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Robotic versus laparoscopic liver resection in complex cases of left lateral sectionectomy

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ABSTRACT

Background: Laparoscopic liver resection is recommended as the standard operation for left lateral sectionectomy (LLS). Robotic liver resection is theoretically better than laparoscopic liver resection in complex cases of liver resection. However, in a complex case of LLS, whether robotic LLS (R-LLS) is still better than laparoscopic LLS (L-LLS) is unclear. This study aims to assess the perioperative outcomes of R-LLS and L-LLS in the overall and in the subgroup of complex cases of LLS.
Methods: From January 2015 to June 2017, the data on consecutive patients who underwent R-LLS were retrospectively compared with those who underwent L-LLS. Based on defined criteria for complex cases, the subgroup of such patients who underwent R-LLS were compared with the subgroup of patients who underwent L-LLS. The patient characteristics and surgical outcomes in the whole groups and subgroups of patients were analyzed.
Results: The overall R-LLS and L-LLS groups showed no significance differences in operative time, intraoperative blood loss, postoperative hospital stay, blood transfusion and morbidity rates. The overall medical costs were significantly higher in the R-LLS group than in the L-LLS group (12786.4 vs. 7974.3 USD; $p < 0.001$). On subgroup analysis of the complex cases, the estimated blood loss was significantly less in the R-LLS subgroup than the L-LLS subgroup (131.9 vs. 320.8 ml, $p = 0.003$). The two subgroups showed no significant differences in postoperative hospital stay (4.7 vs. 5.3 days; $p = 0.054$) and operative times (126.4 vs. 110.8 min; $p = 0.379$). The R-LLS subgroup had significantly higher overall medical costs than the L-LLS subgroup (13536.9 vs. 9186.7 USD, $p = 0.006$).
Conclusion: The overall R-LLS group was comparable to the overall L-LLS group in perioperative outcomes. Although the overall medical costs in the robotic subgroup was higher, R-LLS might be a better choice for the subgroup of patients with complex cases when compared to L-LLS.

1. Introduction

Over 20 years have elapsed since Reich et al. reported on the first successful case of laparoscopic liver resection (LLR) in 1991 [1]. Improvements in techniques and instruments have led to the increase use of LLR [2]. The safety and benefits of minimally invasive surgery allow LLR to grow from minor peripheral segmentectomy [3] to major and extended hemi-hepatectomy [4,5]. When compared with open liver resection, the short-term advantages of LLR include lower morbidity, less operative blood loss and shorter length of hospital stay [6,7]. However, several limitations of the laparoscopic procedure impede its use in complex cases of liver resection [8].

As the most advanced technology in minimally invasive surgery, the robotic surgical system can overcome the shortcomings of the conventional laparoscopic surgery [8]. Robotic surgery provides increased dexterity to perform delicate dissection, a 3-dimensional stereoscopic view with adjustable magnification, and a comfortably-seated operating posture to reduce fatigue and physical stress [9]. Robotic liver surgery allows technical ease in complex hepatic vein and hilar dissection, intra-operative control of bleeding and biliary reconstruction [10].

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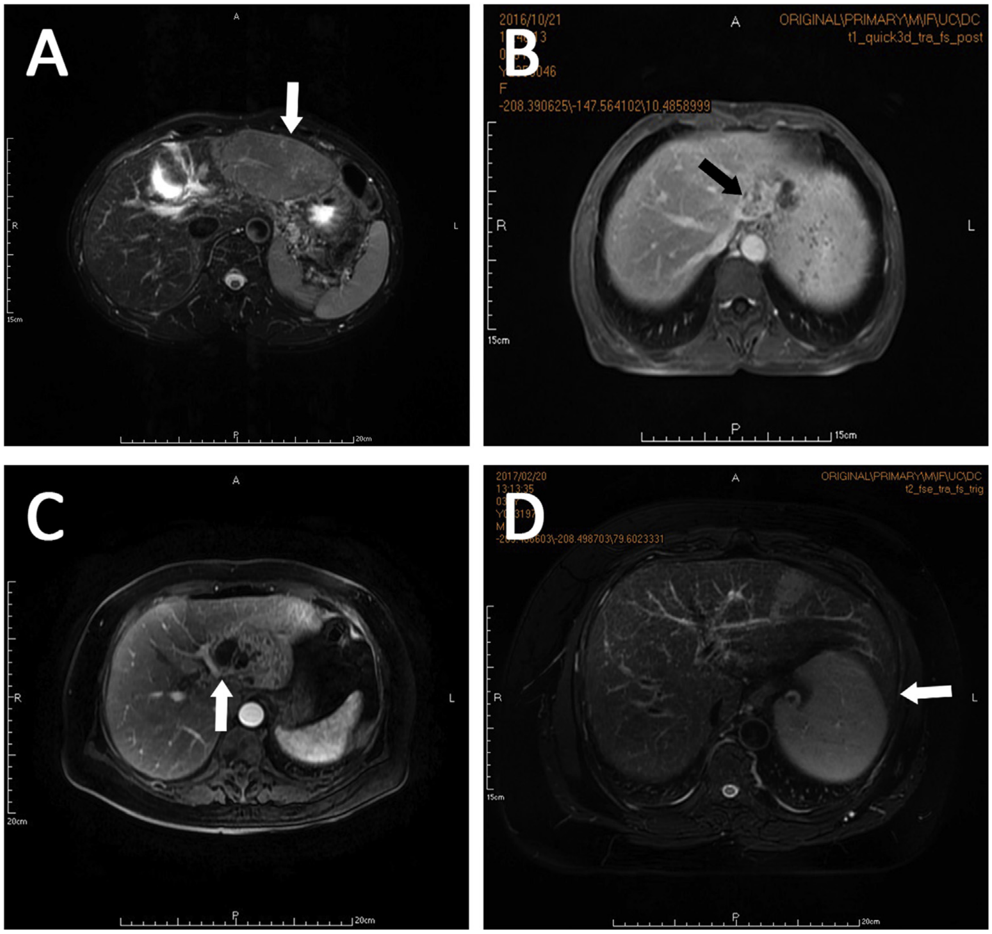

Fig. 1. Illustrative images of a complex-case LLS. A: HCC (arrow) more than 10 cm in diameter. B: Intrahepatic cholangiocarcinoma (arrow) adjacent to the left hepatic vein. C: Liver abscess (arrow) adjacent to the left portal vein. D: Huge left lateral section which as embedded in the splenic fossa (arrow).

Although several studies have been conducted to compare robotic versus laparoscopic liver resection [10–14], there is still very little evidence to guide surgeons in the appropriate selection between these two surgical approaches.

Left lateral sectionectomy (LLS) is considered by many surgeons to be the easiest anatomical liver resection [15]. It accounts for the vast majority of laparoscopic anatomical liver resections [2]. Several studies [16–18] which compared laparoscopic with open LLS showed the laparoscopic approach to be superior to the open approach in short-term outcomes, with significantly reduced intra-operative blood loss, shorter hospital stay but comparable operative times. Laparoscopic LLS (L-LLS) has now been recommended as a standard operation [19–21]. A recent systematic review [12] showed robotic LLS (R-LLS) to account for the second largest number of robotic anatomical liver resection, immediately following right hepatectomy as the highest. Three non-randomized studies [11,22,23] showed robotic and laparoscopic LLS to result in similar surgical outcomes. However, a fourth study by Packiam *et al* [24] suggested robotic LLS to be marginally inferior to laparoscopic approach in clinical outcomes.

The proper preoperative assessment of surgical difficulty for minimally invasive hepatectomy is crucial in the selection of appropriate patients. Several factors have previously been reported to affect the operative difficulty of LLR and the peri-operative outcomes. These factors included tumor location, tumor size, body mass index (BMI) and repeated hepatectomy [25–30]. Ban et al. first proposed a difficulty scoring system for LLR based on the sum of the calculated scores of five factors [31]. This system has been validated in the prediction of the difficulty levels and the peri-operative outcomes using a multicenter analysis by the Endoscopy Liver Surgery Study Group in Japan [32]. Recently, a new classification [33] reported by Kawaguchi et al., and a novel model [34] reported by Hasegawa et al., were developed to evaluate the difficulty of LLR, with highlights on the extent of resection, location of tumor, obesity and platelet count. To our knowledge, the difficulty classification systems for robotic liver resection are still currently lacking.

The proper selection of patients to undergo robotic or laparoscopic liver resection for lesions in the left lateral section is still unclear. For an ordinary case, LLS can be relatively straightforward. However, the difficulty level of surgery can increase tremendously in complex cases. The aims of the present study were to verify if there is any difference of outcomes for patients who underwent R-LLS and L-LLS, as well as if there is any difference of outcomes for selected complex cases who underwent R-LLS and L-LLS.

2. Materials and methods

2.1. Study design

This retrospective study was approved by the Institutional Review Board, and all patients gave informed written consent for their data to be used for research purposes. From January 2015 to June 2017, the data of consecutive patients who underwent R-LLS or L-LLS at the Department of Hepatobiliary and Pancreatic Surgical Oncology, Chinese PLA General Hospital were analyzed retrospectively. The work has been reported in line with the STROCSS criteria [44].

Pre-operative investigations included routine blood examination, serum tumor markers, dynamic contrast-enhanced magnetic resonance imaging (MRI), contrast-enhanced computed tomography (CT),

Table 1
Patient characteristics and pathology.

Characteristic	L-LLS (n = 54)	R-LLS (n = 58)	*p*	*power*
Age (years)	48.9 years)	52.2 years)	0.198	0.1563
Gender (male/female)	26/28	33/25	0.354	
BMI (kg/m2)	23.8 kg/m2) 24.7 kg/m2) 0.201	0.9805		
ASA score			0.400	
1	5	2		
2	48	54		
3	1	2		
Lesion size (cm)	4.7 on siz4.7 on siz0.984	0.6826		
Cirrhosis	18 (33.3%)	16 (27.6%)	0.509	
Previous abdominal surgery	11 (20.4%)	5 (8.6%)	0.105	
Pathology			0.454	
Abscess	1 (1.9%)	0		
Angiomyolipoma	1 (1.9%)	0		
Cholangiocarcinoma	1 (1.9%)	4 (6.9%)		
Colorectal liver metastases	2 (3.7%)	2 (3.4%)		
Cystadenocarcinoma	0	1 (1.7%)		
Focal nodular hyperplasia	9 (16.7%)	5 (8.6%)		
Hepatocellular carcinoma	23 (42.6%)	25 (43.1%)		
Hemangioma	14 (25.9%)	13 (22.4%)		
Hepatolithiasis	1 (1.9%)	3 (5.2%)		
Lung cancer liver metastasis	0	1 (1.7%)		
Mixed HCC-CC	0	2 (3.4%)		
Myofibroblastoma	1 (1.9%)	0		
Nasopharyngeal carcinoma liver metastasis	0	1 (1.7%)		
Parasite	1 (1.9%)	0		
Tuberculosis	0	1 (1.7%)		

contrast-enhanced ultrasonography, and positron emission tomography (PET) if necessary. The peri-operative variables evaluated were operative time, estimated blood loss, transfusion rate, conversion rate, length of hospital stay, morbidity and mortality rates.

The inclusion criteria were benign or malignant lesions localized to the left lateral section (Couinaud's segment II and III) and the liver function was Child-Pugh class A or B. The tumor size was not a factor for patient selection for surgery. The exclusion criteria included a history of a previous complex upper abdominal operation, tumor invasion of main portal vein or inferior vena cava (IVC), and the need for vascular or biliary reconstruction.

Defined criteria of a complex case for LLS were: (i) tumor size more than 10 cm in diameter (Fig. 1A); (ii) proximity of tumor to major vessels (Fig. 1B and C); (iii) obesity (BMI > 30 kg/m^2); (iv) combined lymphadenectomy or choledochoscopy; (v) huge left lateral section (Fig. 1D) which was embedded in splenic fossa. Patients who met any one of the above criteria were included into the complex case group for LLC. Those who did not meet any one of the criteria were included in the ordinary-case group.

2.2. Surgical technique

All robotic liver resection were performed using the da Vinci Si System (Intuitive Surgical Inc., Sunnyvale, CA, USA) by our surgical team. The patient was placed in a supine and reversed Trendelenburg position with splitting of the 2 lower limbs. The body of the robot was docked over the head of the patient, and the assistant surgeon stood between the patient's legs. Four trocars were used, including three 12-mm trocars and an 8-mm trocar. The robotic camera was inserted through a 12-mm trocar placed in the sub-umbilical site and the other three trocars were inserted under laparoscopic guidance. The 8-mm 1st arm and the 12-mm 2nd arm were placed through the trocars which were located in the left subcostal location and the right hypogastrium, respectively. The assistant's 12-mm trocar was positioned in the left hypogastrium for suction, passing on needles, handling of the BiClamp and argon beam coagulation (EREB, Germany). The 12-mm trocar in the right hypogastrium was also used by the assistant surgeon for vascular stapling.

The surgeon performed mobilization of the left lateral section using an ultrasonic scalpel (Ethicon Endo-Surgery, Cincinnati, OH, USA). The round, falciform, left coronary, left triangle, and hepatogastric ligaments were sequentially divided. In some complex cases, the left portal vein and left hepatic vein were isolated early. The liver parenchymal transection plane was along the falciform ligament using an ultrasonic scalpel. Ultrasonic coagulation, bipolar electrocoagulation and BiClamp were used for hemostasis during parenchymal transection. An endoscopic linear cutter-stapler (EC-60, Ethicon Endo-Surgery) was used to transect and seal the Glissonian pedicles of segments 2 and 3. The left hepatic vein was identified and then divided by a linear cutter-stapler. Hemostasis of the transected liver surface was performed by bipolar electrocoagulation and argon beam coagulation. The resected specimen was placed into a disposable sterile endobag (Covidien, Mansfield, OH, USA) and the endobag was retrieved through an extension of the sub-umbilical port incision. A peritoneal drain was placed if necessary.

The surgical approach of L-LLS was conducted using the procedures as previously described [35] and the operative procedure was similar to the robotic approach. In this study, the L-LLS was totally laparoscopic surgery, without using the hand-assisted or hybrid method.

2.3. Statistical analysis

All statistical analyses were performed using the SPSS 22.0 statistical software package (SPSS Inc., Chicago, IL). Continuous data were expressed as means ± standard deviations. The Student's *t*-test was used to compare normally distributed quantitative data while the Mann–Whitney *U* test was used for non-normally distributed quantitative data. For non-statistically quantitative data, the calculations of power were conducted to test whether the means of two groups are equivalent [36]. The Type I error probability associated with tests of null hypothesis is 0.05. All qualitative data were expressed as number (%) and compared using the Chi-squared test. A *P*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Patient characteristics

From January 2015 to June 2017, 112 patients who underwent L-LLS (n = 54) or R-LLS (n = 58) entered into this study. The clinical characteristics are shown in Table 1. The two groups of patients (the L-LLS group and the R-LLS group) were comparable in age, BMI, gender, American Society of Anesthesiologists (ASA) scores, lesion size, and a history of previous abdominal surgery (all $p > 0.05$).

Twenty-six (45%) L-LLS patients and 36 (62%) R-LLS patients had malignant tumors. The major indications for L-LLS were hepatocellular carcinoma (HCC) (n = 23) and hemangioma (n = 14), as well as for R-LLS HCC (n = 25) and hemangioma (n = 13). The mean sizes of the lesions were similar between the two groups (4.7 ± 2.8 vs 4.7 ± 2.6 cm; $p = 0.984$).

3.2. Perioperative outcomes

The perioperative outcomes are summarized in Table 2. All patients who underwent either L-LLS or R-LLS had R0 resection on the final histopathologies. The Pringle's maneuver was not employed in any patient. One patient with a cholangiocarcinoma in the L-LLS group required conversion to open LLS owing to failed lymphadenectomy, while no patients in the R-LLS group required conversion to laparotomy. Patients in the L-LLS group had an insignificantly shorter operative time than those in the R-LLS group (95.7 ± 47.5 vs.

Table 2
Perioperative outcome.

Characteristic	L-LLS (n = 54)	R-LLS (n = 58)	p	power
Operative time (min), mean ± SD	95.7 ± 47.5	107.0 ± 45.2	0.074	0.1147
Estimated blood loss (ml), mean ± SD	108.9 ± 180.8	80.1 ± 144.4	0.523	0.052
Blood transfusion	1 (1.9%)	3 (5.2%)	0.344	
Conversion to laparotomy	1 (1.9%)	0	0.298	
Postoperative hospitalization (days), mean ± SD	4.4 ± 1.8	4.3 ± 1.8	0.448	0.5118
Overall medical costs (USD), mean ± SD	7974.3 ± 1967.4	12786.4 ± 3330.2	< 0.001	
Morbidity	2 (3.7%)	1 (1.7%)	0.517	
Mortality	0	0	N/A	
R1 Resection	0	0	N/A	

107.0 ± 45.2 min; $p = 0.074$). There were no significant differences between the two groups in estimated blood loss (108.9 ± 180.8 vs. 80.1 ± 144.4 ml; $p = 0.523$), blood transfusion rates (1.9% vs. 5.2%) and morbidity rates (3.7% vs. 1.7%). No postoperative mortality occurred in either group in this study.

The postoperative hospital stay was similar for the two groups ($p = 0.448$). The overall medical costs were significantly higher in the R-LLS group (mean 12786.4 USD) than in the L-LLS group (mean 7974.3 USD; $p < 0.001$).

3.3. Outcomes for L-LLS in the complex-case subgroup versus the ordinary-case subgroup

The patient characteristics and surgical outcomes for the two subgroups of patients are shown in Table 3. The two subgroups were comparable in age, gender, cirrhosis, ASA scores and a history of previous abdominal surgery. Patients in the complex-case subgroup who underwent L-LLS had a significantly higher BMI (25.9 ± 3.8 vs. 23.2 ± 2.8 kg/m^2; $p = 0.010$) and larger lesion size (7.5 ± 3.9 vs. 3.9 ± 1.9 cm; $p < 0.001$) than those in the ordinary-case subgroup who underwent L-LLS owning to the defined criteria used for complex cases. There were no significant differences between the two subgroups in operative time (110.8 ± 44.5 vs. 91.4 ± 47.9 min; $p = 0.080$) for patients who underwent L-LLS. The complex-case subgroup, when compared with the ordinary-case subgroup, had significantly more estimated blood loss (320.8 ± 293.5 vs. 48.3 ± 47.6 ml; $p < 0.001$), longer postoperative hospital stay (5.3 ± 1.2 vs. 4.1 ± 1.9 days; $p = 0.010$), and higher medical costs (9186.7 ± 2123.8 vs. 7627.9 ± 1800.1 USD; $p = 0.014$).

3.4. Outcomes for R-LLS in the complex-case subgroup versus the ordinary-case subgroup

The patient characteristics and surgical outcomes for the two subgroups of patients are shown in Table 4. The two subgroups were comparable in age, gender, cirrhosis, ASA scores and a history of previous abdominal surgery. Patients in the complex-case subgroup who underwent R-LLS had an insignificantly higher BMI (26.7 ± 5.0 vs. 23.6 ± 2.7 kg/m^2; $p = 0.003$) and a significantly larger lesion size (6.3 ± 3.3 vs. 3.8 ± 1.5 cm; $p < 0.001$) than those in the ordinary-case subgroup who underwent R-LLS owing to the defined criteria used for complex cases. There were no significant differences between the two subgroups in postoperative hospital stay (4.7 ± 2.6 vs. 4.0 ± 1.1 days; $p = 0.713$) for patients who underwent R-LLS, The complex-case subgroup of patients, when compared with the ordinary-case subgroup of patients, had significantly more estimated blood loss (131.9 ± 221.9 vs. 50.7 ± 56.8 ml; $p = 0.034$), and significantly longer operative time (126.4 ± 55.3 vs. 95.9 ± 34.5 min; $p = 0.015$). There were no significant differences in medical costs between the two subgroups (13536.9 ± 4768.6 vs. 12360.4 ± 2100.2 USD; $p = 0.199$).

3.5. Outcomes for R-LLS in the complex-case subgroup versus the L-LLS in the complex-case subgroup

Table 5 shows the patient characteristics and surgical outcomes for R-LLS for the complex-case subgroup versus L-LLS for the complex-case subgroup. The two subgroups were comparable in age, gender, BMI, lesion size, cirrhosis, ASA scores and a history of previous abdominal surgery. R-LLS for the complex-case subgroup, when compared with L-LLS for the complex-case subgroup, resulted in significantly less estimated blood loss (131.9 ± 221.9 vs. 320.8 ± 293.5 ml, $P = 0.003$). The two subgroups were similar in postoperative hospital stay (4.7 ± 2.6 vs. 5.3 ± 1.2 days; $p = 0.054$) and operative times (126.4 ± 55.3 vs. 110.8 ± 44.5 min; $p = 0.379$). The overall medical costs were significantly higher in the R-LLS subgroup than the L-LLS subgroup (13536.9 ± 4768.6 vs. 9186.7 ± 2123.8 USD, $p = 0.006$).

Table 3
Patient characteristics and surgical outcome of ordinary-case L-LLS and complex-case L-LLS.

Characteristic	ordinary-case L-LLS (n = 42)	complex-case L-LLS (n = 12)	p	power
Age (years)	47.3 years)	54.8 years)	0.080	0.0232
Gender (male/female)	19/23	7/5	0.423	
BMI (kg/m^2)	23.2 kg/mal25.9 kg/mal0.010			
ASA score			0.855	
1	4 (9.5%)	1 (8.3%)		
2	37 (88.1%)	11 (91.7%)		
3	1 (2.4%)	0 (0.0%)		
Lesion size (cm)	3.9 on siz7.5 on siz < 0.001			
Cirrhosis	15 (35.7%)	3 (25.0%)	0.487	
Previous abdominal surgery	10 (23.8%)	1 (8.3%)	0.240	
Postoperative hospitalization (days), mean ± SD	4.1 ± 1.9	5.3 ± 1.2	0.010	
Operative time (min), mean ± SD	91.4 ± 47.9	110.8 ± 44.5	0.080	0.1025
Estimated blood loss (ml), mean ± SD	48.3 ± 47.6	320.8 ± 293.5	< 0.001	
Overall medical costs (USD), mean ± SD	7627.9 ± 1800.1	9186.7 ± 2123.8	0.014	

Table 4
Patient characteristics and surgical outcome of ordinary-case R-LLS and complex-case R-LLS.

Characteristic	ordinary-case R-LLS (n = 37)	complex-case R-LLS (n = 21)	*p*	*power*
Age (years)	51.4 years)	53.7 years)	0.541	0.2822
Gender (male/female)	18/19	15/6	0.092	
BMI (kg/m2)	23.6 kg/m2)26.7 kg/m2)0.003			
ASA score			0.518	
1	1 (2.7%)	1 (4.8%)		
2	34 (91.9%)	20 (95.2%)		
3	2 (5.4%)	0 (0.0%)		
Lesion size (cm)	3.8 on siz6.3 on siz < 0.001			
Cirrhosis	9 (24.3%)	7 (33.3%)	0.461	
Previous abdominal surgery	3 (8.1%)	2 (9.5%)	0.854	
Postoperative hospitalization (days), mean ± SD	4.0 ± 1.1	4.7 ± 2.6	0.713	0.1398
Operative time (min), mean ± SD	95.9 ± 34.5	126.4 ± 55.3	0.015	
Estimated blood loss (ml), mean ± SD	50.7 ± 56.8	131.9 ± 221.9	0.034	
Overall medical costs (USD), mean ± SD	12360.4 ± 2100.2	13536.9 ± 4768.6	0.199	0.0306

4. Discussion

L-LLS is considered to be the most straight-forward anatomical laparoscopic liver resection. It was first reported in 1996 [3,37]. The past decades have witnessed the development of laparoscopic hepatectomy from the exploratory stage gradually to become a standard practice. The 2008 Louisville Statement recommended that L-LLS should be considered as a standard practice [20]. Since then, the number of L-LLS carried out around the world increased from 463 to 1890 within a few years [38,39]. Owing to it being a relatively standardized and reproducible procedure, L-LLS is also an appropriate technique to train inexperienced surgeons in LLR [40].

The major advantage of the robot surgical system over laparoscopic surgery is its high degree of dexterity and accuracy. Many surgeons consider it to be the extension and breakthrough of the traditional laparoscopic technique. Robotic surgery has a shorter learning curve than laparoscopic surgery, mainly due to the improved ergonomics and deft controls [41,42]. However, whether robotic surgery is superior to laparoscopic surgery in minimally invasive hepatectomy is still controversial.

The present study showed R-LLS to produce similar peri-operative outcomes when compared with L-LLS in operative time, intraoperative blood loss, red blood cell transfusion and complication rates. Interestingly, even though an additional docking time was added to the robotic group, there was no significant difference in the operative time between the R-LLS and the L-LLS groups. This result can be explained by the extra time-consumed in docking being saved by the advantages offered by robotic in LLS. Our study agreed with the results of previously reported studies [11,23,24] that the overall medical costs in R-LLS was significantly higher than L-LLS. Thus, in a straight-forward patient with a lesion in the left lateral section of liver, L-LLS should still be the standard practice.

Recent studies have proposed various difficulty scoring systems in laparoscopic liver surgery using several preoperative factors [31,33,34]. Among these factors, the extent of liver resection plays the most important role in determining the difficulty of LLR. Our study stratified patients with lesions in the left lateral section of liver into a complex-case and an ordinary-case subgroups. Several factors were used to separate these patients into the two subgroups which include large tumor size, tumor proximity to major vessels, obesity, combined lymphadenectomy and huge left lateral section. The presence of any one of these factors would put a patient into the complex-case subgroup. Our results showed both L-LLS and R-LLS in the complex-case subgroups had significantly higher estimated blood loss, operative time and hospital stay than the ordinary-case subgroups.

In the subgroup analysis of the complex-case subgroups, R-LLS, when compared with L-LLS, resulted in significantly less intraoperative blood loss, probably because of the enhanced vision and meticulous manipulation of the robotic system. Thus, for complex cases requiring minimally invasive liver resection, robotic liver resection might be a better choice than laparoscopic liver resection. It is worth noted that the difference of intraoperative blood loss using robotic technique and conventional laparoscopic technique for complex subgroup was (131.9 ± 221.9 vs. 320.8 ± 293.5 ml, $P = 0.003$), which is less than 200 ml and might not be clinically significant. This can also explain why there was no difference of transfusion rate. However, the above result were based on an analysis of two subgroup, and for a single case, the difference of blood loss are high likely to be more than 200 ml, thus the application of robotic technique might change the outcome of selected patient, which is a reason why the technique should be recommended for complex cases.

In the patients who underwent L-LLS in our study, the costs of the

Table 5
Patient characteristics and surgical outcome of complex-case L-LLS and complex-case R-LLS.

Characteristic	complex-case L-LLS (n = 12)	complex-case R-LLS (n = 21)	*p*	*power*
Age (years)	54.8 years)	53.7 years)	0.846	0.1281
Gender (male/female)	7/5	15/6	0.443	
BMI (kg/m2)	25.9 kg/m2)26.7 kg/m2)0.607	0.9109		
ASA score			0.679	
1	1 (8.3%)	1 (4.8%)		
2	11 (91.7%)	20 (95.2%)		
3	0 (0.0%)	0 (0.0%)		
Lesion size (cm)	7.5 on siz6.3 on siz0.374	0.1565		
Cirrhosis	3 (25.0%)	7 (33.3%)	0.616	
Previous abdominal surgery	1 (8.3%)	2 (9.5%)	0.909	
Postoperative hospitalization (days), mean ± SD	5.3 ± 1.2	4.7 ± 2.6	0.054	0.1942
Operative time (min), mean ± SD	110.8 ± 44.5	126.4 ± 55.3	0.379	0.2009
Estimated blood loss (ml), mean ± SD	320.8 ± 293.5	131.9 ± 221.9	0.003	
Overall medical costs (USD), mean ± SD	9186.7 ± 2123.8	13536.9 ± 4768.6	0.006	

complex-case subgroup were significantly higher than that of the ordinary-case subgroup. However, there was no significant difference between the ordinary-case and the complex-case subgroups for patients who underwent R-LLS. Thus, R-LLS did not increased the medical cost for the complex-cases. The major hindrance to the development of robotic surgery is its relatively high costs. The huge costs include the expensive purchase fee and its annual maintenance fee [43]. As is known, Da Vinci robotic system is costly, and how to use it cost-effectively is extremely important, especially for those patients who have to afford all the cost of robots or all the cost of hospitalization in some countries, which is why we designed the present study. According to our results, to maximize the cost-effectiveness of minimally invasive surgery for lesions in the left lateral section of liver, L-LLS should be used as a standard practice for ordinary cases, while R-LLS could be used for complex cases. We do know that financial analysis is a sophisticated issue, involving the cost of involve training of staff using the novel equipment, investment in infrastructure and some other factors, and a full-scale analysis should be performed in further study, to guide the medical strategy in a more comprehensive perspective. However, although limited, a single analysis of hospital stay is still useful and worth to be analyzed, especially for those patients who pay for their own bill.

We have to admit it that the present study still has some limitations. First of all, there is no consensus on the evaluation criteria of the difficulty for LLS. Therefore, the evaluation of surgical difficulty in this paper is based on previous studies. In addition, considering the nature of small sample retrospective study, selection bias is inevitable, for some cases, the statistical power was also low. Further prospective randomized controlled studies need to confirm the long-term and short-term outcomes comparison between R-LLS and L-LLS. Third, the study was limited by the relatively small sample size, and benign or malignant cases were not compared separately. Besides, as is proved in the previous studies, the worsted instruments of robotic surgical system can benefit for some complicated procedure, dissection near the hepatic hilum and major blood vessels, lymphadenectomy and suture or reconstruction [41,42], which were not involved in our present study and might be a cause of type II error. However, those procedures are very unlikely to be involved in left lateral sectionectomy, thus the results might be still the same even in a larger sample study. In future research we will further enlarge the sample size and make a stratified comparison, with the analysis of the mid- and long-term oncologic results. However, according to our present results, we are still confident that robotic technique is helpful in some selected cases, and a rational selection criterion might be a good way to improve the cost-effectiveness of robotic surgery.

In conclusion, this study showed that R-LLS was comparable to L-LLS in perioperative outcomes. Although the overall medical costs in the robotic group was higher, robotic surgery might be a better choice for complex cases when compared to the laparoscopic approach. Further studies are required to determine the advantages of robotic surgery in other complex hepatectomies.

Disclosures

The authors declare no conflicts of interest or financial ties to disclose.

Provenance and peer review

Not commissioned, externally peer reviewed.

Data statement

Due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared.

Ethical approval

This study was approved by the ethics committee of Chinese PLA General Hospital and was carried out in accordance with the Declaration of Helsinki of the World Medical Association. All enrolled patients provided written informed consent.

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The authors declare no conflicts of interest in this work.

Author contribution

Conception and design: Minggen Hu, Rong Liu.
Acquisition of the data: Yanzhe Liu, Chenggang Li, Gang Wang, Zhuzeng Yin.
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Conflicts of interest

The authors declare no conflicts of interest in this work.

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Appendix A. Supplementary data

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References

[1] H. Reich, F. McGlynn, J. DeCaprio, et al., Laparoscopic excision of benign liver lesions, Obstet. Gynecol. 78 (1991) 956–958.
[2] R. Ciria, D. Cherqui, D.A. Geller, et al., Comparative short-term benefits of laparoscopic liver resection: 9000 cases and climbing, Ann. Surg. 263 (2016) 761–777.
[3] J.S. Azagra, M. Goergen, E. Gilbart, et al., Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects, Surg. Endosc. 10 (1996) 758–761.
[4] E. Lin, Sarmiento JM Laparoscopic extended right hepatectomy, portal

lymphadenectomy, and hepaticojejunostomy for hilar cholangiocarcinoma, J. Laparoendosc. Adv. Surg. Tech. Part A 24 (2014) 411–416.
[5] N. O'Rourke, G. Fielding, Laparoscopic right hepatectomy: surgical technique, J. Gastrointest. Surg. : Off. J. Soc. Surg. Alimentary Tract 8 (2004) 213–216.
[6] J.J. Lee, J.B. Conneely, R.L. Smoot, et al., Laparoscopic versus open liver resection for hepatocellular carcinoma at a North-American Centre: a 2-to-1 matched pair analysis, HPB : Off. J. Int. Hepato Pancreato Biliary Assoc. 17 (2015) 304–310.
[7] H.S. Han, A. Shehta, S. Ahn, et al., Laparoscopic versus open liver resection for hepatocellular carcinoma: case-matched study with propensity score matching, J. Hepatol. 63 (2015) 643–650.
[8] K. Kitisin, V. Packiam, D.L. Bartlett, et al., A current update on the evolution of robotic liver surgery, Minerva Chir. 66 (2011) 281–293.
[9] K. Idrees, D.L. Bartlett, Robotic liver surgery, Surg. Clin. 90 (2010) 761–774.
[10] A. Tsung, D.A. Geller, D.C. Sukato, et al., Robotic versus laparoscopic hepatectomy: a matched comparison, Ann. Surg. 259 (2014) 549–555.
[11] C. Salloum, C. Lim, E. Lahat, et al., Robotic-assisted versus laparoscopic left lateral sectionectomy: analysis of surgical outcomes and costs by a propensity score matched cohort study, World J. Surg. 41 (2017) 516–524.
[12] J. Qiu, S. Chen, D. Chengyou, A systematic review of robotic-assisted liver resection and meta-analysis of robotic versus laparoscopic hepatectomy for hepatic neoplasms, Surg. Endosc. 30 (2016) 862–875.
[13] R. Montalti, V. Scuderi, A. Patriti, et al., Robotic versus laparoscopic resections of posterosuperior segments of the liver: a propensity score-matched comparison, Surg. Endosc. 30 (2016) 1004–1013.
[14] H. Tranchart, C. Ceribelli, S. Ferretti, et al., Traditional versus robot-assisted full laparoscopic liver resection: a matched-pair comparative study, World J. Surg. 38 (2014) 2904–2909.
[15] MKt Lee, F. Gao, S.M. Strasberg, Perceived complexity of various liver resections: results of a survey of experts with development of a complexity score and classification, J. Am. Coll. Surg. 220 (2015) 64–69.
[16] S. Dokmak, V. Raut, B. Aussilhou, et al., Laparoscopic left lateral resection is the gold standard for benign liver lesions: a case-control study, HPB : Off. J. Int. Hepato Pancreato Biliary Assoc. 16 (2014) 183–187.
[17] L. Aldrighetti, C. Pulitano, M. Catena, et al., A prospective evaluation of laparoscopic versus open left lateral hepatic sectionectomy, J. Gastrointest. Surg. : Off. J. Soc. Surg. Alimentary Tract 12 (2008) 457–462.
[18] M. Abu Hilal, M.J. McPhail, B. Zeidan, et al., Laparoscopic versus open left lateral hepatic sectionectomy: a comparative study, Eur. J. Surg. Oncol. : J. Eur. Soc. Surg. Oncol. Br. Assoc. Surg. Oncol. 34 (2008) 1285–1288.
[19] A. Rao, G. Rao, I. Ahmed, Laparoscopic left lateral liver resection should be a standard operation, Surg. Endosc. 25 (2011) 1603–1610.
[20] J.F. Buell, D. Cherqui, D.A. Geller, et al., The international position on laparoscopic liver surgery: the Louisville Statement, 2008, Ann. Surg. 250 (2009) 825–830.
[21] S. Chang, A. Laurent, C. Tayar, et al., Laparoscopy as a routine approach for left lateral sectionectomy, Br. J. Surg. 94 (2007) 58–63.
[22] K.F. Lee, Y.S. Cheung, C.C. Chong, et al., Laparoscopic and robotic hepatectomy: experience from a single centre, ANZ J. Surg. 86 (2016) 122–126.
[23] J.K. Kim, J.S. Park, D.H. Han, et al., Robotic versus laparoscopic left lateral sectionectomy of liver, Surg. Endosc. 30 (2016) 4756–4764.
[24] V. Packiam, D.L. Bartlett, S. Tohme, et al., Minimally invasive liver resection: robotic versus laparoscopic left lateral sectionectomy, J. Gastrointest. Surg. : Off. J. Soc. Surg. Alimentary Tract 16 (2012) 2233–2238.
[25] Y. Hasegawa, H. Nitta, T. Takahara, et al., Safely extending the indications of laparoscopic liver resection: when should we start laparoscopic major hepatectomy? Surg. Endosc. 31 (2017) 309–316.
[26] X. Yu, H. Yu, X. Fang, The impact of body mass index on short-term surgical outcomes after laparoscopic hepatectomy, a retrospective study, BMC Anesthesiol. 16 (2016) 29.
[27] Y. Kawaguchi, T. Nomi, D. Fuks, et al., Hemorrhage control for laparoscopic hepatectomy: technical details and predictive factors for intraoperative blood loss, Surg. Endosc. 30 (2016) 2543–2551.
[28] F. Cauchy, D. Fuks, T. Nomi, et al., Incidence, risk factors and consequences of bile leakage following laparoscopic major hepatectomy, Surg. Endosc. 30 (2016) 3709–3719.
[29] F. Cauchy, D. Fuks, T. Nomi, et al., Risk factors and consequences of conversion in laparoscopic major liver resection, Br. J. Surg. 102 (2015) 785–795.
[30] R.I. Troisi, R. Montalti, J.G. Van Limmen, et al., Risk factors and management of conversions to an open approach in laparoscopic liver resection: analysis of 265 consecutive cases, HPB : Off. J. Int. Hepato Pancreato Biliary Assoc. 16 (2014) 75–82.
[31] D. Ban, M. Tanabe, H. Ito, et al., A novel difficulty scoring system for laparoscopic liver resection, J. Hepato-Biliary-Pancreatic Sci. 21 (2014) 745–753.
[32] S. Tanaka, S. Kubo, A. Kanazawa, et al., Validation of a difficulty scoring system for laparoscopic liver resection: a multicenter analysis by the endoscopic liver surgery study group in Japan, J. Am. Coll. Surg. 225 (2017) 249–258 e241.
[33] Y. Kawaguchi, D. Fuks, N. Kokudo, et al., Difficulty of laparoscopic liver resection: proposal for a new classification, Ann. Surg. 267 (2017) 13–17.
[34] Y. Hasegawa, G. Wakabayashi, H. Nitta, et al., A novel model for prediction of pure laparoscopic liver resection surgical difficulty, Surg. Endosc. 31 (2017) 5356–5363.
[35] M. Hu, G. Zhao, F. Wang, et al., Single-port and multi-port laparoscopic left lateral liver sectionectomy for treating benign liver diseases: a prospective, randomized, controlled study, World J. Surg. 38 (2014) 2668–2673.
[36] S. Chow, J. Shao, H. Wang, Sample Size Calculations in Clinical Research, second ed., Chapman & Hall/CRC Biostatistics Series, 2008, p. 62.
[37] H. Kaneko, S. Takagi, T. Shiba, Laparoscopic partial hepatectomy and left lateral segmentectomy: technique and results of a clinical series, Surgery 120 (1996) 468–475.
[38] R. Ciria, D. Cherqui, D.A. Geller, et al., Comparative Short-Term Benefits of Laparoscopic Liver Resection: 9000 Cases and Climbing Annals of Surgery, (2015).
[39] K.T. Nguyen, T.C. Gamblin, Geller DA World review of laparoscopic liver resection-2,804 patients, Ann. Surg. 250 (2009) 831–841.
[40] Y. Hasegawa, H. Nitta, A. Sasaki, et al., Laparoscopic left lateral sectionectomy as a training procedure for surgeons learning laparoscopic hepatectomy, J. Hepato-Biliary-Pancreatic Sci. 20 (2013) 525–530.
[41] C. Salloum, C. Lim, A. Malek, et al., Robot-assisted laparoscopic liver resection: a review, J. Visc. Surg. 153 (2016) 447–456.
[42] L.M. Ocuin, Tsung A Robotic liver resection for malignancy: current status, oncologic outcomes, comparison to laparoscopy, and future applications, J. Surg. Oncol. 112 (2015) 295–301.
[43] A. Amodeo, A. Linares Quevedo, J.V. Joseph, et al., Robotic laparoscopic surgery: cost and training, Minerva urologica e nefrologica = Ital. J. Urol. Nephrol. 61 (2009) 121–128.
[44] R.A. Agha, M.R. Borrelli, M. Vella-Baldacchino, R. Thavayogan, D.P. Orgillfor the STROCSS Group, The STROCSS statement: strengthening the reporting of cohort studies in surgery, Int. J. Surg. 46 (2017) 198–202.