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

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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...
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 (CO2) 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 χ² 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 hepectomy (Table I). The most common indication for surgery (Table II) was hepatocellular carcinoma, accounting for 425 (45.3%) cases. This was followed by haemangiomia (165, 17.6%), metastatic cancer of the liver (76, 8.1%), focal nodular hyperplasia (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 cholecdochoscopy 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   | 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)             |         |
| Hepatolithiasan                                    | 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

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

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/m²]:                      |                           |         |
| < 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/m²]:                      |                               |         |
| < 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.

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Conflict of interest

The authors declare no conflict of interest.

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