA	10 (7.1 %)	1 (1.1 %)	
Medical	6 (4.3 %)	4 (4.4 %)	
Surgery + RFA	2 (1.4 %)	1 (1.1 %)	
TACE + RFA	28 (19.9 %)	15 (16.5 %)	
Transplantation	1 (0.7 %)	0	

TACE transarterial chemoembolization, *RFA* radiofrequency ablation

LR for HCC [14]. The incidence of PHLF after conventional LR ranges from 1.2 to 32 % [38–41]. LLR is expected to have lower incidence of PHLF and ascites. This may be attributed to less invasiveness of laparoscopy which entails preserved abdominal musculature by avoiding large abdominal incisions and preserved parietal circulation and lymphatics [42, 43]. This advantage could be the most important in the postoperative course after LLR in cirrhotic patients, who could achieve results comparable to non-cirrhotic patients. In the current study, although PHLF and ascites occurred more in LC group, the difference was not statistically significant.

Another important advantage in the postoperative course after LLR in cirrhotic patients is its lower rate of infectious complications. Cirrhotic patients are more vulnerable to such complications because of deterioration of protein



Number at risk

LC	141	117	73	47	26
Non-LC	91	71	42	16	11

Fig. 1 Overall survival rates of patients in the LC and non-LC groups ($p = 0.908$, log-rank test)

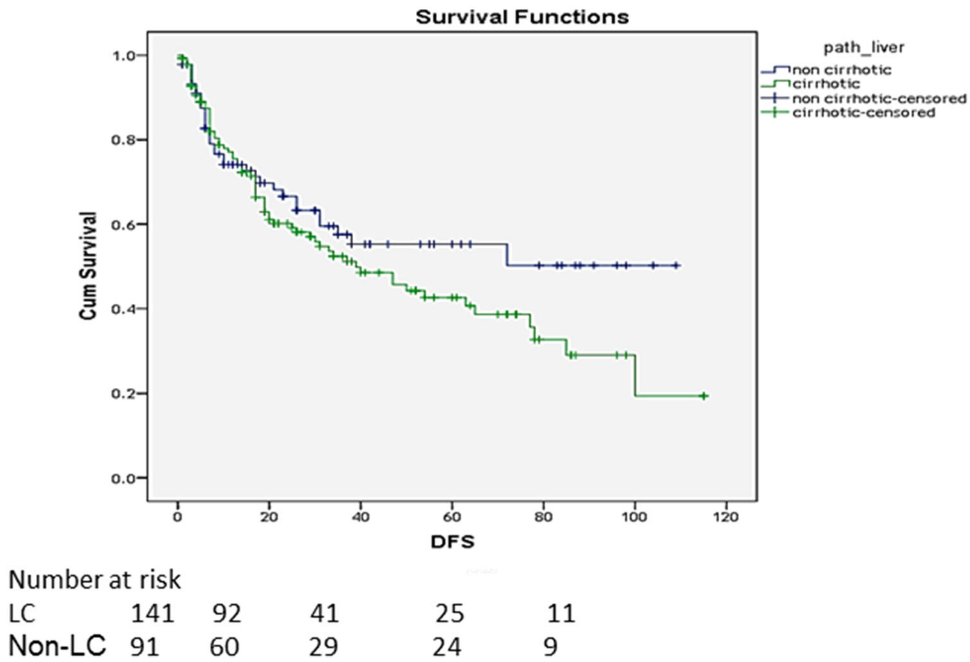


Fig. 2 Disease-free survival rates of patients in the LC and non-LC groups ($p = 0.197$, log-rank test)

synthesis and metabolism, pancytopenia and hypersplenism, and ascites leakage though the wound prevents healing and encounters infection [44]. In the current study, there was no statistically significant difference in the incidence of systemic or local infectious complications between the two groups.

One of the major obstacles of LLR in cirrhotic patients is the risk of massive bleeding. Cirrhotic patients are at great risk of bleeding related to primary hemostasis dysfunction [44]. In the current study, there was no significant difference in the incidence of intraoperative blood loss and transfusion requirements between the two groups. This can be explained by the hemostatic effect of pneumo-peritoneum, better magnification, the use of new devices for parenchymal transection, and the application of anatomical resections. The use of Pringle maneuver in LLR is recommended particularly when performing non-anatomical resections [45, 46].

A high recurrence rate after LR adversely affects the prognosis of HCC patients [47]. Coexisting LC is associated with a higher recurrence rate, possibly due to multicentric carcinogenesis, and lower DFS and OS rates after conventional LR for HCC [48]. In the current study, the recurrence rate was higher in the LC group than in the non-LC group, although the difference was not significant.

In HCC patients, a previous liver resection may compromise subsequent liver transplantation due to postoperative adhesions that increase the surgical difficulty. Such technical obstacles can be reduced by the use of laparoscopy, especially in cirrhotic patients. Laurent et al. [49] compared the outcomes of liver transplantation after initial LLR or OLR. They found that LLR facilitated liver transplantation, in comparison with OLR, in terms of reduced operative time, blood loss, and transfusion requirements. Still there is no data regarding the effect of LLR on liver transplantation regarding tumor recurrence and survival.

Previous studies had identified LC as a negative predictive factor for OS after conventional LR for HCC [44, 50–52]. In the current study, both groups showed similar OS rates up to 7 years after LLR, which is different from other studies reporting conventional LR [44, 50–52]. This advantage could be attributed to the strong follow-up protocol used after LLR, which enables early detection and management of tumor recurrence and thereby improves patient survival (Table 6).

Although the current study included a large number of patients with histologically confirmed liver cirrhosis, it still has some limitations because it was a retrospective and non-randomized study.

In conclusion, the current study demonstrated that LLR for HCC is feasible in patients with cirrhosis. LLR in cirrhotic patients showed comparable results to non-cirrhotic patients in terms of perioperative and long-term outcomes. However, prospective comparative studies are still necessary to prove the superiority of LLR for HCC in cirrhotic patients.

Table 6 Previous studies of laparoscopic liver resection for hepatocellular carcinoma in liver cirrhosis

	Study type	Patients number	Indications	Morbidity	PHLF	Early mortality	5 years OS	5 years DFS
Belli et al. [11]	Whole cohort (lap vs. open)	54	Sub-capsular, in antero-lateral segments, <5 cm	10 (19 %)	8 (14.8 %)	1 (2 %)	NA	NA
Santambrogio et al. [12]	Single group	22	Superficial, in antero-lateral segments, <5 cm	2 (9 %)	NA	No	NA	NA
Truant et al. [13]	Case-matched (lap vs. open)	36	Sub-capsular, in antero-lateral segments, <5 cm	9 (25 %)	5 (13.9 %)	No	35.5 %	70 %
Casaccia et al. [14]	Single group	20	Peripheral, in antero-lateral segments, <5 cm	3 (15 %)	1 (5 %)	No	NA	NA
Cheung et al. [16]	Case-matched (lap vs. open)	32		2 (6.3 %)	NA	No	54.5 %	76.6 %
Kanazawa et al. [15]	Whole cohort (lap vs. open)	28	<3 cm	3 (10.7 %)	No	No	NA	NA
Memeo et al. [30]	Case-matched (lap vs. open)	63		9 (20 %)	1 (2 %)	1 (2 %)	19 %	59 %
Current study	Whole cohort (cirrhosis vs. non-cirrhosis)	141		27 (19.1 %)	7 (5 %)	2 (1.4 %)	79.4 %	42.6 %

PHLF posthepatectomy liver failure, *DFS* disease-free survival, *OS* overall survival, *NA* not addressed

Disclosures Ahmed Shehta, Ho-Seong Han, Yoo-Seok Yoon, Jai Young Cho, and YoungRok Choi declared that there were no conflicts of interest or financial ties to disclose.

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