Original paper General surgery

Videosurgery

Risk factors associated with postoperative complications and prolonged postoperative length of stay after laparoscopic liver resection

Haili Zhang[1], Dufu Kang[2], Fei Liu[1], Bo Li[1], Wei Zhang[3], Yonggang Wei[1]

[1]Department of Liver Surgery and Liver Transplantation Centre, West China Hospital of Sichuan University, Chengdu, China
[2]Department of Liver Surgery, People's Hospital of Pu'er, Pu 'er City, Yunnan Province, China
[3]Sichuan University, West China Hospital, Laboratory of Critical Care Medicine, Shuang Liu District, Chengdu, China

Videosurgery Miniinv 2022; 17 (3): 515–523
DOI: https://doi.org/10.5114/wiitm.2022.118104

Abstract

Introduction: *Laparoscopic liver resection (LLR) has expanded rapidly. Previously published studies are limited to small samples and selected patients. Comprehensive data that may significantly influence the incidence of perioperative complications and postoperative length of stay (PLOS) are lacking.*
Aim: *To characterize complications after LLR and to identify risk factors associated with postoperative complications and prolonged PLOS.*
Material and methods: *This study was carried out at a high-volume HPB centre and included all patients who underwent LLRs between 2015 and 2018. Postoperative complications were analysed in detail. Logistic regression was used to identify independent risk factors. The primary outcome was postoperative complications with a comprehensive complication index (CCI) ≥ 26.2. The second outcome was prolonged length of stay.*
Results: *We identified 938 patients who underwent LLR. In the full cohort, 79 (8.4%) patients experienced major complications with a CCI ≥ 26.2, with postoperative mortality in 4 (0.4%) patients. On multivariate analysis, the diagnosis of primary (OR = 8.97, 95% CI: 2.54–43.74, p = 0.001) and metastatic liver tumours (OR = 5.74, 95% CI: 1.20–30.90, p = 0.028), infectious liver disease (OR = 24.04, 95% CI: 5.30–129.53, p < 0.001), difficult liver resection (OR = 2.77, 95% CI: 1.29–6.69, p = 0.014), and intraoperative bleeding > 1000 ml (OR = 9.29, 95% CI: 3.40–26.43, p < 0.001) were independent factors that increased the odds of major complications. The median PLOS after the operation was 5 days (range: 2–35 days). Factors that independently influenced prolonged PLOS on multivariate analysis were age over 70 years, metastatic liver tumour, difficult liver resection, liver cirrhosis, and right hepatectomy.*
Conclusions: *LLR remains safe for most liver space-occupying lesions. Several preoperative and intraoperative factors associated with the risk of complications and prolonged PLOS were identified. These factors should be considered during patient selection and perioperative management.*

Key words: *laparoscopic liver resection, postoperative complication, comprehensive complication index, prolonged postoperative length of stay.*

Introduction

Laparoscopic liver surgery was first reported in 1991 [1]. Over the past 3 decades, laparoscopic liver resections (LLRs) have been introduced into clinical practice based on meta-analyses and large propensity score-matched studies [2–5], which demonstrated

Address for correspondence
Dr. Yonggang Wei, Department of Liver Surgery and Liver Transplantation Centre, West China Hospital of Sichuan University, 37 Guo Xue Road, Wu hou District, Chengdu 610041, China, e-mail: drweiyg@163.com; Wei Zhang, Sichuan Univ, West China Hospital, Laboratory of Critical Care Medicine, 777 Xin Tong Avenue, Shuang Liu District, Chengdu 610200, China, e-mail: zhangwei197610@163.com

the usual benefits of minimally invasive procedures, without loss of efficacy of the operations.

For minor resections, a laparoscopic approach was found to be the only independent factor to reduce the complication rate in resections for HCC [6]. However, minor resections involved a wide range of procedures, including partial resection, anatomic mono- or bisegmentectomies, and complex resections of tumours in close proximity to vessels. Theoretically, different minor resections are associated with different difficulties of LLR, leading to different outcomes. For major resections, LLR was also feasible and safe [7]. Although postoperative complications after LLR have declined compared with open liver resection, approximately 10.5% to 54.6% of patients still experience postoperative complications after LLR [7–9]. Previously published studies are limited to small samples and selected patients [7, 10]. Comprehensive data that may significantly influence the incidence of perioperative complications and postoperative length of stay (PLOS) are lacking. Traditionally, the most widely used grading system of surgical complications was the Clavien-Dindo [11] classification, but more recently, the comprehensive complication index (CCI) – which integrates all recorded complications weighted by severity in a single formula – has been shown to be a more sensitive measure [12].

Today, LLR is a reality that continues to evolve, and a comprehensive analysis is necessary to assess the current short-term outcomes of minimally invasive liver surgery.

Aim

The goal of this study was to identify risk factors for postoperative complications and prolonged PLOS.

Material and methods

Patient selection

We performed a retrospective analysis of all patients who underwent LLRs performed by surgeons from the Department of Liver Surgery and Liver Transplantation Centre. The period spanned from May 2015 to April 2018. From a prospectively maintained database, patients who underwent pure LLRs were included. Institutional review board approval was obtained from the West China Hospital of Sichuan University. The study was reported in line with the STROCSS criteria [13].

All patients who presented with a liver mass were discussed by an expert team before surgical resection. Resectability and staging were estimated using abdominal enhanced computed tomography (CT) or magnetic resonance imaging (MRI). Patients could be considered to receive LLR only if all tumours could be treated by radical resection with negative surgical margins and a sufficient future liver remnant volume. For primary liver cancer, patients who had Child-Pugh A liver function or selected patients with Child-Pugh B liver function, and ICG R15 < 14% [14] were included. Indications of benign liver tumours for LLR were based on the European Association for the Study of the Liver (EASL) guidelines: (1) Symptomatic or growing lesions, including pedunculated or large lesions with associated compression of adjacent organs; (2) Malignancies could not be excluded; and (3) When hepatocellular adenomas (HCA) are diagnosed, resection or curative treatment is recommended for all HCA diagnosed in men.

Operative and perioperative management

Data were collected on patient demographics, comorbidities, diagnosis, operative details, pathology, and perioperative outcomes. All patients underwent routine blood tests before and after surgery, and abdominal ultrasonography was performed before discharge from the hospital. The preoperative albumin-bilirubin (ALBI) grade was calculated from available data as a measure of liver reserve function [15]. The diagnosis of liver cirrhosis was based on histological examination. In the Ishak staging system, a score of 5 or 6 points was defined as liver cirrhosis [16]. On the basis of the difficulty scoring system, the difficulty of LLR was divided into 3 levels [17]. The primary outcome was overall complications within 30 days of surgery. Postoperative complications were graded using the Dindo-Clavien classification [18], and cumulative morbidity was measured using the CCI [12]. A CCI ≥ 26.2 was used as a threshold to define patients with at least one grade III (major) complication, according to the Clavien-Dindo classification [19]. However, this cut-off also takes into account the weight of multiple low-grade complications (e.g. grade I–II), which are normally not considered an endpoint but, using CCI, may add to the patients' postoperative experience more than a single grade III complication. Liver-specific complications were defined as follows: liver failure was defined according to the '50–50 criteria' on postoperative day 5 [20]; ascites was defined as postoperative daily ascitic fluid drainage from thoracic and abdominal drains exceeding 10 ml/kg of preoperative body weight [21]; and biliary leakage was defined as a discharge of fluid with an increased bilirubin concentration via the intra-abdominal drains on or after postoperative day 3 or as the need for radiological intervention (i.e. interventional drainage) and relaparotomy for biliary collections and bile peritonitis, respectively [22]. Secondary outcomes included prolonged PLOS, which was defined as a PLOS longer than the 75th percentile of the cohort.

Our detailed techniques for LLRs have been described previously [23, 24]. Briefly, the operation was performed under general anaesthesia, and carbon dioxide (CO_2) was infused to keep the pneumoperitoneum pressure at 12–13 mm Hg. Intraoperative ultrasonography was performed routinely to identify the location, size, and number of tumours, identify the adjacent vasculature, and maintain an appropriate resection margin. Patients were placed in the semi-left lateral position and reversed Trendelenburg position. Hepatic inflow occlusion methods, the intermittent Pringle manoeuvre, or continuous hemi-hepatic vascular inflow occlusion were used to control surgical blood loss. Parenchymal transection of the liver was performed using a harmonic scalpel, CUSA [25], with central venous pressure maintained at < 5 mm Hg. Bleeding was usually controlled by BiClamp and Ligasure.

Statistical analysis

Continuous variables were expressed as the median (interquartile range, IQR) and were compared using the Mann-Whitney *U* test. Categorical variables were expressed as *n* (%) and were compared between groups using Fisher's exact test or the χ^2 test, as appropriate. A logistic regression model analysis was used to predict the incidence of complications (CCI score 26.2 or higher) and prolonged PLOS. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each factor. Significance levels were set at 0.05, and all analyses were two-tailed. Statistical analyses were performed using SPSS software 22.0 (IBM SPSS Inc, Chicago, IL) and R 3.3.1 (https://cran.r-project.org/).

Results

Patients' characteristics

We identified 938 patients who underwent LLR during this period. Of these, 565 (60.2%) were male, and the full cohort had a median (IQR) age of 52 (43–61) years at the time of operation. Of the 938 patients, 489 (52.1%) had a preoperative diagnosis of hepatitis B. A total of 149 (15.9%) patients had a history of previous abdominal surgery and 26 (2.8%) had previous hepatectomy (Table I). The most common indication for surgery (Table II) was hepatocellular carcinoma, accounting for 425 (45.3%) cases. This was followed by haemangioma (165, 17.6%), metastatic cancer of the liver (76, 8.1%), focal nodular hyperplasia (69, 7.4%), and hepatolithiasis (58, 6.2%). The median overall tumour size was 4.0 cm (IQR: 3–6 cm). Of the 938 patients, 337 (35.9%) had a tumour size of 5 to 10 cm, and 27 (2.9%) had a tumour size greater than 10 cm. The largest tumour removed laparoscopically was 17 cm.

The overall conversion rate was 2.2% (21 cases). The most common reason for conversion was intraoperative bleeding. In 3 patients, difficulty in dissecting the primary tumour from the diaphragm was the primary reason for open conversion.

Surgical complications after hepatic resection

In the full cohort, 135 (14.4%) patients experienced 200 complications with a Dindo-Clavien grade 2 or greater, as detailed in Table III. Most complications were associated with pneumonia, followed by liver failure. Ten patients required radiological drainage because of peritoneal effusion. Eight patients required choledochoscopy because of residual or recurrent stones. Three (0.3%) patients required reoperation, 2 for bleeding and 1 because of biliary stricture. Four (0.4%) patients died postoperatively. Two patients with HCC, who underwent major LLR died of liver failure 10 and 14 days separately after surgery. Another HCC patient was a 65-year-old man, who experienced intra-abdominal haemorrhage and underwent reoperation. He died 2 days postoperatively of disseminated intravascular coagulation. The fourth patient was a 28-year-old woman. She had hydatid disease and underwent partial resection. During the procedure, the operative field was soaked in sterile 20% saline solution to avoid

Table I. Baseline features of the study population and by high CCI (≥ 26.2)

Variable	All patients (*n* = 938)	CCI ≥ 26.2 (*n* = 79)	CCI < 26.2 (*n* = 859)	*P*-value
Age, median [years] (IQR)	52 (43–61)	56 (47.3–65)	51 (43–61)	0.008
Male, *n* (%)	573 (61.1)	55 (69.6)	518 (60.3)	0.104
BMI, mean [kg/m^2] (SD)	23.2 (3.2)	23.1 (3.3)	23.2 (3.2)	0.545
Diagnosis, *n* (%):				< 0.001
Benign liver tumour	275 (29.4)	3 (3.8)	272 (31.0)	
Primary liver tumour	481 (51.3)	56 (70.9)	425 (49.9)	
Metastatic liver tumour	79 (8.4)	4 (5.1)	75 (8.8)	
Infectious liver disease	33 (3.5)	5 (6.3)	28 (3.3)	
Hepatolithiasis	55 (5.9)	11 (13.9)	44 (5.2)	
Living donor	15 (1.6)	0 (0)	15 (1.8)	
ALBI grade, *n* (%):				0.011
1	770 (82.0)	58 (73.4)	712 (84.6)	
2	151 (16.1)	21 (26.6)	130 (15.4)	
Post-ALT [IU/l], median (IQR)*	201.2 (120–342.4)	234.3 (159.4–510.2)	198.3 (118.6–336.4)	0.011
Post-AST [IU/l], median (IQR)*	163.5 (103–263.8)	230.0 (151.4–395.0)	158.5 (99–254.4)	< 0.001
Post-TB [µmol/l], median (IQR)*	29.4 (19.7–79.6)	68.3 (30.7–170.8)	28.2 (19.3–71.3)	< 0.001
Post-ALB [g/l], median (IQR)*	35.7 (33.3–37.8)	33.6 (32.0–35.6)	35.8 (33.5–38.0)	< 0.001
Drainage [ml], median (IQR)	110 (53–253)	310.0 (155–1000)	103.3 (50–220)	< 0.001
Operation procedure, *n* (%):				0.001
Left hepatectomy	109 (11.6)	11 (13.9)	98 (11.4)	
Left lateral hepatectomy	168 (17.9)	6 (7.6)	162 (18.9)	
Right hepatectomy	82 (8.7)	15 (19.0)	67 (7.8)	
Tri-segmentectomy	23 (2.5)	4 (5.1)	19 (2.2)	
PS hepatectomy	50 (5.2)	3 (3.8)	47 (5.5)	
AL hepatectomy	119 (12.7)	12 (15.2)	107 (12.5)	
Right anterior/Posterior sectionectomy	88 (9.4)	12 (15.2)	76 (8.9)	
Complex limit hepatectomy	60 (6.4)	3 (3.8)	57 (6.6)	
Limit hepatectomy	239 (25.5)	13 (16.9)	226 (26.2)	
Difficulty level, *n* (%):				< 0.001
1	169 (19.5)	8 (11.1)	161 (20.2)	
2	370 (42.6)	21 (29.2)	349 (43.9)	
3	329 (37.9)	43 (59.7)	285 (35.8)	
Operation time, median (IQR)	210 (150–270)	270 (210–345)	200 (150–260)	< 0.001
Pringle, *n* (%)	728 (77.6)	60 (75.9)	668 (77.8)	0.559
Conversion, *n* (%)	21 (2.2)	1 (1.3)	20 (2.3)	0.460
Blood loss [ml], median (IQR)	200 (100–300)	400 (150–575)	200 (50–300)	< 0.001
Transfusion, *n* (%)	33 (3.5)	7 (8.9)	26 (3.0)	0.016
Tumour size [cm], median (IQR)	4.0 (3–6)	4.5 (3–6.3)	4.0 (3–6)	0.337
Tumour number, *n* (%):				0.885
Single	721 (83.1)	58 (82.9)	663 (83.1)	
Multiple	147 (16.9)	12 (17.1)	135 (16.9)	
Cirrhosis, *n* (%)	278 (29.6)	37 (46.8)	241 (28.1)	0.001
Previous abdominal surgery, *n* (%)	149 (15.9)	8 (10.1)	141 (16.4)	0.143
PLOS, median [days] (IQR)	5 (4–7)	7.5 (6–10)	5 (4–6)	< 0.001

*BMI – body mass index, ALBI – albumin–bilirubin (formula: –0.085*ALBumin/L + 0.66*lg TB µmol/l); Post – postoperative, PS – posterosuperior, AL – anterolateral, ALT – alanine aminotransferase, AST – aspartate aminotransferase, TB – total bilirubin, ALB – albumin. *Average values of liver function tests at 1, 3, and 5 days after operation.*

contamination. Then, she occurred hypernatraemia (> 190 mmol/l) and died 6 days postoperatively of encephaloma.

A high CCI (≥ 26.2) was observed in 8.4% (n = 79) of the whole population. Patients with CCI ≥ 26.2 were significantly different from the CCI < 26.2 group in terms of demographics and clinical data (Table I).

The median PLOS after the operation was 5 days (range: 2–35 days). A prolonged PLOS was defined as any longer than 7 days (which was found to be longer than the 75th percentile of the cohort); this was seen in 98 (10.4%) patients.

Predictors of CCI ≥ 26.2 and prolonged PLOS

Table IV describes potential factors associated with perioperative complications. In the multivariate logistic analysis, tumour-associated factors that increased the odds of complications included the diagnosis of primary (OR = 8.97, 95% CI: 2.54–43.74, p = 0.001), metastatic liver tumours (OR = 5.74, 95% CI: 1.20–30.90, p = 0.028), and infectious liver disease (OR = 24.04, 95% CI: 5.30–129.53, p < 0.001). Also, difficult liver resection (OR = 2.77, 95% CI: 1.29–6.69, p = 0.014) and intraoperative bleeding > 1000 ml (OR = 9.29, 95% CI: 3.40–26.43, p < 0.001) were independent factors that increased the odds of complications. The factors that independently influenced prolonged PLOS on multivariate analysis (Table V), which differed from postoperative complications, included age above 70 years (OR = 14.87, 95% CI: 2.23–302.69, p = 0.014), liver cirrhosis (OR = 2.27, 95% CI; 1.28–4.13, p = 0.004), and right hepatectomy (OR = 7.16, 95% CI: 2.91–19.06, p < 0.001).

Discussion

In this high-volume, single-institution analysis, we demonstrate that LLR is a safe technique with low postoperative morbidity and rare postoperative mortality for a range of indications. The overall complication rate of 14.4% in this study is similar to that described in many publications [8, 9, 26]. The low postoperative mortality rate of 0.4% in this study compares well with the rate of 0% to 2.7% [7–9, 26, 27]. This highlights the overall safety of this surgical approach.

Conversion to a hand-assisted approach or full laparotomy was reported in 2.2% of cases in this study. We expected to find that conversion did not increase the odds of postoperative complications. Conversion from pure LLR should not be viewed as a failure. Uncontrolled bleeding and difficulty in dissecting the tumour for a long time led to increased postoperative complications. As mentioned in the literature, not delaying conversion may reduce blood loss and operative time [28]. Hence, for the patients' safety, surgeons should not hesitate to convert to hand-assisted or open liver resection in certain circumstances, for instance to control bleeding or to complete a difficult liver resection.

In LLR, difficult liver resection was associated with an increased likelihood of complications. This factor was universally accepted to influence postoperative short-term outcomes [10, 29, 30]. The difficulty of

Table II. Indications for laparoscopic liver resection

Indications	N (%)
Primary liver cancer:	
Hepatocellular carcinoma	425 (45.3)
Cholangiocarcinoma	49 (5.2)
Mixed liver cancer	4 (0.4)
Metastatic cancer of the liver:	
Colorectal liver metastasis	65 (6.9)
Neuroendocrine tumour metastasis	4 (0.4)
Breast cancer metastasis	3 (0.3)
Ovarian cancer metastasis	1 (0.1)
Sarcoma metastasis	1 (0.1)
Lung cancer metastasis	1 (0.1)
Pancreatic cancer metastasis	1 (0.1)
Benign liver tumour:	
Cavernous haemangioma	165 (17.6)
Focal nodular hyperplasia	69 (7.4)
Angiomyolipoma	12 (1.3)
Inflammatory pseudotumour	3 (0.3)
Adenoma	2 (0.2)
Tuberculosis granuloma	1 (0.1)
Infectious liver lesion:	
Hydatid disease	17 (1.8)
Parasites	12 (1.3)
Liver abscess	4 (0.4)
Hepatolithiasis	58 (6.2)
Living donor	15 (1.6)
Other	26 (2.8)

Table III. Description of complications with Dindo-Clavien grade 2 or greater

Complication	*N* (%)
Dindo-Clavien grade 2:	
Pneumonia	70 (7.5)
Wound infection	6 (0.6)
Intra-abdominal infection	6 (0.6)
Biliary related	7 (0.7)
Perioperative blood transfusion	10 (1.1)
Ascites	10 (1.1)
Ileus	1 (0.1)
Intractable hiccup	1 (0.1)
Thrombogenesis	4 (0.4)
Pancreatitis	1 (0.1)
Hyperglycaemia	3 (0.3)
Atrial fibrillation	2 (0.2)
Dindo-Clavien grade 3a:	
Hydrops requiring puncture drainage	10 (1.1)
Invasive operation for bile duct	8 (0.9)
Dindo-Clavien grade 3b:	
Reoperation	3 (0.3)
Dindo-Clavien grade 4:	
Liver failure	51 (5.4)
Respiratory failure	2 (0.2)
Sepsis	1 (0.1)
Dindo-Clavien grade 5 (deaths)	4 (0.4)

Biliary related complications include bile leakage and biliary structure

LLR depends not only on the technical complexity of liver resection but also on various factors, such as a patient's background, tumour size and location, and the degree of liver fibrosis. Difficult surgery is bound to increase operative time and intraoperative blood loss, resulting in poor short-term outcomes. We concluded that residual liver volume and surgical complexity were the most important factors affecting postoperative complications. A meta analyses suggested that 3D visualization technology will enable surgeons to perform virtual surgery, calculate liver volume, and significantly guide them through the clinical surgery [31]. This finding emphasized the importance of tailoring perioperative management by surgical complexity to improve outcomes after liver resection.

In previous studies, better pulmonary outcomes were observed in laparoscopic surgeries [32, 33]. However, pneumonia was still the most common complication in this study. Although perioperative antibiotics are routinely used, there is currently no evidence to support or refute the use of any treatment to reduce infectious complications after liver resections [34]. Postoperative pneumonia is still a leading hospital-acquired infection. Russotto *et al.* identified 5 independent variables (functional status, preoperative SpO_2 value, breathing room air, intraoperative colloid administration, intraoperative blood transfusion, and surgical site) associated with postoperative pneumonia [35], which may help in the management of patients at risk of postoperative pneumonia.

Aside from surgical factors, the pathological diagnosis also has an important effect on postoperative outcomes. Compared with benign liver tumours, malignant liver tumours (both primary and metastatic) and infectious diseases could be attributable to more postoperative complications. It is important to note that 54.5% of infectious liver tumours were echinococcosis. These patients usually live in high-altitude areas with relatively underdeveloped social and economic conditions, and such a background could increase the risk of severe complications after surgery. In addition, the case of death previously mentioned stressed that the use of hypertonic saline during surgery is potentially risky.

None of the patients suffered from venous gas embolism in this study. CO_2 embolism is much safer than air embolism because of the greater solubility of CO_2. When CO_2 enters the blood it can be detected by blood gas analysis, but it does not create significant haemodynamic instability. This phenomenon was also observed in animal experiments [36]. Although CO_2 pneumoperitoneum is safe, extreme caution should be taken when there is a hole on the vein, to vent excessive gas pressure and enhance intraoperative monitoring.

In this study, the factors affecting the length of postoperative hospital stay were relatively diverse. Similarly, we found that a diagnosis of metastatic cancer of the liver, rather than primary liver cancer, was a predictor of prolonged PLOS. There might be several explanations for this finding. First, preoperative chemotherapy has previously been shown to be particularly associated with pathologic changes in the liver parenchyma, which may translate into

Table IV. Multivariate analysis for factors associated with a high CCI (≥ 26.2)

Variable	OR for CCI ≥ 26.2 (95% CI)	*P*-value
Age [years]:		
< 30	1 [Reference]	NA
30–39	0.38 (0.06–2.49)	0.301
40–49	0.48 (0.12–2.48)	0.332
50–59	0.99 (0.26–4.98)	0.988
60–69	0.87 (0.22–4.41)	0.849
≥ 70	1.16 (0.24–6.74)	0.851
Male	1.02 (0.52–2.11)	0.956
BMI [kg/m^2]:		
< 18.5	1 [Reference]	NA
18.5–23.9	0.98 (0.34–3.63)	0.976
24.0–26.9	0.73 (0.23–2.88)	0.626
≥ 27.0	1.15 (0.32–4.79)	0.841
Diagnosis:		
Benign liver tumour	1 [Reference]	NA
Primary liver tumour	8.97 (2.54–43.74)	0.001
Metastatic liver tumour	5.74 (1.20–30.90)	0.028
Infectious liver disease	24.04 (5.30–129.53)	< 0.001
Comorbidities: yes vs. no	1.26 (0.65–2.37)	0.476
ALBI grade: 2 vs. 1	1.30 (0.66–2.49)	0.280
Difficulty level:		
Level 1	1 [Reference]	NA
Level 2	1.12 (0.45–2.59)	0.941
Level 3	2.77 (1.29–6.69)	0.014
Previous abdominal surgery	1.01 (0.38–2.39)	
Pringle	0.97 (0.50–1.97)	0.434
Conversion: yes vs. no	0.11 (0.01–0.79)	0.063
Bleeding > 1000 ml	9.29 (3.40–26.43)	< 0.001
Cirrhosis: yes vs. no	1.66 (0.90–3.12)	0.110
Extent:		
Left lateral	1 [Reference]	NA
LH	0.26 (0.03–1.53)	0.165
RH	1.88 (0.48–7.80)	0.367
Tri-segmentectomy	1.56 (0.26–8.57)	0.612
PS hepatectomy	0.73 (0.12–3.92)	0.718
AL hepatectomy	1.69 (0.54–5.59)	0.373
Right anterior/ Posterior sectionectomy	1.60 (0.46–5.87)	0.463
Complex limit hepatectomy	0.87 (0.15–4.04)	0.868
Limit hepatectomy	1.35 (0.45–4.37)	0.602

Table V. Multivariate analysis for factors associated with prolonged length of stay

Variable	OR for prolonged PLOS (95% CI)	*P*-value
Age [years]:		
< 30	1 [Reference]	NA
30–39	2.4 (0.29–51.68)	0.385
40–49	7.54 (1.29–146)	0.045
50–59	6.14 (1.03–119.78)	0.074
60-69	7.48 (1.23–147.12)	0.054
≥ 70	14.87 (2.23–302.69)	0.014
Male	1.06 (0.60–1.89)	0.835
BMI [kg/m^2]:		
< 18.5	1 [Reference]	NA
18.5–23.9	2.19 (0.74–8.34)	0.211
24.0–26.9	1.99 (0.63–7.88)	0.284
≥ 27.0	2.59 (0.75–10.93)	0.179
Diagnosis:		
Benign liver tumour	1 [Reference]	NA
Primary liver tumour	1.94 (0.84–4.64)	0.118
Metastatic liver tumour	4.79 (1.91–12.35)	< 0.001
Infectious liver disease	3.0 (0.67–11.33)	0.146
Comorbidities: yes vs. no	0.85 (0.47–1.49)	0.632
ALBI grade: 2 vs. 1	1.5 (0.86–2.60)	0.148
Difficulty level:		
Level 1	1 [Reference]	NA
Level 2	1.92 (0.78–5.11)	0.171
Level 3	5.33 (1.88–16.22)	0.002
Conversion: yes vs. no	2.87 (0.73–10.33)	0.090
Cirrhosis: yes vs. no	2.27 (1.28–4.13)	0.004
Extent:		
LH	1 [Reference]	NA
Left lateral	1.08 (0.34–3.50)	0.856
RH	7.16 (2.91–19.06)	< 0.001
Tri-segmentectomy	2.69 (0.73–9.70)	0.135
PS hepatectomy	0.89 (0.26–2.27)	0.838
AL hepatectomy	1.90 (0.75–5.11)	0.171
Right anterior/ Posterior sectionectomy	0.80 (0.29–2.27)	0.727
Complex limit hepatectomy	0.24 (0.01–1.59)	0.176
Limit hepatectomy	1.24 (0.39–3.95)	0.681

adverse clinical outcomes after hepatic surgery [37]. Second, patients suffering from other cancers tend to have poorer personal status. Thus, it is important to focus on multidisciplinary management. Although age > 70 years, liver cirrhosis, and right hepatectomy were not associated with perioperative complications, these factors were more likely to cause prolonged PLOS.

Some limitations do exist in our study. First, because of the nature of the retrospective study, all the associated bias risks exist. However, to the best of our knowledge, this study represents the largest single-centre experience of LLR published in the literature. This allows the delineation of specific patient-associated and disease-associated factors that influence complications and prolonged PLOS, while largely removing confounders associated with the institution, surgeon volume, and specialty. Consequently, these results are relatively representative and reliable.

Conclusions

LLR remains safe for most liver space-occupying lesions. Metastatic liver tumour and difficult liver resection are at risk for increased both postoperative complications and prolonged PLOS. These factors should be considered during patient selection and perioperative management.

Acknowledgments

This work was supported by Sichuan Province Science and Technology Program (2022YFS0090).

Conflict of interest

The authors declare no conflict of interest.

References

1. Reich H, McGlynn F, DeCaprio J, Budin R. Laparoscopic excision of benign liver lesions. Obstet Gynecol 1991; 78: 956-8.
2. Cheung TT, Dai WC, Tsang SH, et al. Pure laparoscopic hepatectomy versus open hepatectomy for hepatocellular carcinoma in 110 patients with liver cirrhosis: a propensity analysis at a single center. Ann Surg 2016; 264: 612-20.
3. Cho CW, Choi GS, Kim JM, et al. Long-term oncological outcomes of laparoscopic liver resection for solitary hepatocellular carcinoma: comparison of anatomical and nonanatomical resection using propensity score matching analysis. J Laparoendosc Adv Surg Tech A 2019; 29: 752-8.
4. Witowski J, Rubinkiewicz M, Mizera M, et al. Meta-analysis of short- and long-term outcomes after pure laparoscopic versus open liver surgery in hepatocellular carcinoma patients. Surg Endosc 2018; 33: 1491-507.
5. Takahara T, Wakabayashi G, Beppu T, et al. Long-term and perioperative outcomes of laparoscopic versus open liver resection for hepatocellular carcinoma with propensity score matching: a multi-institutional Japanese study. J Hepatobiliary Pancreat Sci 2015; 22: 721-7.
6. Abu Hilal M, Aldrighetti L, Dagher I, et al. The Southampton Consensus Guidelines for laparoscopic liver surgery: from indication to implementation. Ann Surg 2018; 268: 11-8.
7. Nomi T, Fuks D, Govindasamy M, et al. Risk factors for complications after laparoscopic major hepatectomy. Br J Surg 2015; 102: 254-60.
8. Chen TH, Yang HR, Jeng LB, et al. Laparoscopic liver resection: experience of 436 cases in one center. J Gastrointest Surg 2019; 23: 1949-56.
9. Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. Ann Surg 2009; 250: 831-41.
10. Tranchart H, Gaillard M, Chirica M, et al. Multivariate analysis of risk factors for postoperative complications after laparoscopic liver resection. Surg Endosc 2014; 29: 2538-44.
11. Slankamenac K, Graf R, Barkun J, et al. The comprehensive complication index: a novel continuous scale to measure surgical morbidity. Ann Surg 2013; 258: 1-7.
12. Staiger RD, Cimino M, Javed A, et al. The Comprehensive Complication Index (CCI(R)) is a novel cost assessment tool for surgical procedures. Ann Surg 2018; 268: 784-91.
13. Agha R, Abdall-Razak A, Crossley E, et al. STROCSS 2019 Guideline: strengthening the reporting of cohort studies in surgery. Int J Surg 2019; 72: 156-65.
14. ST. F. Liver functional reserve estimation: state of the art and relevance for local treatments: the Eastern perspective. J Hepatobiliary Pancreat Sci 2010; 17: 308-12.
15. Pinato DJ, Sharma R, Allara E, et al. The ALBI grade provides objective hepatic reserve estimation across each BCLC stage of hepatocellular carcinoma. J Hepatol 2017; 66: 338-46.
16. Ishak K, Baptista A, Bianchi L, et al. Histological grading and staging of chronic hepatitis. J Hepatol 1995; 22: 696-9.
17. Ban D, Tanabe M, Ito H, et al. A novel difficulty scoring system for laparoscopic liver resection. J Hepatobiliary Pancreat Sci 2014; 21: 745-53.
18. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004; 240: 205-13.
19. Kobayashi K, Kawaguchi Y, Schneider M, et al. Probability of postoperative complication after liver resection: stratification of patient factors,operative complexity, and use of enhanced recovery after surgery. J Am Coll Surg 2021; 233: 357-68 e2.
20. Balzan S, Belghiti J, Farges O, et al. The “50-50 criteria” on postoperative day 5: an accurate predictor of liver failure and death after hepatectomy. Ann Surg 2005; 242: 824-8, discussion 8-9.
21. Ishizawa T, Hasegawa K, Kokudo N, et al. Risk factors and management of ascites after liver resection to treat hepatocellular carcinoma. JAMA Surg 2009; 144: 46-51.
22. Koch M, Garden OJ, Padbury R, et al. Bile leakage after hepatobiliary and pancreatic surgery: a definition and grading of

severity by the International Study Group of Liver Surgery. Surgery 2011; 149: 680-8.
23. Liu F, Wei Y, Chen K, et al. The extrahepatic glissonian versus hilar dissection approach for laparoscopic formal right and left hepatectomies in patients with hepatocellular carcinoma. J Gastrointest Surg 2019; 23: 2401-10.
24. Liu F, Zhang J, Lei C, et al. Feasibility of laparoscopic major hepatectomy for hepatic paragonimiasis: two case reports. Medicine 2016; 95: e4939.
25. Liu F, Wei Y, Li H, et al. LigaSure versus CUSA for parenchymal transection during laparoscopic hepatectomy in hepatocellular carcinoma patients with cirrhosis: a propensity score-matched analysis. Surg Endosc 2018; 32: 2454-65.
26. Cai X, Li Z, Zhang Y, et al. Laparoscopic liver resection and the learning curve: a 14-year, single-center experience. Surg Endosc 2014; 28: 1334-41.
27. Ciria R, Cherqui D, Geller DA, et al. Comparative Short-term benefits of laparoscopic liver resection: 9000 cases and climbing. Ann Surg 2016; 263: 761-77.
28. Costi R, Scatton O, Haddad L, et al. Lessons learned from the first 100 laparoscopic liver resections: not delaying conversion may allow reduced blood loss and operative time. J Laparoendosc Adv Surg Techn 2012; 22: 425-31.
29. Chen Y, Huang Z, Dong J, et al. Risk factors for postoperative complications and in-hospital death in distal pancreatectomy. Zhonghua Yi Xue Za Zhi 2015; 95: 96-9.
30. Periyasamy M, Cho JY, Ahn S, et al. Prediction of surgical outcomes of laparoscopic liver resections for hepatocellular carcinoma by defining surgical difficulty. Surg Endosc 2017; 31: 5209-18.
31. Zhang S, Huang Z, Cai L, et al. Three-dimensional versus two-dimensional video-assisted hepatectomy for liver disease: a meta-analysis of clinical data. Videosurgery Miniinv 2021; 16: 1-9.
32. Celik S, Yilmaz EM. Effects of laparoscopic and conventional methods on lung functions in colorectal surgery. Med Sci Monit 2018; 24: 3244-8.
33. Wen N, Liu F, Zhang H, et al. Laparoscopic liver resection for hepatocellular carcinoma presents less respiratory complications compared with open procedure: a propensity score analysis in the elderly. Eur J Surg Oncol 2021; 47: 2675-81.
34. Gurusamy KS, Naik P, Davidson BR. Methods of decreasing infection to improve outcomes after liver resections. Cochrane Database Syst Rev 2011; 11: CD006933.
35. Russotto V, Sabate S, Canet J, group P, of the European Society of Anaesthesiology Clinical Trial N. Development of a prediction model for postoperative pneumonia: a multicentre prospective observational study. Eur J Anaesthesiol 2019; 36: 93-104.
36. Jayaraman S, Khakhar A, Yang H, et al. The association between central venous pressure, pneumoperitoneum, and venous carbon dioxide embolism in laparoscopic hepatectomy. Surg Endosc 2009; 23: 2369-73.
37. Vauthey JN, Pawlik TM, Ribero D, et al. Chemotherapy regimen predicts steatohepatitis and an increase in 90-day mortality after surgery for hepatic colorectal metastases. J Clin Oncol 2006; 24: 2065-72.

Received: 24.01.2021, **accepted:** 20.04.2022.