



# Laparoscopic versus open hemihepatectomy: a 1:1 matched analysis

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**Background:** Laparoscopic liver resection has increased rapidly and procedure has almost extended to all the types of liver resection. Major liver resections, such as hemihepatectomies, were still innovative procedures in the exploration phase and continued cautious introduction of major laparoscopic liver resections was recommended by experts. The study aims to evaluate the safety of laparoscopic hemihepatectomy (LH) by the comparing with open hemihepatectomy (OH).

**Methods:** Patients who underwent hemihepatectomy in Sir Run Run Shaw Hospital from January 2012 to December 2017 were reviewed. A 1:1 matched study was performed between LH group and OH group. Patients who fail to be matched were excluded. Perioperative outcomes, complications and cost were compared between LH group and OH group.

**Results:** One hundred and thirty-eight exact matches for all matching variables were found between LH patients and OH patients. The length of postoperative hospital stay of LH group was significant shorter than the OH group ( $P=0.031$ ). Intraoperative blood loss ( $P=0.005$ ) and transfusion rate ( $P=0.001$ ) in the LH group were significantly lower than the OH group. There was no mortality in either group. Twenty-six patients in LH group and 31 patients in OH group had complications and all of them recovered uneventfully after immediate treatments. The hospital expense of LH group was significantly higher than OH group ( $P<0.001$ ).

**Conclusions:** These results lead us to believe that LH is a safe procedure and it could be performed routinely in experienced laparoscopic centers.

**Keywords:** Laparoscopic liver resection; hemihepatectomy; cost

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## Introduction

Laparoscopic liver resection was firstly reported in 1990s (1). The use of laparoscopic liver resection for liver lesions is increasing rapidly after dozens of years of exploration by liver surgeons (2-4). The First International Consensus Conference on Laparoscopic Liver Surgery was held in Louisville in 2008 (5). Since then, the reported number of laparoscopic liver resections has increased rapidly and procedure has almost extended to all the types of liver resection. On the Second International Consensus Conference on Laparoscopic Liver Resections which held in Japan in 2014, the status of laparoscopic liver resection was evaluated by 34 experts and a 9-member jury based on reported outcomes of laparoscopic liver resection (6). The jury finally concluded that minor liver resections had become standard practice and that major liver resections, such as hemihepatectomies, were still innovative procedures in the exploration phase and continued cautious introduction of major laparoscopic liver resections was recommended. In Sir Run Run Shaw Hospital, laparoscopic hemihepatectomies (LHs) had been performed as routine procedures for liver lesions in the past decade and a series of patients had been accumulated. Results of these patients were analyzed to evaluate the safety of laparoscopic major liver resection performed as routine procedures in medical centers with experiences in liver surgery and laparoscopic surgery.

## Methods

### *Inclusion criteria for LH*

The inclusion criteria for LH have been standardized in Sir Run Run Shaw Hospital, which included: unilateral liver lesion having the indication of hemihepatectomy; liver function of child A to B classification; no extrahepatic bile duct stricture or suppurative cholangitis in patients of hepatolithiasis; no past history of cholangiojejunostomy. In patients with liver malignancy, those who were diagnosed with tumor invasion in or close to the hepatic hilum or the hepatic venous trunk, cancer embolus in the main portal vein or the vena cava, or adjacent organ invasion by preoperative computed tomography (CT) or magnetic resonance imaging (MRI) were excluded.

Patient were excluded: who proceeded associating liver partition and portal vein ligation for staged hepatectomy (ALPPS); simultaneous bilateral liver resection; Simultaneous resection of other organs during the

operation; undergoing biliary-enteric anastomosis during the operation; those who with incomplete data.

### *Procedure*

In the LH group, LH was performed as described in previous articles (7,8). Briefly, patients were placed in a supine position under general anesthesia. Four entries were made and liver lesions were located by the direct vision and the laparoscopic ultrasonography. Laparoscopic selective inflow occlusion was performed before the liver transection. The laparoscopic multifunctional operative dissector (LPMOD) was used as the major instrument for transecting the liver parenchyma. Vessels and bile duct were dissected with LPMOD and were ligated with titan clips, absorbable clips, ham-locks or laparoscopic linear staples. The integral specimen was packed into a plastic bag and was removed via an incision of 4–6 cm.

In the open hemihepatectomy (OH) group, a reverse L-shaped incision was made and Peng's multifunctional operative dissector (PMOD) was used as an instrument for liver transaction and the manner of liver transection was similar to the LH. Vessels and bile duct were ligated with sutures. All the operations were performed by surgeons who have at least 3-year experience of laparoscopic or OH.

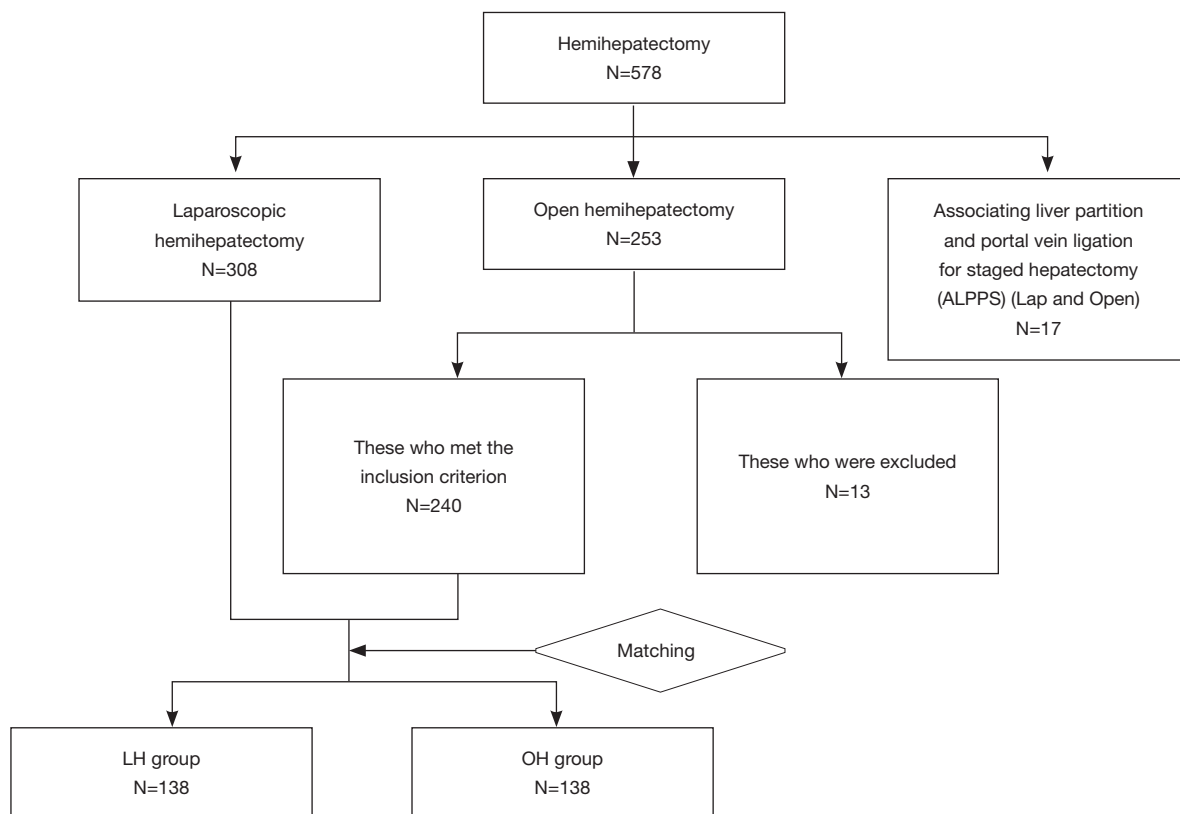
### *Patients*

Patients underwent laparoscopic or OH in Sir Run Run Shaw Hospital from January 2012 to December 2017 were reviewed. These patients had a completely preoperative medical evaluation including liver function, cardiovascular and pulmonary assessment. Preoperative CT scan or MRI was done to locate the liver lesions accessing the feasibility of laparoscopic resection. All patients who met the inclusion criteria for LH were included for matching.

### *Study design*

Each patient who underwent LH was individually matched with one control patient who underwent OH. A case-matched study was performed according to the same gender, age, diagnosis, procedure, liver cirrhosis, child classification, tumor size, branch of portal vein invasion, hepatic vein invasion and pre-operative transarterial chemoembolization (TACE). Patients who failed to be matched were excluded from the analyses.

Total of 578 patients underwent hemihepatectomy



**Figure 1** The flowchart of patients matching. LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy.

during the period including 308 LH, 253 OH and 17 ALPPS. One hundred and thirty-eight pairs of patients were matched and constituted LH group and OH group. The detailed flowchart was shown in *Figure 1*.

### Statistical analysis

Categorical data were presented as frequency (percentage) and were compared by Pearson Chi-square test or Fisher's exact test ( $n \leq 40$  or  $n \geq 40$  but  $1 \leq T < 5$ ). Continuous variables were presented as mean  $\pm$  standard deviation and were compared by paired-samples *t*-test. All tests were two-tailed and  $P < 0.05$  was considered statistically significant. All analyses were performed with SPSS (IBM SPSS Statistics, Version 20.0).

## Results

### Patients characteristics

Total of 54 males and 84 females were included in

each group. There was no significant difference of the age between LH group and OH group ( $56.6 \pm 8.8$  vs.  $56.5 \pm 9.1$  years,  $P = 0.572$ ). Characteristics of the 138 pairs of patients are shown in *Table 1*.

### Perioperative outcomes

The length of postoperative hospital stay of the LH group was significantly shorter than the OH group. Intraoperative blood loss and transfusion rate in the LH group were significantly lower than the OH group. No significant differences of operating time and complication rate were found between the two groups. There is no positive resection margin found in patients (*Table 2*).

### Complications

According to the Clavien-Dindo classification of surgical complications (9), total of 26 patients (18.8%) had complications in the LH group including 24 Grade I–IIIa complications and 1 Grade IIIb–V complication, and

**Table 1** General characteristics of the 138 pairs of patients underwent laparoscopic or open hemihepatectomy

Variables	LH group (n=138)	OH group (n=138)	P value
Age (years), mean $\pm$ SD	56.6 $\pm$ 8.8	56.5 $\pm$ 9.1	0.572
Gender			1.000
Male	54	54	
Female	84	84	
Procedure			1.000
Right hepatectomy	40	40	
Left hepatectomy	98	98	
Diagnosis			1.000
Hepatolithiasis	96	96	
Malignant tumor	37	37	
Benign tumor	5	5	
Liver cirrhosis			1.000
Yes	18	18	
No	120	120	
Child classification			1.000
A	138	138	
B	0	0	
Branch of portal vein invasion			1.000
Yes	8	8	
No	130	130	
Hepatic vein invasion			1.000
Yes	2	2	
No	136	136	
Preoperative TACE			1.000
Yes	2	2	
No	136	136	
Tumor size (n=42) (cm)	6.7 $\pm$ 3.2	7.6 $\pm$ 3.8	0.236
Number of lesions(n=42)			0.070
Single	35	29	
Multiple	7	13	
Number of comorbidities			
Hypertension	33	24	0.181

**Table 1** (continued)**Table 1** (continued)

Variables	LH group (n=138)	OH group (n=138)	P value
Diabetes	6	3	0.501
Depression	0	1	1.000
Lung disease	2	0	1.000
Heart disease	1	3	0.498
ASA score			1.000
II	134	134	
III	4	4	
BMI (kg/m <sup>2</sup> ), mean $\pm$ SD	22.9 $\pm$ 3.1	22.3 $\pm$ 3.3	0.098

LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy; SD, standard deviation; TACE, transarterial chemoembolization; ASA, American Society of Anesthesiologists; BMI, body mass index.

31 patients (22.5%) had complications in the OH group including 29 Grade I–IIIa complications and 2 Grade IIIb–V complication. Details of these complications are shown in the *Table 3*. There was one severe complication, acute renal failure (Grade IV), occurred in LH group and he recovered uneventfully after 3 days of continuous renal replacement therapy in the intensive care unit. Two severe complications, a liver dysfunction (Grade IV) and a bleeding (Grade IIIb), occurred in the OH group. One and a half months of supporting therapy including ICU management was administrated on the patient with liver dysfunction. Laparotomy was performed on the patient with bleeding. All the three patients with severe complications were recovered uneventfully. Two patients in the LH group and 3 patients in the OH group had bile leakage. All of them were treated by percutaneous drainage. One patient in the LH group was found having a hematoma close to the raw surface and vital signs of the patient were stable. The patient was observed without any further treatment. There was no mortality in either group and all these patients with complications recovered uneventfully after immediate treatment.

### Conversions

Out of the 138 patients in LH group, 17 patients were converted to open procedures. Causes of these conversions

**Table 2** Perioperative outcomes

Variables	LH	OH	P value
Intraoperative blood loss (mL), mean $\pm$ SD	364.3 $\pm$ 389.7	517.0 $\pm$ 576.1	0.005
Operating time (minutes), mean $\pm$ SD	251.9 $\pm$ 108.1	232.6 $\pm$ 63.3	0.065
Postoperative hospital stay (days), mean $\pm$ SD	10.8 $\pm$ 6.3	12.6 $\pm$ 8.4	0.031
Intraoperative transfusion, n (%)	23 (16.7)	49 (35.5)	0.001
Complication rate, n (%)	26 (18.8)	31 (22.5)	0.457
Grade I–IIIa	25	29	0.544
Grade IIIb–IV	1	2	1.000
Grade V	0	0	1.000
Positive resection margin	0	0	1.000

LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy, SD, standard deviation.

were showed in the *Table 4*. Characteristics of the 17 pairs of patients are shown in *Table S1*. Three patients had massive bleeding and emergent conversions were carried out immediately. Results of these converted patients were compared to their paired patients in the OH group. The operating time of converted patients was significantly longer than their paired patients, but there was no significant difference in blood loss, transfusion rate, length of postoperative hospital stay and complication rate (*Table 5*).

### Cost

The expense of hospitalization in the LH and the OH group were showed in the *Table 6*. The hospital expense of LH group was significantly higher than the OH group. The cost of medical consumables and the operation fee of LH group were significantly higher than the OH group, but no significant differences of medicine cost and other treatment cost was found between the two groups.

### Discussion

Laparoscopic local resection of liver lesion was firstly reported in 1991 (1) and it is still the major procedure of laparoscopically non-anatomical liver resection now. Left lateral segmentectomy is the major procedure of laparoscopically anatomical liver resection. It was recommended as a routine procedure by the first international expert consensus on laparoscopic liver resection (5). Some procedures, including isolated caudate lobectomy, trisegmentectomy and middle hepatic lobectomy

(segments 4, 5, and 8), are rarely performed even in experienced institutes because of technique difficulties and the risk of massive bleeding (10,11). For tumors located in segment VII and VIII, normal laparoscopic instruments are difficult to reach, but it could be resected laparoscopically by experienced surgeons or with special instruments such as trans-thoracic laparoscopic devices (12–15). Laparoscopic major liver resection including left hemihepatectomy and right hemihepatectomy were performed in some institutes, but it is still in controversy. Experts of laparoscopic liver resection still could not reach a consensus on its outcomes and cost because of the lack of high or moderate quality evidence from clinical practice (5,6). However, LH is still a promising procedure even for patients with liver cirrhosis (16). Laparoscopic hemihepatectomies have been performed as a routine procedure in our institute for a decade. Here we tried to provide some evidences on the potential value of this procedure by performing the 1:1 matched study between LH and OH.

According to the definition of major hepatectomy, it includes the resection of 3 or more Couinaud segments (6,17). Some experts have the resection of right posterior section or anterior section included in major hepatectomy because of the unique techniques required (18). In our institute, the majority of laparoscopic liver resection of 3 or more Couinaud segments was hemihepatectomy and laparoscopic extended hemihepatectomy did not be performed routinely for the risk of intraoperative massive bleeding. Indications for laparoscopic major hepatectomy included hepatolithiasis, hepatocellular carcinoma, metastatic liver cancer, cholangiocarcinoma

**Table 3** Detail of complications

Complications	LH		OH	
	Grade I–IIIa	Grade IIIb–IV	Grade I–IIIa	Grade IIIb–IV
Postoperative infection	1	0	6	0
Incisional infection	2	0	4	0
Liver dysfunction	2	0	2	1
Peri-hepatic effusion	5	0	5	0
Bile leakage	2	0	3	0
Plural effusion	3	0	5	0
Plural embolism	1	0	0	0
Bleeding	0	0	0	1
Intra-abdominal hematoma	1	0	0	0
Abdominal effusion collection	3	0	3	0
Intestinal obstruction	1	0	0	0
lower limb venous thrombosis	1	0	1	0
Gastric dysfunction	2	0	0	0
Pneumonia	1	0	0	0
Renal failure	0	1	0	0

LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy.

**Table 4** Causes of conversions

Causes	Total	Left hepatectomy	Right hepatectomy
Adhesion	4	1	3
Fail to expose the lesion	10	3	7
Unmanageable bleeding	3	2	1
Fail to locate tumors	0	0	0

and benign tumors. Hepatolithiasis is a prevalent liver disease in eastern China where our institute is located in and hemihepatectomy is the most common procedure for this disease (19,20). A large number of patients underwent hemihepatectomy for this disease in our institute.

In 2009, we had reported the initial experience of LH as well as the learning curve of this procedure (8). With the accumulation of experience on this procedure, laparoscopic left and right hemihepatectomy became a routine procedure in our institute and surgical results might be improved, so we collected the data in recent years and compared it with OH by the matched method for the potential value of the procedure. In this study, the blood loss and

transfusion rate of LH group was significantly lower than the OH group. The magnification of operating area by the laparoscope as well as the meticulous dissection could explain these results. Vessels in the transection plane could be clearly observed in laparoscope and were meticulously freed and ligated by experienced laparoscopic surgeons. Blood loss, as well as the possibility of massive bleeding, decreased as the consequence of less injury of vessels. There was no difference of mortality and morbidity between the LH group and the OH group. Complications were classified according to the Clavien-Dindo classification (9). Three patients had severe complications and need ICU management or re-operation under general anesthesia.

**Table 5** Comparison between converted patients and their paired patients (17 patients)

Variables	LH	OH	P value
Intraoperative blood loss (mL), mean $\pm$ SD	938.2 $\pm$ 667.0	691.2 $\pm$ 705.8	0.211
Operating time (minutes), mean $\pm$ SD	330.9 $\pm$ 181.3	235.0 $\pm$ 39.3	0.037
Postoperative hospital stay (days), mean $\pm$ SD	15.5 $\pm$ 8.2	11.6 $\pm$ 5.8	0.122
Intraoperative transfusion, n (%)	9 (52.9)	9 (52.9)	1.000
Complication rate, n (%)	5 (29.4)	2 (11.8)	0.398
Grade I–IIIa	5	2	0.398
Grade IIIa–IV	0	0	1.000
Grade V	0	0	1.000

LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy; SD, standard deviation.

**Table 6** The expense of hospitalization

Variables	LH (mean $\pm$ SD)	OH (mean $\pm$ SD)	P value
Total hospital expense	65,944.4 $\pm$ 24,295.9	49,918.7 $\pm$ 23,950.5	0.000
Medical consumables	26,142.9 $\pm$ 12,039.3	11,869.3 $\pm$ 593.3	0.000
Medicine	20,986.5 $\pm$ 11,327.3	21,844.2 $\pm$ 14,628.2	0.520
Transfusion cost	503.3 $\pm$ 847.2	845.3 $\pm$ 1,392.8	0.003
Operation fee	6,805.7 $\pm$ 1,763.0	5,033.8 $\pm$ 1,432.4	0.000
Other treatment cost	2,157.6 $\pm$ 1,606.4	1,947.9 $\pm$ 1,271.6	0.224

Costs are reported in Chinese Yuan. LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy; SD, standard deviation.

All patients with complications recovered uneventfully after immediate treatments. According to these results, LH could be as safe as OH if performed in an experienced laparoscopic center. In this study, LH still had merits of laparoscopic surgery over conventional open surgery. The length of postoperative hospital stay was decreased and the incision was minimized.

Previously, Cleary *et al.* had reviewed published literatures and found that the overall cost of laparoscopic liver resection was less than open liver resection because of the short hospital stay and the evidence was strongest for minor hepatic resection (21). In this study, cost did not decrease along with the decreased length of postoperative hospital stay, on the contrary, the hospital expense of LH group was significantly higher than the OH group. The cost of medical consumables and operation fee were significantly higher in the LH group as compared to the OH group that lead to a high hospital cost of laparoscopic hemihepatectomies. The use of kinds of clips and more

linear staples for ligating blood vessels and bile duct in laparoscopic surgery, as well as disposable trocars, could be the major reason for the high cost of medical consumables in the LH group. The high operation fee in LH group could be explained by the charge policy in which charge of a laparoscopic surgery is higher than its open equivalent. Lower transfusion rate in the LH group could explain the lower transfusion fee in LH group compared with the OH group.

Recently, there is a multicenter retrospective study published in 2019 by Cipriani *et al.* containing 545 pairs of laparoscopic and open hemihepatectomies from nine European referral centers after propensity score matching. They found that Laparoscopy was associated with reduced blood loss, postoperative stay and minor morbidity (22). Our study found that the length of postoperative hospital stay of LH group was significant shorter than the OH group ( $P=0.031$ ). Intraoperative blood loss ( $P=0.005$ ) and transfusion rate ( $P=0.001$ ) in the LH group were



significantly lower than the OH group which were consistent with their results.

In the second international consensus conference on laparoscopic liver resection in Morioka, a hot debate on the value of laparoscopic living donor hepatectomy occurred between experts and the jury and they failed to reach a consensus on this procedure. The point of the debate was whether surgeons could convert to open in time and finish the operation without a severe consequence. In this study, 17 patients converted to open. As compared to their paired patients in OH group, no significant difference in blood loss and transfusion rate was found. The operating time of converted patients was significantly longer than their paired patients. No mortality or severe complication occurred in these converted patients. These results led us to believe that conversion should not increase the surgical risk as compared with OH and the importance of a judicious surgical attitude toward conversion, which means surgeons should master the timing of conversion to open surgery during laparoscopic liver resection. Cipriani *et al.* in 2019 confirmed some associated advantages of laparoscopic and highlighting the need for realistic expectations of the minimally invasive approach based on the resected hemiliver and the patients treated (22).

## Conclusions

The results of this study lead us to believe that LH is a safe procedure as OH and could be performed routinely in experienced laparoscopic centers. Use of laparoscopic technique for hemihepatectomy could increase the hospital expense as the consequence of using high cost of medical consumables.

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## Footnote

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/atm.2020.03.188>). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are

appropriately investigated and resolved. The Institutional Review Board of the Sir Run Run Shaw Hospital of Zhejiang University approved protocols of the study (No. 2020-373-01). Informed consent was taken from all the patients

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## Supplementary

**Table S1** General characteristics of patients and their paired patients (17 patients)

Variables	LH group (n=17)	OH group (n=17)	P value
Age (year), mean $\pm$ SD	56.4 $\pm$ 5.6	55.9 $\pm$ 6.4	0.405
Gender			1.000
Male	10	10	
Female	7	7	
Procedure			1.000
Right hepatectomy	11	11	
Left hepatectomy	6	6	
Diagnosis			1.000
Hepatolithiasis	11	11	
Malignant tumor	6	6	
Benign tumor	0	0	
Liver cirrhosis			1.000
Yes	2	2	
No	15	15	
Child classification			1.000
A	17	17	
B	0	0	
Branch of portal vein invasion			1.000
Yes	1	1	
No	16	16	
Hepatic vein invasion			1.000
Yes	1	1	
No	16	16	
Preoperative TACE			1.000
Yes	1	1	
No	16	16	
Tumor size (n=6) (cm), mean $\pm$ SD	7.7 $\pm$ 4.8	8.4 $\pm$ 4.6	0.813
Number of lesions(n=6)			1.000
Single	16	16	
Multiple	1	1	
ASA score			0.500
II	16	15	
III	1	2	
BMI (kg/m <sup>2</sup> ), mean $\pm$ SD	22.7 $\pm$ 1.7	22.2 $\pm$ 2.1	0.478

LH, laparoscopic hemihepatectomy; OH, open hemihepatectomy; ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.