Pure Laparoscopic Liver Resection for Malignant Liver Tumor: Anatomic Resection Versus Nonanatomic Resection

Ya-Xi Chen, Dian-Rong Xiu, Chun-Hui Yuan, Bin Jiang, Zhao-Lai Ma
Department of General Surgery, Peking University Third Hospital, Beijing 100191, China

Abstract

Background: Laparoscopic liver resection (LLR) has been considered to be safe and feasible. However, few studies focused on the comparison between the anatomic and nonanatomic LLR. Therefore, the purpose of this study was to compare the perioperative factors and outcomes of the anatomic and nonanatomic LLR, especially the area of liver parenchymal transection and blood loss per unit area.
Methods: In this study, surgical and oncological data of patients underwent pure LLR procedures for malignant liver tumor were prospectively collected. Blood loss per unit area of liver parenchymal transection was measured and considered as an important parameter. All procedures were conducted by a single surgeon.
Results: During nearly 5 years, 84 patients with malignant liver tumor received a pure LLR procedure were included. Among them, 34 patients received anatomic LLR and 50 received nonanatomic LLR, respectively. Patients of the two groups were similar in terms of demographic features and tumor characteristics, despite the tumor size was significantly larger in the anatomic LLR group than that in the nonanatomic LLR group (4.77 ± 2.57 vs. 2.87 ± 2.10 cm, $P = 0.001$). Patients who underwent anatomic resection had longer operation time (364.09 ± 131.22 vs. 252.00 ± 135.21 min, $P < 0.001$) but less blood loss per unit area (7.85 ± 7.17 vs. 14.17 ± 10.43 ml/cm^2, $P = 0.018$). Nonanatomic LLR was associated with more blood loss when the area of parenchymal transection was equal to the anatomic LLR. No mortality occurred during the hospital stay and 30 days after the operation. Moreover, there was no difference in the incidence of postoperative complications. The disease-free and overall survival rates showed no significant differences between the anatomic LLR and nonanatomic LLR groups.
Conclusions: Both anatomic and nonanatomic pure LLR are safe and feasible. Measuring the area of parenchymal transection is a simple and effective method to estimate the outcomes of the liver resection surgery. Blood loss per unit area is an important parameter which is comparable between the anatomic LLR and nonanatomic LLR groups.

Key words: Anatomic Liver Resection; Area of Parenchymal Transection; Blood Loss per Unit Area; Laparoscopic Liver Resection; Malignant Liver Tumor

Introduction

Laparoscopic liver resection (LLR) for liver tumor was firstly reported by Gagner *et al*.[1] in 1992. The first anatomic liver resection was performed in 1996[2] and had progressed greatly in the last two decades. Initially, LLR was considered for benign, peripheral, and small liver lesions and was carried out by experienced surgeons. Compared with open liver resection (OLR), the advantage of LLR procedure is less blood loss, less complication rates and shorter length of hospital stay, lower incidence of repeat liver resection, and with no difference in oncological outcomes for malignant liver tumors.[3-9] The safety and feasibility of LLR had been proved by a series of studies.[3,6] However, compared with other domains of laparoscopic surgery, the hepatic surgery has developed slowly. The techniques of parenchymal transection and the fear of uncontrolled bleeding might be the biggest obstacle for young surgeons to perform LLR.[6,10-12] Recently, with the advances in surgical devices and perioperative management, an increasing number of

Access this article online
Quick Response Code:
Website: www.cmj.org
DOI: 10.4103/0366-6999.172567

Address for correspondence: Prof. Dian-Rong Xiu,
Department of General Surgery, Peking University Third Hospital,
Beijing 100191, China
E-Mail: xiudianrong@163.com

Received: 27-09-2015 **Edited by:** Qiang Shi
How to cite this article: Chen YX, Xiu DR, Yuan CH, Jiang B, Ma ZL. Pure Laparoscopic Liver Resection for Malignant Liver Tumor: Anatomic Resection Versus Nonanatomic Resection. Chin Med J 2016;129:39-47.

reports in LLR was published, including complex pure laparoscopic anatomic segmentectomy and major liver resection procedures.[13] LLR is thus considered to be a curative and popular therapy for malignant liver tumors.[3,6,10]

Anatomic liver resection is defined as the complete removal of at least one Couinaud's segment which contains the tumor.[14] It has been advocated that anatomic liver resection might be a potentially better procedure for a malignant hepatic tumor in the open liver surgery. Consequently, malignant hepatic tumor spreads mainly by portal vein and vascular invasion.[13,15-17] Anatomic liver resection allows the complete removal of the main tumor and possible venous tumor thrombi, theoretically.[14] Therefore, some authors believe that the anatomic resection technique could minimize the loss of functional liver parenchyma and ensure an adequate surgical margin at the same time.[13-16]

There have been some reports comparing the anatomic and nonanatomic procedures in OLR for malignant liver tumor. However, to our best knowledge, currently there is no study focused on the comparison between the perioperative outcomes of anatomic and nonanatomic LLR. In this study, we prospectively collected a database of patients who underwent pure LLR for malignant liver tumor by a single surgeon. The aim of this study was to compare and analyze the perioperative factors and outcomes for anatomic resection and nonanatomic resection, especially the area of liver parenchymal transection and blood loss per unit area, which has not been mentioned in previous studies.

Methods

Patient selection

From October 2010 to June 2015, 423 patients received liver resections at Peking University Third Hospital. A total of 301 operations were performed by Prof. Dian-Rong Xiu. Moreover, 84 patients who received the pure LLR procedure for malignant liver tumors were included in this study [Figure 1]. Currently, there are still no widely accepted indications for LLR.[3,8,18] We took the tumor status (size, number, and location), the hepatic function, and the patient's general condition into account to select the type of liver resection procedure for each patient. First, all patients received the LLR procedure, at least for exploration to exclude the disseminated metastasis, except for those who had follows conditions: (1) a tumor was with a portal vein thrombus; (2) a tumor invaded into inferior vena cava; (3) the predictable future liver remnant was insufficient; and (4) the operation needed biliary reconstruction. The decision to perform an LLR anatomically or nonanatomically was based on surgeon's experience. However, we considered more than 3 lesions located in one single segment or lobe as an absolute indication for the anatomic resection. And an exophytic lesion was inclined to be local resected. Liver function was estimated by Child-Pugh classification. All patients selected for LLR were categorized according to the

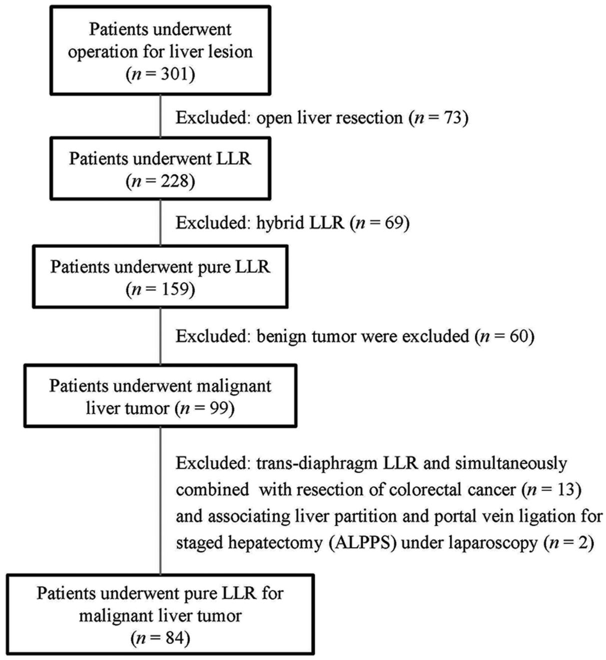

Figure 1: The flow chart of patient selection process. LLR: Laparoscopic liver resection.

American Society of Anesthesiologists' (ASA) classification. Regular follow-up was carried out for all patients. Disease recurrence was defined as an enlarging lesion revealed by computed tomography scan or magnetic resonance imaging.

This study was approved by the Peking University Third Hospital. All the patients had signed consents before the operation.

Surgical procedure

All patients were under general anesthesia. The position of patients (supine or lateral decubitus) depended on the tumor location. The intra-abdominal pressure was maintained at 10–12 mmHg (1 mmHg = 0.133 kPa) during the operation. Four or five trocars were used, and the insertion site was determined by the surgical requirement and the tumor location. In this study, the pure LLR was defined as a liver resection conducted under the laparoscopy and the specimen were removed via a small incision extended from the insertion site of the trocars.[10]

Nonanatomic liver resection

When a nonanatomic resection was performed, we aimed to remove the tumor plus a rim of nonneoplastic liver parenchyma [Figure 2]. The corresponding ligament was divided firstly to ensure that the liver was movable. Then the tumor status was explored, and the demarcation was determined by the intraoperative ultrasonography probe. The intended surgical margin was considered to be 1 cm for hepatocellular carcinoma (HCC) and 0.5 cm for the metastatic liver lesion under the ultrasonography. Finally, the monopolar coagulation devices were utilized to perform the parenchymal transection.

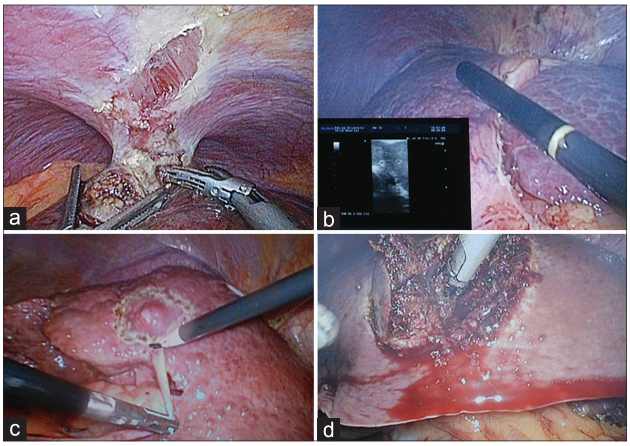

Figure 2: Nonanatomic laparoscopic liver resection. (a) Dividing the corresponding liver ligament (b) exploration of the tumor using intraoperative ultrasonography probe (c) marking the area to be dissected (d) liver parenchymal transection.

Anatomic liver resection

To perform an anatomic liver resection procedure, we firstly divided the corresponding ligament to expose the target segment and achieved the Glissonian pedicle at the hepatic hilus [Figure 3a and 3b]. Identifying and isolating and ligating the corresponding hepatic artery, portal vein, and bile duct were a technically demanding and dangerous step for an anatomic liver resection, and surgeons must consider the variations of the biliary ducts. All the patients received a preoperative magnetic resonance cholangiopancreatography to seek the possible variations, especially for patients who was expected to undergo a left hepatectomy. The variation of right posterior branch draining into the left hepatic duct was reported with a rate of about 4.15%–19.1% of the population.[19] The Glissonian approach during hepatectomy is a selective vascular clamping procedure associated with low rates of technical failure and complications.[20] The control of the Glissonian pedicle depended on the type of procedure.[20-22] For the left hepatectomy, we performed a Glissonian intrafascial approach by opening the Glissonian sheath and dividing the hepatic artery, biliary duct, and portal vein, respectively, to avoid misligating variant bile ducts. For right hepatectomy, right anterior or right posterior segmentectomy, and left lateral segmentectomy, a Glissonian approach was applied by clamping the entire Glisson sheath supplying the target segment or sector before liver parenchymal transection.[20] Successful clamping was defined as the appearance of ischemic demarcation on the surface of the liver [Figure 3c]. Second, we recognized the ischemic demarcation and marked it as the transection line [Figure 3d]. Then, we transect the liver parenchyma [Figure 3e]. The clipping of hepatic vein is the final step [Figure 3f]. No Pringle maneuver was applied in this group.

For parenchymal transection, we used monopolar coagulation together with the harmonic scalpel or a thermofusion device. To achieve and isolate the hepatic

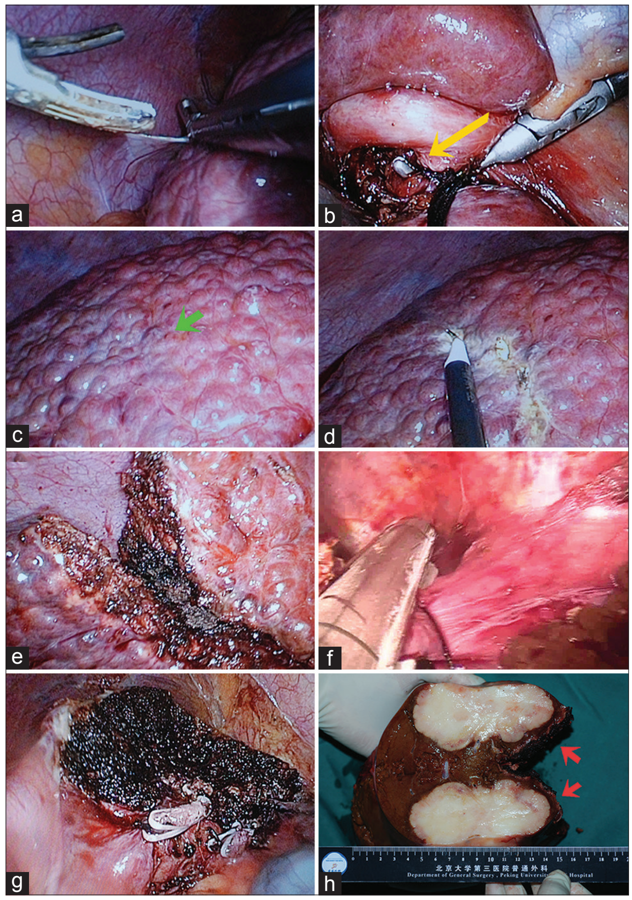

Figure 3: Anatomic laparoscopic liver resection (a) dividing the corresponding liver ligament (b) isolation and ligation of the Glissonian pedicle facilitated by a right angle laparoscopic forcep (long arrow) (c) the ischemic demarcation (short arrow) appears on the surface of liver (d) marking the transection line (e) liver parenchymal transection (f) dividing and transecting the hepatic vein (g) the surgical field after laparoscopic liver resection (h) the cut margin (red arrows).

pedicle, a right angle laparoscopic forcep with 10 mm in diameter was used as shown in Figure 3b. Intraoperative ultrasonography was a standard technique as a guidance to localize the tumor and to determine the transection plate. The amount of intraoperative blood loss was estimated according to the volume of blood collected in the container of the aspirator and was recorded on the electronic anesthetic note.

Area of liver parenchymal transection

We focused on the area of liver parenchymal transection and blood loss per unit area, expecting to estimate the blood loss of the surgical procedure more accurately, to compare the two types of liver resection procedure, anatomic and nonanatomic resection. The area of liver parenchymal transection was measured by the Image-Pro Plus software (Media Cybernetics Inc. Bethesda, MD, USA), using the images of specimens. The procedures for measuring the area of parenchymal transection are shown in Figures 4 and 5. The area of liver transection plane measured *in vitro* might be smaller than the true value; however, we measured and computed all specimens using the same method.

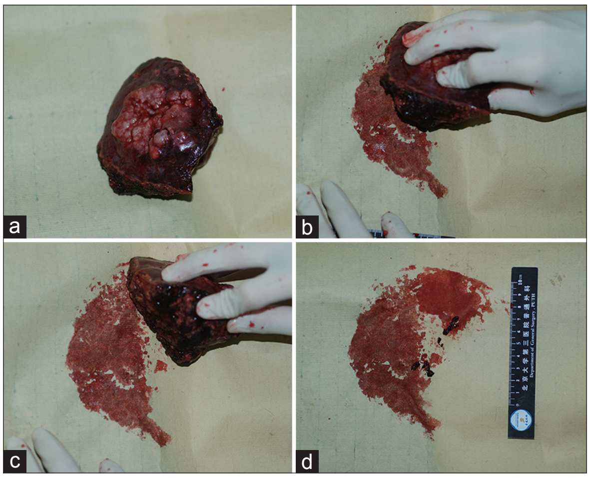

Figure 4: (a-d) Method of measuring the area of parenchymal transection. Rolling the specimen on the water-absorbed paper to print every part of its surface on the paper.

Statistical analysis

Categorical variables were compared by the Chi-square test. Continuous variables were expressed as a mean ± standard deviation (SD) and median, range. The normal distributed variables were compared by the Student's *t*-test, and others were compared by the Mann-Whitney *U*-test. All statistical data were analyzed by IBM SPSS Statistics 20 software (IBM SPSS Inc. Chicago, IL, USA). Values of $P < 0.05$ were considered statistically significant.

Results

Demographic characteristics

From October 2010 to June 2015, 301 liver resection were performed in our department by Prof. Xiu. Among them, 159 patients received pure LLR, 73 patients received OLR and 69 patients received hybrid technique (defined as a procedure which starts as a laparoscopic procedure to isolate the peri-hepatic ligament but the resection is performed through a minilaparotomy incision).[12] In the 159 patients who underwent pure laparoscopic resection, 84 patients were with the malignant liver tumor [Figure 1], including 52 male (61.9%) and 32 female (38.1%). The mean age was 58.6 ± 12.7 years. Anatomic resections were performed in 34 patients, and nonanatomic resections were performed in 50 patients. Types of liver resection are shown in Table 1.

Most preoperative parameters, including age, sex, body mass index, serum aspartate aminotransferase level, serum alanine aminotransferase level, international normalized ratio, total bilirubin, albumin, Child-Pugh classification, cirrhosis status, ASA classification, and number of hepatic tumors, were similar between the two groups. Patients who underwent anatomic resection had a much larger tumor size than patients with a nonanatomic resection (4.77 ± 2.57 vs. 2.87 ± 2.10 cm, $P = 0.001$). Demographic features and tumor characteristics are summarized in Table 2.

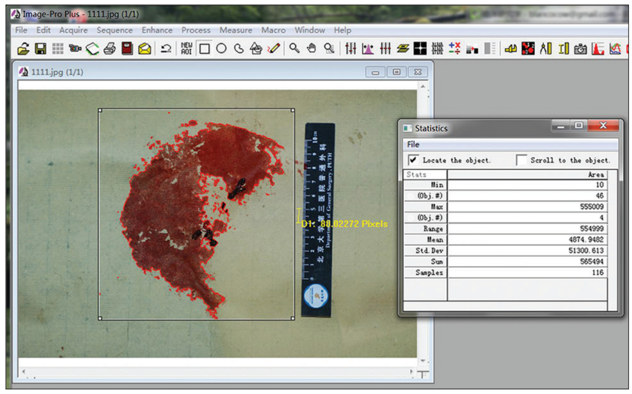

Figure 5: The Image-Pro Plus 6.0 software was used to compute the area of parenchymal transection.

Table 1: Types of liver resection performed by laparoscopy

Types of resection	*n* (%)
Anatomic liver resection	34 (40.5)
Right hepatectomy	10 (11.9)
Left hepatectomy	7 (8.3)
Left lateral segmentectomy	8 (9.5)
Right posterior sector (segment 6 and 7)	4 (4.8)
Right anterior sector (segment 5 and 8)	1 (1.2)
Segment 3	1 (1.2)
Segment 4	2 (2.4)
Segment 6	1 (1.2)
Nonanatomic liver resection	50 (59.5)
Total	84 (100)

Surgical and pathologic results

As shown in Table 3, patients who underwent anatomic resection had a longer operation time (364.09 ± 131.22 vs. 252.00 ± 135.21 min, $P < 0.001$). The two groups did not differ significantly in terms of intraoperative transfusion rate (11.8% vs. 20.0%, $P = 0.320$). The surgical margin in anatomic and nonanatomic LLR groups were 9.50 ± 8.91 mm and 6.45 ± 6.24 mm, respectively, with no significant difference between the two groups ($P = 0.225$). Although the average blood loss in the anatomic group was greater than in the nonanatomic group (623.53 ± 607.31 vs. 389.90 ± 553.48 ml), no statistically significant difference was revealed ($P = 0.072$). The area of parenchymal transection was larger (88.77 ± 66.45 vs. 32.15 ± 34.67 cm^2, $P < 0.001$), and blood loss per unit area was less (7.85 ± 7.17 vs. 14.17 ± 10.43 ml/cm^2, $P = 0.018$) in the anatomic LLR group. The pathological diagnosis of the liver lesion in the two groups showed no significant difference ($P = 0.214$). No death was observed during the surgery.

Linear correlation analyses showed that there was a positive correlation between the intraoperative blood loss and the area of parenchymal transection in the nonanatomic LLR group ($n = 49$, $r = 0.558$, $P < 0.001$). A similar result was found in the anatomic LLR group with a weak association ($n = 34$, $r = 0.424$, $P = 0.014$) [Figure 6]. Although no significant difference in terms of the intraoperative blood

Table 2: Demographic characteristics and liver characteristics

Characteristics	Anatomic group (n = 34)	Nonanatomic group (n = 50)	Statistic values	P
Age (years)	58.8 ± 11.9 (59.0, 30.0–78.0)	58.5 ± 13.3 (58.5, 33.0–83.0)	−0.126*	0.898
Sex (male/female)	21/13	31/19	0.000†	0.983
BMI (kg/m^2)	24.53 ± 3.63 (23.67, 18.10–32.22)	23.87 ± 3.48 (23.75, 16.80–31.25)	−0.825*	0.412
ALT (U/L)	30.1 ± 19.2 (25.5, 11.0–132.0)	27.7 ± 23.6 (21.5, 6.0–121.0)	−0.463*	0.644
AST (U/L)	30.2 ± 19.2 (26.0, 14.0–122.0)	32.0 ± 27.1 (25.0, 14.0–97.0)	0.348*	0.729
INR	1.05 ± 0.09 (1.04, 0.91–1.23)	1.06 ± 0.11 (1.03, 0.89–1.45)	0.099*	0.921
Albumin (g/L)	40.8 ± 4.2 (39.7, 34.7–49.4)	41.5 ± 4.7 (41.5, 32.7–50.4)	−0.825*	0.564
Total bilirubin (μmol/L)	13.7 ± 4.6 (12.8, 6.3–24.6)	16.2 ± 8.8 (14.8, 6.1–49.3)	−0.825*	0.208
Etiology of hepatitis (HBV/HCV)	17 (50.0)/0	21 (42.0)/3 (6.0)	0.032†	0.857
Cirrhosis	17 (50.0)	28 (56.0)	0.239†	0.588
Child-Pugh (A/B)	32/2	47/3	0.001†	0.982
ASA classification (I/II/III)	4/28/2	6/35/9		
Size of largest tumor (cm)	4.77 ± 2.57 (3.80, 1.00–13.00)	2.87 ± 2.10 (2.50, 0.50–12.00)	492.000‡	0.001
Number of hepatic tumors (n)	1.7 ± 1.2 (1.0, 1.0–5.0)	1.6 ± 1.1 (1.0, 1.0–6.0)	821.500‡	0.759

*t; †χ^2; ‡U values. Values are n (%) or mean ± standard deviation (median, range). BMI: Body mass index; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; INR: International normalized ratio; HBV: Hepatitis B virus; HCV: Hepatitis C virus; ASA: American Society of Anesthesiologists.

Table 3: Surgical and oncological results for patients underwent pure laparoscopic liver resection

Items	Anatomic group (n = 34)	Nonanatomic group (n = 50)	Statistic values	P
Operation time (min)	364.09 ± 131.22 (369.50, 185.00–787.00)	252.00 ± 135.21 (199.50, 62.00–742.00)	−3.774†	<0.001
Blood loss (ml)	623.53 ± 607.31 (450.00, 50.00–2500.00)	389.90 ± 553.48 (100.00, 5.00–3000.00)	−1.825†	0.072
Transfusions	4 (11.8)	10 (20.0)	0.988‡	0.320
Area of parenchymal transection (cm^2)	88.77 ± 66.45 (61.25, 22.87–291.73)	32.15 ± 34.67 (24.96, 1.00–198.00)*	241.000§	<0.001
Blood loss per unit area (ml/cm^2)	7.85 ± 7.17 (5.20, 0.66–28.79)	14.17 ± 10.43 (12.05, 0.78–50.01)*	515.000§	0.018
Surgical margin (mm)	9.50 ± 8.91 (7.00, 0.10–30.00)	6.45 ± 6.24 (5.00, 0.30–30.00)	666.500§	0.225
R0/R1	34/0	49/1	0.688‡	0.407
Diagnosis			1.542‡	0.214
HCC	21 (61.8)	24 (48.0)	–	–
Others	13 (38.2)	26 (52.0)	–	–

*The data of one patient in the nonanatomic group were lost; †t; ‡χ^2; §U values. Values are n (%) or mean ± SD (median, range). HCC: Hepatocellular carcinoma; SD: Standard deviation.

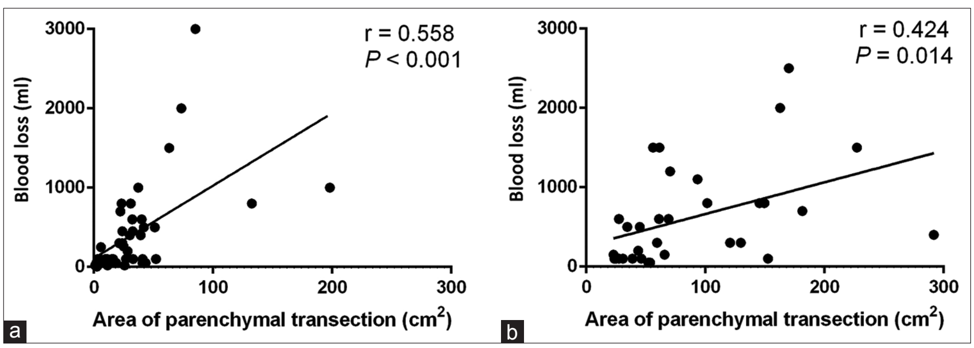

Figure 6: Correlation between the area of parenchymal transection and the intraoperative bleeding in the anatomic and nonanatomic laparoscopic liver resection groups. (a) The intraoperative blood loss showed a positive correlation with the area of parenchymal transection (n = 49, r = 0.558, P < 0.001). (b) There was weak correlation shown in the anatomic laparoscopic liver resection group (n = 34, r = 0.424, P = 0.014).

loss is revealed in the two groups, the nonanatomic LLR group is associated with more blood loss compared with the anatomic LLR group when the area of parenchymal transection is equal or more than 30 cm^2 [Figure 7].

In all 84 patients, 45 had HCC and six had intrahepatic cholangiocarcinoma. The remaining 33 patients had metastatic neoplasms, including colorectal cancer, neuroendocrine tumors, and other metastatic lesions [Table 4]. Twenty-one patients in the anatomic LLR group and 24 patients in the nonanatomic LLR group had HCC, and there was no statistical difference.

Postoperative results

We compared mortality and morbidity data between the anatomic and nonanatomic LLR groups [Table 5]. The

30-day mortality rates were zero in both groups. Four (11.8%) patients in the anatomic LLR group and 5 (10.0%) patients in the nonanatomic LLR group suffered specific postoperative complications ($P = 0.797$). Ascites was observed in 3 (8.8%) and 4 (8.0%) patients, respectively ($P = 0.893$), and biliary collection was observed in one patient in each group (2.9% vs. 2.0%, $P = 0.781$). The incidence of general morbidity of the two groups did not differ statistically either (17.6% vs. 12.0%, $P = 0.468$). The average length of the hospital stay after surgery was shorter for patients in the nonanatomic LLR group (7.5 ± 3.5 vs. 5.9 ± 2.5 days, $P = 0.014$).

Regarding the long-term outcomes, disease-free survival rate and overall survival rate for the anatomic LLR and nonanatomic LLR groups were not significantly different [Figure 8], and the median duration of follow-up was 11 months.

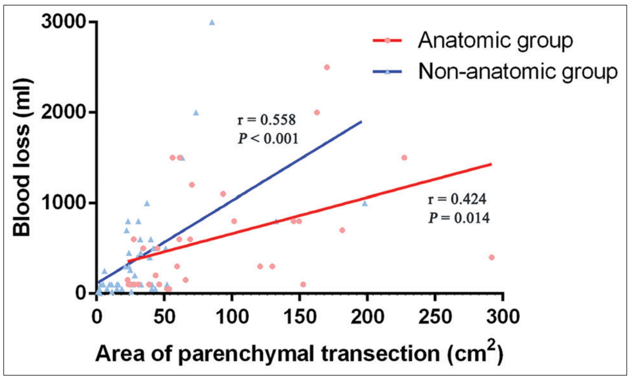

Figure 7: Nonanatomic laparoscopic liver resection is associated with more blood loss compared with anatomic laparoscopic liver resection when the area of parenchymal transection is equal or more than 30 cm^2. Anatomic group: n = 34, nonanatomic group: n = 49.

Table 4: Pathologic characteristics for patients underwent pure laparoscopic liver resection

Pathologic diagnosis	*n* (%)
Hepatocellular carcinoma	45 (53.6)
Cholangiocarcinoma	6 (7.1)
Metastatic colorectalcarcinoma	21 (25.0)
Metastatic neuroendocrine carcinoma	4 (4.8)
Metastatic breast carcinoma	2 (2.4)
Metastatic vater ampulla carcinoma	3 (3.6)
Metastatic ovarian carcinoma	1 (1.2)
Metastatic lung squamous carcinoma	1 (1.2)
Metastatic adrenocortical carcinoma	1 (1.2)
Total	84 (100)

Discussion

In the year 2008, the Louisville statement had suggested the indications for laparoscopy should be: (1) solitary lesions; (2) tumor diameter <5 cm; and (3) tumor locates in left lateral or anterior hepatic segments (Couinaud's segment 4b, 5 and 6).[10] With the surgical technique developed and experience accumulated, multiple tumor or tumor larger than 5 cm are no longer considered to be a contraindication. In our study, we performed 19 cases of operations for tumors larger than 5 cm (14 for the anatomic procedure and 5 for the nonanatomic procedure), and 24 cases for multiple tumors (10 for the anatomic procedure and 14 for the nonanatomic procedure). We also performed LLR for tumors in the posterior segments or central liver. There were 15 cases for the segment 7, 8 operations (4 for anatomic procedure and 11 for nonanatomic procedure), which used to be considered as a "forbidden area" for laparoscopic liver surgery.[10] However, we still take operations requiring vascular or biliary reconstruction as the contraindication for laparoscopy. Over the past decade, there was a tendency toward a more extensive hepatectomy procedure selected among patients with larger tumors or more deeply located tumors.[3,10,18]

How to decide the exact type of liver resection in open surgery, anatomic or nonanatomic resection, has been a controversy for a long time. To our best knowledge, there is no published study discussing this issue in the LLR. Earlier studies have advocated that anatomic liver resection is surgically and oncologically superior to nonanatomic liver resection in open procedures, especially for primary HCC.[15,16] In treatment of primary HCC, complete removal of intraoperative metastasis occurring by vascular invasion is one of the most important considerations. Moreover, anatomic liver resection allows the complete removal of the main tumor and possible venous tumor thrombi, as mentioned before. Although the oncological benefit of anatomic resection for liver metastasis may not be as significant as for the treatment of HCC theoretically, it is considered that anatomic resection still has some advantages.[13] In the case

Table 5: Postoperative results for patients underwent pure laparoscopic liver resection

Variables	Anatomic group (n = 34)	Nonanatomic group (n = 50)	Statistic values	*P*
Mortality	0	0	–	–
Specific morbidity	4 (11.8)	5 (10.0)	0.066*	0.797
Ascites	3 (8.8)	4 (8.0)	0.018*	0.893
Biliary collection	1 (2.9)	1 (2.0)	0.077*	0.781
General morbidity	6 (17.6)	6 (12.0)	0.527*	0.468
Pulmonary	4 (11.8)	4 (8.0)	0.333*	0.564
Infection	2 (5.9)	2 (4.0)	0.158*	0.691
Admission to ICU	6 (17.6)	8 (16.0)	0.040*	0.842
ICU stay (days)	1.2, 1.0–2.0	1.5, 1.0–3.0	–	–
Hospital stay (days)	7.5 ± 3.5 (6.5, 3.0–19.0)	5.9 ± 2.5 (6.0, 2.0–14.0)	−2.503†	0.014

*χ^2; †t values. Values are n (%) or mean ± standard deviation (median, range); ICU: Intensive care unit.

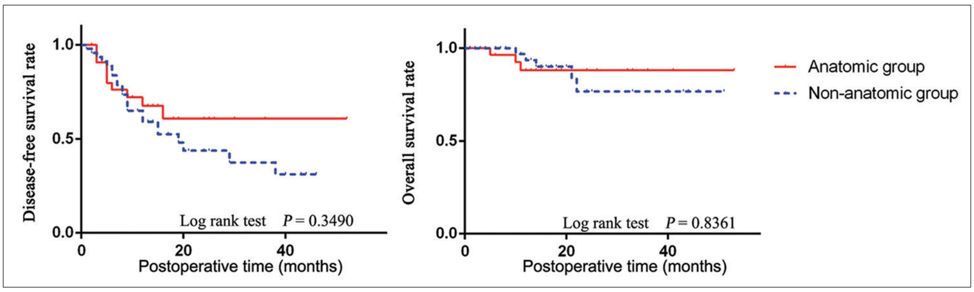

Figure 8: Disease-free and overall survival curve of the anatomic and nonanatomic laparoscopic liver resection groups.

of patients with a liver metastasis who is expected to receive a liver resection after neoadjuvant chemotherapy, the tumor boundary may be sometimes unclear on the intraoperative ultrasonography, and then an anatomic liver resection has the potential advantage of ensuring an adequate surgical margin.[17] In addition, there is also a possibility of reducing the risk of bile leakage.[23-25]

It was previously reported that the open anatomic liver resection had a longer operation time, more bleeding during operation, similar or better surgical margin, same perioperative mortality and morbidity, and same length of hospital stay, but a larger tumor size compared with the nonanatomic procedure. This study shows the similar perioperative results in pure laparoscopic surgery.

Intraoperative bleeding is a major concern during LLR. Postoperative mortality and morbidity are correlated with the amount of blood loss.[26] There are some techniques to reduce intraoperative blood loss by selective vascular clamping, which are the most important techniques because bleeding control is more difficult in the laparoscopic surgeries than in the open surgeries. The Glissonian approach has been established and evaluated before.[19-22] The Glissonian pedicle approach is one of the key techniques of laparoscopic anatomic liver resection. As mentioned before, the extra-Glissonian approach is an extremely useful method in an open liver surgery. Selectively clamping with extra-Glissonian pedicle can avoid ischemia of the other parts of the liver.[27] Therefore, we applied this feasible and effective technique in laparoscopic procedures. However, during the LLR procedure for left liver sectors, we always open the Glisson sheath and clamp vessels and bile ducts, respectively, to avoid the mis-clamping of variant vessels draining in the right anterior sector and hepatic bile ducts collecting from the right liver.[19] After ligating the Glissonian pedicle, we dissected the liver parenchyma with the combination of ultrasonic shears and the LigaSure (Covidien Plc. Dublin, Ireland). Any vessel >3 mm was ligated or clipped. Monopolar electrocoagulation of spray mode was used to control the oozing of blood.

Although having a longer operation time, the anatomic group also have the larger tumor size, the deeper and more complex tumor location, and the larger area of parenchymal transection. Liver parenchymal transection is one of the most difficult and time-consuming parts of anatomic liver resection. The fear of bleeding during parenchymal transection has deterred many surgeons from attempting to carry out the pure laparoscopic procedures. The nonanatomic LLR group has more blood loss compared with the anatomic LLR group when the area of parenchymal transection is equal or more than 30 cm^2. This result infers that the nonanatomic LLR may lead to a difficult blood control and more blood loss, compared with the anatomic LLR, for a similar size and located tumor. Not only provide a potentially better oncological outcome compared with nonanatomic liver resection, but the anatomic procedure also reduce the blood loss during the parenchymal transection in some difficult procedures which need to transect a large area of parenchyma.

Surgeons are accustomed to select the nonanatomic procedure for small and superficial lesions and choose the anatomic liver resection for large and deep tumors. This study may provide some evidence for this usual practice. We suggest that anatomic procedure may be more advantageous for a large size or deeply located tumor, when a large area of parenchymal resection is predicted, only if we control and ligate the corresponding Glisson pedicle successfully and remove the complete segment or sector.

In respect to the long-term outcomes, the disease-free and overall survival rates were similar between the anatomic and nonanatomic groups. However, the observation period was short in this study with a median follow-up time of 11 months, as the laparoscopic anatomic liver resection was extensively performed in recent years, further studies with longer follow-ups are needed.

Some inherent limitations need to be mentioned. In our study, a larger tumor size was observed in the anatomic LLR group. It might be influenced by the selection bias in the early period of this study. Because the absence of recognized criteria for anatomic liver resection, surgeons tend to select surgical procedure depending on their personal experiences. At the early period of study, we preferred local resections for small tumors like most surgeons. However, we found that nonanatomic LLR was not safer and easier than anatomic procedures in some conditions. With the number of cases increasing, we believed the tumor location and lesion numbers should be placed in the same position with tumor maximal size for the selection of surgical procedures. Liver lesions with these features as follows were considered as absolute indications of anatomic resection in our hospital: (1) the maximal diameter of tumor was more than 3 cm, and the tumor was located more than 3 cm from the liver capsule; (2) there were more than 3 lesions located in a single liver segment or lobe. An exophytic lesion was inclined to be locally resected. The maximal tumor diameter in the nonanatomic LLR group is 12.0 cm, and the tumor size is no longer the only important criterion of choosing surgical procedure. The sample size is inadequate for subgroup analysis, and future matched pair studies are warranted. Besides, this study was limited to malignant lesions as the diagnosis (benign or malignant) may influence the types of resection and the surgical principles. The perioperative parameters we focused on for benign and malignant liver lesions were also different. In addition, we always slice the benign specimens piece by piece before delivered from the abdomen to minimize the abdominal incision, which makes it impossible to measure and compute the area of parenchymal transection.

In conclusion, both anatomic and nonanatomic pure LLRs are safe and feasible as it is shown in this study. Anatomic LLR is associated with more operation time and more intraoperative blood loss. However, the blood loss per unit area is less in the anatomic LLR group compared with nonanatomic LLR group. The measure for the area of parenchymal transection is a simple and effective method to estimated liver resection surgery. For the large or deeply located tumors, it may be appropriate to perform an anatomic liver resection when the remnant liver function is adequate. Further studies involving a larger number of patients underwent pure LLR are warranted.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Gagner M, Rheault M, Dubuc J. Laparoscopic partial hepatectomy for liver tumor. Surg Endosc 1992;6:99.
2. Azagra JS, Goergen M, Gilbart E, Jacobs D. Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects. Surg Endosc 1996;10:758-61. doi: 10.1007/BF00193052.
3. Tranchart H, Dagher I. Laparoscopic liver resection: A review. J Visc Surg 2014;151:107-15. doi: 10.1016/j.jviscsurg.2013.10.003.
4. Shafaee Z, Kazaryan AM, Marvin MR, Cannon R, Buell JF, Edwin B, *et al.* Is laparoscopic repeat hepatectomy feasible? A tri-institutional analysis. J Am Coll Surg 2011;212:171-9. doi: 10.1016/j.jamcollsurg. 2010.10.012.
5. Martin RC, Scoggins CR, McMasters KM. Laparoscopic hepatic lobectomy: Advantages of a minimally invasive approach. J Am Coll Surg 2010;210:627-34, 634-6. doi: 10.1016/j.jamcollsurg. 2009.12.022.
6. Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. Ann Surg 2009;250:831-41. doi: 10.1097/SLA.0b013e3181b0c4df.
7. Fong Y, Fortner J, Sun RL, Brennan MF, Blumgart LH. Clinical score for predicting recurrence after hepatic resection for metastatic colorectal cancer: Analysis of 1001 consecutive cases. Ann Surg 1999;230:309-18. doi: 10.1097/00000658-199909000-00004.
8. Franken C, Lau B, Putchakayala K, DiFronzo LA. Comparison of short-term outcomes in laparoscopic vs open hepatectomy. JAMA Surg 2014;149:941-6. doi: 10.1001/jamasurg.2014.1023.
9. Adam R, Bismuth H, Castaing D, Waechter F, Navarro F, Abascal A, *et al.* Repeat hepatectomy for colorectal liver metastases. Ann Surg 1997;225:51-60. doi: 10.1097/00000658-199701000-00006.
10. Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, Dagher I, *et al.* The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Ann Surg 2009;250:825-30. doi: 10.1097/SLA.0b013e3181b3b2d8.
11. Vigano L, Laurent A, Tayar C, Tomatis M, Ponti A, Cherqui D. The learning curve in laparoscopic liver resection: Improved feasibility and reproducibility. Ann Surg 2009;250:772-82. doi: 10.1097/SLA.0b013e3181bd93b2.
12. Cai X, Li Z, Zhang Y, Yu H, Liang X, Jin R, *et al.* Laparoscopic liver resection and the learning curve: A 14-year, single-center experience. Surg Endosc 2014;28:1334-41. doi: 10.1007/s00464-013-3333-5.
13. Ishizawa T, Gumbs AA, Kokudo N, Gayet B. Laparoscopic segmentectomy of the liver: From segment I to VIII. Ann Surg 2012;256:959-64. doi: 10.1097/SLA.0b013e31825ffed3.
14. Wakai T, Shirai Y, Sakata J, Kaneko K, Cruz PV, Akazawa K, *et al.* Anatomic resection independently improves long-term survival in patients with T1-T2 hepatocellular carcinoma. Ann Surg Oncol 2007;14:1356-65. doi: 10.1245/s10434-006-9318-z.
15. Hasegawa K, Kokudo N, Imamura H, Matsuyama Y, Aoki T, Minagawa M, *et al.* Prognostic impact of anatomic resection for hepatocellular carcinoma. Ann Surg 2005;242:252-9. doi: 10.1097/01.sla.0000171307.37401.db.
16. Yamamoto M, Ariizumi S, Katagiri S, Kotera Y, Takahashi Y. The value of anatomical liver sectionectomy for patients with a solitary hepatocellular carcinoma from 2 to 5 cm in greatest diameter. J Surg Oncol 2009;100:585-8. doi: 10.1002/jso.21363.
17. Kokudo N, Tada K, Seki M, Ohta H, Azekura K, Ueno M, *et al.* Anatomical major resection versus nonanatomical limited resection for liver metastases from colorectal carcinoma. Am J Surg 2001;181:153-9. doi: 10.1016/S0002-9610(00)00560-2.
18. Martin RC 2nd, Mbah NA, St Hill R, Kooby D, Weber S, Scoggins CR, *et al.* Laparoscopic versus open hepatic resection for hepatocellular carcinoma: Improvement in outcomes and similar cost. World J Surg 2015;39:1519-26. doi: 10.1007/s00268-015-2974-z.
19. Uysal F, Obuz F, Uçar A, Seçil M, Igci E, Dicle O. Anatomic variations of the intrahepatic bile ducts: Analysis of magnetic resonance cholangiopancreatography in 1011 consecutive patients. Digestion 2014;89:194-200. doi: 10.1159/000358558.
20. Mouly C, Fuks D, Browet F, Mauvais F, Potier A, Yzet T, *et al.* Feasibility of the Glissonian approach during right hepatectomy. HPB (Oxford) 2013;15:638-45. doi: 10.1111/hpb.12035.
21. Yamamoto M, Katagiri S, Ariizumi S, Kotera Y, Takahashi Y, Egawa H. Tips for anatomical hepatectomy for hepatocellular carcinoma by the Glissonean pedicle approach (with videos). J Hepatobiliary Pancreat Sci 2014;21:E53-6. doi: 10.1002/jhbp.117.
22. Kogure K, Ishizaki M, Nemoto M, Kuwano H, Yorifuji H, Takata K, *et al.* Morphogenesis of an anomalous ligamentum venosum terminating in the superior left hepatic vein in a human liver. J Hepatobiliary Pancreat Surg 2005;12:310-3. doi: 10.1007/s00534-005-0987-y.
23. Spatz J, Holl G, Sciuk J, Anthuber M, Arnholdt HM, Märkl B. Neoadjuvant chemotherapy affects staging of colorectal liver metastasis – A comparison of PET, CT and intraoperative ultrasound. Int J Colorectal Dis 2011;26:165-71. doi: 10.1007/s00384-010-1065-8.
24. Abdalla EK, Adam R, Bilchik AJ, Jaeck D, Vauthey JN, Mahvi D. Improving resectability of hepatic colorectal metastases: Expert consensus statement. Ann Surg Oncol 2006;13:1271-80. doi: 10.1245/s10434-006-9045-5.

25. Gold JS, Are C, Kornprat P, Jarnagin WR, Gönen M, Fong Y, *et al.* Increased use of parenchymal-sparing surgery for bilateral liver metastases from colorectal cancer is associated with improved mortality without change in oncologic outcome: Trends in treatment over time in 440 patients. Ann Surg 2008;247:109-17. doi: 10.1097/1SLA.0b013e3181557e47.
26. Figueras J, Llado L, Ruiz D, Ramos E, Busquets J, Rafecas A, *et al.* Complete versus selective portal triad clamping for minor liver resections: A prospective randomized trial. Ann Surg 2005;241:582-90. doi: 10.1097/01.sla.0000157168.26021.b8.
27. Giordano M, Lopez-Ben S, Codina-Barreras A, Pardina B, Falgueras L, Torres-Bahi S, *et al.* Extra-Glissonian approach in liver resection. HPB (Oxford) 2010;12:94-100. doi: 10.1111/j.1477-2574.2009.00135.x.