Original Article

Assessment of Learning Curve for Laparoscopic Liver Resection in Low-Volume Center

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Background: Laparoscopic liver resection (LLR) is considered as alternative procedure to open liver resection. However, the laparoscopic approach requires advanced laparoscopic skill. Most studies were limited to high-volume specialized center.

Objective: To assess the learning curve for LLR in low-volume center.

Materials and Methods: Between July 2008 and June 2015, all patients that underwent LLR were included. The effect of learning curve was evaluated by comparing peri-operative outcomes of LLR between two periods, the early versus the late group.

Results: Nine hundred sixty patients underwent liver resection and 67 patients (7%) had laparoscopic approach. Peri-operative outcomes of the early 30 patients were compared to the late 37 patients. The proportion of patients who had laparoscopic approach was not different between the two periods (early 7.2% versus late 6.8%). Most procedures were minor liver resection. Complication rate was significantly lower in the late group. Most common complication in the early group was bile leakage. There were no differences in operative time, blood loss, blood transfusion, conversion rate, length of stay, and number of positive resected margin.

Conclusion: The learning curve for LLR in low-volume liver center may require more patients. These results suggested that the learning curve required a minimum of 30 patients.

Keywords: Laparoscopic liver resection, Learning curve, Low-volume center

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Since the first report of successful laparoscopic liver resection (LLR) in 1992[1], the proportion and number of laparoscopic approaches have been increasing. Many studies showed good outcomes regarding feasibility, safety, and reproducibility when performed by experienced surgeons[2-5]. Comparing to open liver resection, several studies showed favorable peri-operative outcomes such as shorter hospital stay and lower blood loss for laparoscopic approach, and comparable long-term outcomes[6-9].

Prior studies showed the effect of learning curve for LLR[10]. The number of patients required to overcome the learning curve for minor LLR was between 22 and 60 patients[11,12] and for major LLR was between 45 and 75 patients[13,14]. Recent recommendations from the second international consensus suggested that laparoscopic minor liver resection is a standard procedure[15]. However, most studies that supported these were from high-volume and high-experienced center[16-20].

The development and learning curve for LLR in low-volume center remain challenging and controversial. The aim of the present study was to assess the learning curve for LLR in low-volume center.

Materials and Methods

Study design

The present study was a retrospective study that included all the patients that underwent LLR at King

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Chulalongkorn Memorial Hospital, Chulalongkorn University, Thailand between July 2008 and June 2015. To assess the effect of learning curve in LLR, the peri-operative outcomes of two groups of patients were compared. Patients who underwent surgery in the first half of the study period were considered as early group and those who had surgery after this were considered as late group.

All the treatment plans of the patients were discussed in multidisciplinary conference that included hepatobiliary surgeons, hepatologist, interventional radiologists, diagnostic radiologists, and medical oncologists. The decision for a laparoscopic approach was initially based on tumor location (segment 2 to 6) and tumor size (5 cm or smaller). However, the type of resection was not modified when using the laparoscopic approach.

The baseline patient characteristics and peri-operative outcomes including operative time, conversion rate, blood loss, blood transfusion, length of hospital stay, status of resected margin, post-operative complications, and death were recorded. Post-operative morbidity was defined as events that occurred during the first 60 days after surgery. Complications were graded by using Clavien-Dindo classification[21]. Post-operative mortality was defined as death within 90 days after surgery.

The present study was approved by the Institutional Review Board of Faculty of Medicine, Chulalongkorn University.

Surgical procedure

The type of liver resection was defined according to the Brisbane 2000 terminology. For hepatocellular carcinoma, anatomical liver resections including segmentectomy, lateral sectionectomy, or hemihepatectomy were performed according to tumor location and vascular involvement. However, for tumor that was less than 2 cm in maximal diameter and located peripherally, partial or wedge liver resection was performed. For other types of tumor, non-anatomical liver resection was preferentially performed.

For the technique of LLR, patient was placed in supine, French, or lateral decubitus position according to the tumor location. A supraumbilical incision was performed by open technique to create a pneumoperitoneum with a pressure of 12 mmHg and for camera insertion. Then, an additional three to four ports were placed. Pringle's maneuver was prepared in some patients. Parenchymal transection was performed by using a Cavitron Ultrasonic Surgical Aspirator (CUSA, Valley Labs, Inc., CO, USA), a Harmonic scalpel (Ethicon Endo-Surgery, Inc.), surgical clips, and a vascular stapler. The resected specimen was placed in a plastic bag and removed through the extended umbilical incision or the Pfannelstiel incision.

Statistical analysis

Patients' characteristics were described using mean ± standard deviation or median and interquartile range. The authors compared patients' characteristics and peri-operative outcomes between early and late group using chi squared and unpaired t-tests as appropriate. All analyses were performed in Stata, version 13 (StataCorp LP, College Station, TX, USA), and p-values of less than 0.05 were considered statistically significant.

Results

Nine hundred sixty patients underwent liver resection between July 2008 and June 2015. However, only 67 patients (7%) underwent LLR. There were 30 patients in early group and 37 patients in late group. Proportion of patients who had laparoscopic approach was not different between each group (early 7.2% versus late 6.8%)

Baseline characteristics

Baseline characteristics are showed in Table 1. Most patients in both groups underwent minor liver resection. The number of patients who was diagnosed with benign versus malignant tumor was not different between both groups. However, there were more patients with colorectal liver metastases in the late group compare to the early group. The others baseline characteristics were not different between both groups.

Peri-operative outcomes

The peri-operative outcomes are shown in Table 2. There was higher number of segmentectomy in the early group compared to the late group. These were probably related to higher number of patients with colorectal liver metastases in the late group. Operative time, conversion rate, blood loss, blood transfusion, and length of hospital stay were not different between both groups.

Post-operative complications were significantly higher in the early group compared to the late group. The most frequent complication in the early group was bile leakage that required additional percutaneous drainage. One patient with prolong bile leakage

Table 1. Baseline patient characteristics

Characteristics	Early group (n=30) n (%)	Late group (n=37) n (%)	p-value
Age (years); mean±SD	58.5±10.8	61.9±11.0	0.20
Sex: male	22 (73.3)	24 (64.9)	0.46
BMI (kg/m^2); mean±SD	23.5±4.3	24.4±3.6	0.33
ASA classification			
Class I	8 (26.7)	9 (24.3)	0.83
Class II	20 (66.7)	27 (73.0)	0.58
Class III	2 (6.6)	1 (2.7)	0.44
Malignant vs. benign tumor			0.38
HCC	18 (60.0)	16 (43.3)	
CRLM	5 (16.7)	9 (24.3)	
Other malignancy	3 (10.0)	4 (10.8)	
Benign tumor	4 (13.3)	8 (21.6)	
Tumor size (cm); mean±SD	3.6±1.6	3.7±2.8	0.84
Tumor location (segment)			
I	1	0	0.26
II	2	5	0.36
III	5	6	0.96
IV	2	3	0.82
V	9	10	0.79
VI	10	10	0.58
VII	1	2	0.68
VIII	0	1	0.36

ASA=American society of Anesthesiologists physical status; BMI=body mass index; CRLM=colorectal liver metastases; HCC=hepatocellular carcinoma; SD=standard deviation

Table 2. Peri-operative outcomes

	Early group (n=30) n (%)	Late group (n=37) n (%)	p-value
Type of resection			
Partial resection	12 (40.0)	20 (54.1)	0.25
Segmentectomy	13 (43.3)	7 (18.9)	0.03
Lateral sectionectomy	2 (6.7)	5 (13.5)	0.36
Hemihepatectomy	3 (10.0)	5 (13.5)	0.66
Operative time (minute); median (IQR P25, P75)	180 (150, 240)	180 (150, 360)	0.56
Conversion (%)	4 (13.3)	7 (18.9)	0.54
Blood loss (ml); median (IQR P25, P75)	100 (50, 300)	200 (100, 300)	0.36
Blood transfusion	4 (13.3)	8 (21.6)	0.38
Postoperative complications	13 (43.3)	3 (8.1)	0.001
Grade I	2	0	
Grade II	2	0	
Grade III	9	3	
Positive resection margins (R1)	2/26 (7.7)	5/29 (17.2)	0.31
Length of stay (days); median (IQR P25, P75)	5 (4, 7)	5 (4, 6)	0.69

IQR=interquartile range

underwent endoscopic biliary plastic stent placement. There was no bile leakage in the late group. There was no peri-operative death in either groups.

The number of microscopic positive resection margins (R1) in patients with malignant tumor did not differ between both groups.

Discussion

LLR is a complex procedure that required both hepatobiliary experience and laparoscopic skill. Since the first international consensus on LLR in 2008(22), the number of LLR performed worldwide has increased exponentially(23,24), and LLR has expanded to include minor resection(18,19), major resection(20,25,26), anatomical resection(27-29), and donor hepatectomy(30-34). Then the second international consensus in 2014 recommended that minor LLR was a standard procedure and recognized the need for a formal structure of education for those interested in performing major LLR because of the steep learning curve(15).

The present study suggests that the development of LLR in low-volume center occurred over time and the effect of the learning curve shows an improvement of post-operative complications in the later period. However, there was no consensus statement to define low volume center. In the authors' center, the proportion of laparoscopic approach for liver resection was less than 15% and the number of LLR was less than 15 cases per year, which may be considered a low volume center. The proportion of patients that underwent laparoscopic approach compared to open approach in the prior studies from high-volume center was about 17% to 80%(8,10,35). The present study had proportion only 7% and did not increase between the two periods. Therefore, low-volume center may need more time to incorporate LLR into the treatment pathways and then slowly increase the proportion of patients. To speed up the learning curve, specific laparoscopic training with supervision by expert surgeon, standardization of own procedural protocol, and familiarity of advanced laparoscopic instruments may be required.

Different outcomes have been used to assess the learning curve including operative time, conversion rate, and post-operative complications. Vigano et al[10] used conversion rate as outcome to assess the learning curve and included both minor and major liver resection. Those authors suggested that LLR was a reproducible procedure and required 60 patients to improve the conversion rate. In the present study, the conversion in the late group was slightly higher than in the early group but did not reach statistical significance. This finding probably related to the higher number of patients with segment 7 or 8 lesions in the late group. Hasegawa et al[12] used post-operative morbidities to assess the learning curve and recommended 60 patients with minor LLR before the adoption of major LLR. However, the present study needed almost nine years to have an adequate number of patients to achieve the learning curve. The present study showed that post-operative complications were lower in the late group. Most common complication was bile leakage, which probably related to the relatively high number of non-anatomical liver resection. There were a lot of small biliary pedicles in transected plane of the non-anatomical liver resection that probably increased the risk of bile leakage. Therefore, the technique of parenchymal transection has to be performed precisely and meticulously for the prevention of bile leakage and can improve with the effect of the learning curve. Besides, regularity of practice may speed up the learning curve.

As most of the procedures in the present study were minor LLR, the surgeons need a second learning curve for major LLR and for approach to difficult tumor locations. Lin et al[11] reported that after completing the first learning curve for minor LLR, the number of major operative events including long operative time, more blood loss, and major post-operative complications had increased for major LLR or difficult tumor locations (segment 4a, 7, and 8). This number started to decreased after an additional 40 patients.

There were some limitations in the present study that should be considered. The type of liver resection was mainly minor resection in both groups and the number of patients was small as representing a low-volume center. Therefore, the results of the present study may have to apply to selected patients but not to overall patients.

Conclusion

The learning curve for LLR in low-volume liver center may require more patients. These results suggest that the learning curve required a minimum of 30 patients.

What is already known on this topic?

The learning curve for LLR has been assessed in high-volume center, which required certain number of patients to achieve the learning curve. However, there is no study in low-volume center especially in Thai center.

What this study adds?

The learning curve for laparoscopic minor liver resection in low-volume center especially for center in Thailand requires a minimum 30 patients.

Conflicts of interest

All of authors in the present study declared that there were no competing financial interests exist.

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