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AIMS AND SCOPE

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The primary task of *WJG* is to rapidly publish high-quality original articles, reviews, and commentaries in the fields of gastroenterology, hepatology, gastrointestinal endoscopy, gastrointestinal surgery, hepatobiliary surgery, gastrointestinal oncology, gastrointestinal radiation oncology, gastrointestinal imaging, gastrointestinal interventional therapy, gastrointestinal infectious diseases, gastrointestinal pharmacology, gastrointestinal pathophysiology, gastrointestinal pathology, evidence-based medicine in gastroenterology, pancreatology, gastrointestinal laboratory medicine, gastrointestinal molecular biology, gastrointestinal immunology, gastrointestinal microbiology, gastrointestinal genetics, gastrointestinal translational medicine, gastrointestinal diagnostics, and gastrointestinal therapeutics. *WJG* is dedicated to become an influential and prestigious journal in gastroenterology and hepatology, to promote the development of above disciplines, and to improve the diagnostic and therapeutic skill and expertise of clinicians.

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ORIGINAL ARTICLE

Retrospective Study

Clinical advantages of single port laparoscopic hepatectomy

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Author contributions: Han JH collected and analyzed the data, and drafted the manuscript; You YK designed and supervised the study; Choi HJ, Hong TH and Kim DG offered the technical and statistical support; all authors have read and approved the final version to be published.

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Abstract

AIM

To evaluate the clinical advantages of single-port laparoscopic hepatectomy (SPLH) compare to multi-port laparoscopic hepatectomy (MPLH).

METHODS

We retrospectively reviewed the medical records of 246 patients who underwent laparoscopic liver resection between January 2008 and December 2015 at our hospital. We divided the surgical technique into two groups; SPLH and MPLH. We performed laparoscopic liver resection for both benign and malignant disease. Major hepatectomy such as right and left hepatectomy was also done with sufficient disease-free margin. The operative time, the volume of blood loss, transfusion rate, and the conversion rate to MPLH or open surgery was evaluated. The post-operative parameters included the meal start date after operation, the number of postoperative days spent in the hospital, and surgical complications was also evaluated.

RESULTS

Of the 246 patients, 155 patients underwent SPLH and 91 patients underwent MPLH. Conversion rate was 22.6% in SPLH and 19.8% in MPLH (P = 0.358). We performed major hepatectomy, which was defined as resection of more than 2 sections, in 13.5% of patients in the SPLH group and in 13.3% of patients in the MPLH group (P = 0.962). Mean operative time

was 136.9 ± 89.2 min in the SPLH group and 231.2 ± 149.7 min in the MPLH group (P < 0.001). The amount of blood loss was 385.1 ± 409.3 mL in the SPLH group and 559.9 ± 624.9 mL in the MPLH group (P = 0.016). The safety resection margin did not show a significant difference (0.84 ± 0.84 cm in SPLH *vs* 1.04 ± 1.22 cm in MPLH, P = 0.704). Enteral feeding was started earlier in the SPLH group (1.06 ± 0.27 d after operation) than in the MPLH group (1.63 ± 1.27 d) (P < 0.001). The mean hospital stay after operation was non-significantly shorter in the SPLH group than in the MPLH group (7.82 ± 2.79 d *vs* 7.97 ± 3.69 d, P = 0.744). The complication rate was not significantly different (P = 0.397) and there was no major perioperative complication or mortality case in both groups.

CONCLUSION

Single-port laparoscopic liver surgery seems to be a feasible approach for various kinds of liver diseases.

Key words: Hepatectomy; Laparoscopy; Minimally invasive surgery; Treatment outcome; Feasibility study

Core tip: The progress on the laparoscopic technique has led to single-port laparoscopic surgery as a feasible modality in several abdominal surgeries. However, in the field of liver surgery, single-port surgery have been reported sporadically because of its technical difficulties. In this study, we evaluated the feasibility of single-port laparoscopic hepatectomy (SPLH) compared to multi-port laparoscopic hepatectomy (MPLH). The present study showed that SPLH is not inferior to MPLH in terms of surgical and oncological results. Furthermore, left liver surgery, such as left lateral sectionectomy and left hepatectomy, is possible through single-port without any significant deterioration in results if it is performed by an experienced surgeon.

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INTRODUCTION

After introduction of the first laparoscopic surgery, noticeable technical developments have imposed laparoscopic surgery as a valuable alternative to the traditional open surgery[1,2]. Since then, the progress on the laparoscopic technique has led to reduced port surgery including single-port laparoscopic surgery as a safe and feasible modality in the field of appendectomy, cholecystectomy, splenectomy, gastrectomy and colectomy[3-6].

However, in the field of liver surgery, after the first laparoscopic surgery in 1993, complexity of the procedure and technical difficulty are the main causes of delay in its widespread adoption, but its use has steadily and slowly spread in tandem with advances in surgical skill and devices[7,8]. In the Louisville Statement 2008, Buell *et al*[9] declared that laparoscopic liver surgery is a safe and effective approach for the surgical management of liver disease.

Recently, several investigators have reported that single-port laparoscopic hepatectomy (SPLH) is also a feasible modality like any other single-port laparoscopic surgery[10-12]. Nevertheless, almost of these studies are only case reports or small-sized retrospective studies and there is a lack of large clinical randomized trials or systematic reviews that prove its clinical benefits.

The aim of the present study is to investigate the technical feasibility and perioperative results of SPLH compared to the conventional laparoscopic or open surgery in a large volume center.

MATERIALS AND METHODS

We retrospectively reviewed the medical records of 246 patients who underwent laparoscopic liver resection with curative intent between January 2008 and December 2015 at Seoul St. Mary's Hospital. The patients who underwent concomitant other abdominal surgery were excluded. This study was approved by the Institutional Review Board of our center.

This record was obtained by several experienced hepatobiliary surgeons in our hospital; however, SPLH was performed by one of the surgeons who mainly performed laparoscopic liver resection.

We performed laparoscopic liver resection for both benign and malignant disease. The indications of SPLH and MPLH were not different. Left-lateral sectionectomy and partial hepatectomy for the lesion in the antero-lateral portion of the liver were routinely performed *via* laparoscopy. Major hepatectomy, such as right hepatectomy and left hepatectomy, was also performed *via* laparoscopy if a disease-free margin was expected to be achieved without any major problems. However, the patients with a history of major upper abdominal surgery and cardiac or respiratory impairment were excluded from the laparoscopic approach. Considering the general criteria for liver resection, we excluded the patients with a large amount of ascites or hyperbilirubinemia from liver resection. Patients with Child Pugh class (Child - Turcotte - Pugh) C were also excluded from resection and partial hepatectomy was performed in selected Child Pugh class B patients.

The operative time for each procedure was recorded,

as well as the volume of blood loss, transfusion rate, and the conversion rate to multi-port laparoscopic hepatectomy (MPLH) or open surgery. The post-operative parameters were also recorded, which included the meal start date after operation, the number of postoperative days spent in the hospital, and surgical complications according to the Dindo-Clavien classification[13].

Surgical procedure

Overall, there were few differences between the SPLH and MPLH surgical procedures, except for the difference in trocar use. Generally, the patient was placed in a supine position and for resection of the right liver lobe lesion, the leg was parted. The body of the patient was tilted 10-20° in the head-up and feet-down position. If the lesion was located in the right posterior section, the patient was placed in the right lateral decubitus position at approximately 90°.

For resection of the left liver lobe lesion, the operator stood on the right side of the patient with a scopist, and for right liver lobe resection, the operator stood between the patient's legs with the scopist on the left side of the patient.

For SPLH, a 30 to 40 mm skin incision was made in the right or left upper abdominal quadrant, depending on the location of the liver lesion. Then, Glove port (Nelis, Seoul, South Korea) consisting of four trocar channels with gas insufflation and exsufflation lines was placed. For MPLH, a 10 mm trocar for laparoscopy was inserted into the umbilicus. The 12 mm primary working port was placed below the costal margin depending on the location of the lesion. Then, one or two 5 mm additional working ports were inserted. CO_2 pneumoperitoneum was established at 12 mmHg.

The procedure of laparoscopic hepatectomy was not very different from that in previous studies. We performed intraoperative ultrasonography in almost all cases for the marking of the lesion and hepatic veins. Mobilization of the liver was performed by hook type electrocautery and an ultrasonic scalpel (Harmonic ACE; Ethicon Endo-Surgery, Cincinnati, Ohio, United States) and we generally used a laparoscopic ultrasonic dissector (CUSA; Integra LifeSiences, Plainsboro, NJ, United States) for the deeper part of liver parenchymal dissection and an ultrasonic scalpel for the superficial part of the liver. Small vascular pedicles were sealed with an ultrasonic scalpel, while large vessels and bile ducts were ligated with a metal clip and Hem-o-lok clips (Weck, Research Triangle Park, NC, United States). We generally did not use the argon beam coagulator for coagulation of the resection surface concerning gas embolization.

For retrieval of the specimen, we extended the trocar site in consideration of the specimen volume. In MPLH, we generally extended the trocar site of the umbilicus. A closed suction drain was inserted only when necessary, in MPLH, a 5mm trocar site was used, and in SPLH, a drain was rarely inserted.

Statistical analysis

Mean, standard deviation, and ranges were used to present numerical variables. Continuous variables were compared by Student's *t*-test. Differences in categorical variables were analyzed with the chi-square test. Logistic regression was used for the multivariate analysis and Cox proportional hazards regression model analysis was used to identify risk factors independently associated with recurrence or survival. The Kaplan-Meier method was used to calculate the disease-free survival and survival rates. The survival time in the groups was compared using the log-rank test. *P*-values < 0.05 were considered to indicate statistical significance.

RESULTS

Of the 246 patients, 155 patients had undergone SPLH, and among them, 120 patients (77.4%) had undergone single-port laparoscopic surgery without open or multiport conversion. In the MPLH group, open conversion was performed in 18 patients (19.8%) and there was no statistically significant difference (P = 0.358).

The most common cause of conversion was bleeding in both groups (60% and 33.3%, respectively) and the next most common cause of conversion was adhesion in the MPLH group (22.2%) and technical failure in the SPLH group (14.3%) (Table 1).

The most commonly performed procedure in both groups was partial hepatectomy (65.2% and 39.65%, respectively) and the next most commonly performed procedure was left lateral sectionectomy. Major hepatectomy was performed in 22 cases (14.1%) using a single port and in 12 cases (13.2%) in the MPLH group (Table 2). We did more partial hepatectomy with single-port however, extended cholecystectomy for gallbladder cancer and hepatic cyst marsupialization was done by multi-port.

Tumor distribution was not significant different between both groups, 11.6% of the SPLH group and 12.1% of the MPLH groups had the tumors over 2 segments (P < 0.969).

Patient's demographics was not significantly different between the two groups except BMI. BMI was lower in the MPLH group (P < 0.001).

We performed laparoscopic hepatectomy for malignant disease, such as hepatocellular carcinoma and metastatic tumor especially from colon cancer, if we could obtain an adequate safety resection margin. In the SPLH group, 74.8% of patients had malignant disease, and in the MPLH group, the rate of malignant disease was 70.3% (P = 0.459).

Table 1 Cause of conversion *n* (%)

Cause of conversion	SPLH (*n* = 35, 22.6%)	MPLH (*n* = 18, 19.8%)
Bleeding	21 (60.0)	6 (33.3)
Adhesion	3 (8.5)	4 (22.2)
Poor localization of tumor	3 (8.5)	2 (11.1)
Advanced tumor	2 (5.7)	1 (5.6)
Technical failure	5 (14.3)	3 (16.7)
Others	1 (3.0)	2 (11.1)

SPLH: Single-port laparoscopic hepatectomy; MPLH: Multi-port laparoscopic hepatectomy.

Table 2 Comparison of procedure between single-port laparoscopic hepatectomy and multi-port laparoscopic hepatectomy group *n* (%)

Name of procedure	SPLH (*n* = 155, 63.0%)	MPLH (*n* = 91, 37.0%)
Right hepatectomy	5 (3.2)	0
Left hepatectomy	17 (10.9)	12 (13.2)
Left lateral sesctionectomy	29 (18.7)	19 (20.8)
Segmentectomy	2 (1.3)	3 (3.3)
Partial hepatectomy	101 (65.2)	36 (39.6)
Extended cholecystectomy	0	14 (15.4)
Others	1 (0.7)	7 (7.7)

SPLH: Single-port laparoscopic hepatectomy; MPLH: Multi-port laparoscopic hepatectomy.

We performed single-port laparoscopic major hepatectomy, which was defined as resection of more than 2 sections, in 21 patients (13.5%), and this rate was not significantly different from that in the MPLH group (13.3%, $P = 0.962$).

With respect to operative parameters, we evaluated mean operative time, the amount of transfusion (red blood cell), and safety margin in final pathology reports. Operative time was significantly shorter in the SPLH group ($P < 0.001$). The amount of transfusion was not significantly different between the two groups ($P = 0.513$). The safety resection margin did not show a significant difference between the two groups ($P = 0.704$).

Enteral feeding was started earlier in the SPLH group than in the MPLH group ($P < 0.001$). However, the mean hospital stay after operation was not significantly different between the two groups ($P = 0.744$).

Post-operative complications requiring intervention or surgery occurred at a rate of 7.7% in the SPLH group and at a rate of 3.3% in the MPLH group ($P = 0.397$). However, there was no life-threatening complication or perioperative mortality case in both groups (Table 3).

Comparative results of left lateral sectionectomy and left hepatectomy (SPLH vs MPLH)

We compared the demographic features and operation-related factors between the two groups among cases that underwent left lateral sectionectomy and left hepatectomy. Of the 155 patients in the SPLH group, 46 patients (29.7%) underwent left hepatectomy or left lateral sectionectomy, and the number of patients who underwent left hepatectomy or left lateral sectionectomy was 31 (34.1%) in the MPLH group.

Patient's demographics was also not significantly different between the two groups. BMI was not significantly different between the two groups ($P = 0.337$). The rate of liver cirrhosis and the CTP score were also not significantly different between the two groups ($P = 0.355$ and $P = 0.106$, respectively).

The mean operative time was significantly shorter in the SPLH group ($P < 0.003$). The amount of transfusion was not significantly different between the two groups ($P = 0.513$). The safety resection margin also did not show a significant difference between the two groups ($P = 0.354$).

Enteral feeding was also started earlier in the SPLH group than in the MPLH group ($P < 0.001$). However, the mean hospital stay after operation was not significantly different between the two groups ($P = 0.738$).

Post-operative complications requiring intervention or surgery occurred in 4 patients (8.7%) in the SPLH group and in 1 patient (3.2%) in the MPLH group. There was no statistically significant difference (Table 4).

DISCUSSION

After the first report of single-port laparoscopic surgery in the field of the liver surgery[10,11], several studies have assessed the feasibility of SPLH in selected cases such as left lateral sectionectomy and partial hepatectomy. Most of these studies have reported that SPLH is not inferior to the conventional multiport surgery due to cosmetic advantages, less invasiveness, less hospital duration, and acceptable complication rates like other single-port laparoscopic surgeries such as cholecystectomy and appendectomy[12,14-17].

As previously noted, single-port laparoscopic surgery for the liver has some intrinsic technical limitations[18,19]. At first, the loss of triangulation and interference between instruments makes surgery difficult and causes ergonomic problems. Then, the surgical view is relatively narrow because the scope and the instruments are placed in the same line. Thus, if complications develop during surgery such as bleeding or bile leakage during liver resection, it may be difficult to manage with only a single port. In fact, most of the previous studies were regarding left lateral sectionectomy and partial hepatectomy, which are less complex.

In the present study, there is no definite evidence that SPLH could be regarded as an easier technique than MPLH considering the presence of liver cirrhosis and the CTP score. Although, the mean age was lesser

Table 3 Comparison of results between single-port laparoscopic hepatectomy and multi-port laparoscopic hepatectomy group *n* (%)

Variables	SPLH (*n* = 155, 63.0%)	MPLH (*n* = 91, 37.0%)	*P* value
Age	57.1 ± 13.3	60.8 ± 13.4	0.037
Sex (M:F)	105:50	49:42	0.040
BMI	24.1 ± 3.1	22.5 ± 2.9	< 0.001
Liver cirrhosis	51 (32.9)	31 (34.3)	0.887
CTP score	5.37 ± 0.73	5.21 ± 0.64	0.297
Malignant disease	116 (74.8)	64 (70.3)	0.459
Major operation	21 (13.5)	12 (13.3)	0.962
Operation time	136.9 ± 89.2	231.2 ± 149.7	< 0.001
Blood loss (mL)	385.1 ± 409.3	559.9 ± 624.9	0.016
RBC T/F (unit)	0.62 ± 1.98	0.79 ± 1.44	0.513
Conversion rate	35 (22.6)	18 (19.8)	0.358
Enteral feeding (d)	1.06 ± 0.27	1.63 ± 1.27	< 0.001
Hospital stay (d)	7.82 ± 2.79	7.97 ± 3.69	0.744
Disease free margin	0.84 ± 0.84	1.04 ± 1.22	0.704
Complication rate	12 (7.7)	3 (3.3)	0.397
Post op bleeding	1 (8.3)	0	
Pleural effusion	4 (33.3)	1 (33.3)	
Fluid accumulation	6 (50.1)	1 (33.3)	
Others	1 (8.3)	1 (33.3)	

SPLH: Single-port laparoscopic hepatectomy; MPLH: Multi-port laparoscopic hepatectomy; BMI: Body mass index; CTP: Child-Turcotte-Pugh; T/F: Transfusion.

in the SPLH group, the body mass index (BMI) was rather lower in the MPLH group.

Considering surgical results such as the operative time and the mean amount of blood transfusion, the SPLH group seemed to show more favorable results than the MPLH group. However, these commonly unacceptable results can be explained in two ways. The first reason is that the present work was a retrospective study. Although there were no statistically differences between the two groups in terms of patient characteristics, it is possible that SPLH was preferentially applied to cases that appeared slightly easier. The second reason is the surgeon factor. SPLH was initiated at our hospital from 2008 and it has been mostly performed by a single highly experienced liver surgeon. On the other hand, MPLH has been performed by several surgeons with a variety of experience including the one mentioned above. Therefore, it may be inappropriate to compare the two groups; however, it is at least possible to state that SPLH is not very inferior to MPLH considering the surgical results themselves.

The rate of surgical complications showed no significant differences between the two groups. Severe complications such as post-operative bleeding or bile leakage were rare in both groups and the rate of complications that needed surgical or radiologic interventional treatment was comparable to the previously noted results for the conventional open liver surgery[20,21].

This result may be due to a selection bias that there is a possibility that we chose the patients with less degree of liver cirrhosis for laparoscopic liver surgery. It may also be another reason behind why we preferably selected the cases in which the tumor location is on the antero-lateral surface of the liver as far as possible. However, even on comparing the two laparoscopic hepatectomy groups, the complication rate in the SPLH group was not statistically higher than that in the MPLH group.

We experienced nearly 20% of conversion rate in both groups and it seemed to be higher than previously reported data[17] (Aldrighetti, 2012 #220). However, because we preferentially consider laparoscopic surgery and actively adopted it, it will be obviously higher than ordinary cases. What we should be noted is that the conversion rate of both groups was not significantly different.

The length of the hospital stay and the duration of resumption of enteral feeding were shorter in the SPLH group than in the MPLH group. This result has been commonly reported in other previous studies for other single port surgeries[4,22]. There are some controversies regarding the claim that single-port laparoscopic surgery needs a shorter recovery period after surgery.

Most of the previous studies for SPLH were performed for benign disease, except for a few studies including our initial reports of SPLH for hepatocellular carcinoma[12]. However recently, there have been some controversies regarding the application of MPLH to malignant disease[23,24]. Furthermore, the present study also showed that SPLH is not inferior to MPLH in terms of obtaining a sufficient safety resection margin.

The present work includes the results of left lateral

Table 4 Comparison of results between single-port laparoscopic hepatectomy and multi-port laparoscopic hepatectomy group in left hepatectomy and left lateral sectionectomy *n* (%)

Variables	SPLH (*n* = 46, 59.7%)	MPLH (*n* = 31, 40.3%)	*P* value
Age	59.0 ± 11.1	62.0 ± 9.9	0.223
Sex (M:F)	26:20	16:15	0.816
BMI	23.3 ± 2.8	22.7 ± 2.5	0.337
Liver cirrhosis	9 (19.6)	4 (12.9)	0.525
CTP score	5.44 ± 0.81	5.20 ± 0.56	0.355
Malignant disease	27 (58.7)	12 (38.7)	0.106
Operation time	177.9 ± 114.6	277.6 ± 140.6	0.003
Blood loss (mL)	389.0 ± 270.0	576.9 ± 298.1	0.013
RBC T/F (unit)	0.38 ± 0.9	0.83 ± 0.9	0.094
Conversion rate	15 (32.6)	8 (25.8)	0.616
Enteral feeding (d)	1.08 ± 0.35	1.61 ± 0.89	< 0.001
Hospital stay (d)	9.08 ± 3.21	9.36 ± 3.19	0.738
Disease free margin (cm)	1.17 ± 0.99	1.67 ± 1.92	0.354
Complication rate	4 (8.7)	1 (3.2)	0.402
Post op bleeding	1 (25.0)		
Pleural effusion	0		
Fluid accumulation	2 (50.0)		
Others	1 (25.0)	1 (100)	

SPLH: Single-port laparoscopic hepatectomy; MPLH: Multi-port laparoscopic hepatectomy; BMI: Body mass index; CTP: Child-Turcotte-Pugh; T/F: Transfusion.

sectionectomy, as the previous studies[15,17] as well as those of major hepatectomy that involved resection of more than two sections. However, the results of major hepatectomy, especially right hepatectomy showed a largely deviated result in the operative time and the amount of transfusion because of the technical limitations that have been mentioned above. Thus, it is not desirable to compare the results including right hepatectomy and some difficult partial hepatectomy cases that are not suitable for laparoscopic surgery from the beginning. Therefore, we evaluated the results of the left lateral hepatectomy and the left hepatectomy cases that showed the result of even deviations. The results also showed that SPLH is comparable, at least not inferior, to MPLH.

The present study has the limitations of being a retrospective study with a small patient group. However, to the best of our knowledge, it is the first report that adopted SPLH for malignant diseases with compatible results and showed the possibility that it is favorable to apply SPLH for a left liver lobe lesion in terms of surgical and oncologic outcomes.

We have not taken a position that SPLH is superior to MPLH throughout this study. There is an inevitable limitation as it is a retrospective study and the experience of the surgeon who performed SPLH is more than that of another surgeon who performed MPLH.

However, the present study at least showed that SPLH is not inferior to MPLH in terms of surgical and oncological results after favorable patient selection. Furthermore, left liver lobe surgery, such as left lateral sectionectomy and left hepatectomy, is possible through single-port laparoscopic surgery without any significant deterioration in results compared to MPLH if it is performed by an experienced surgeon.

ARTICLE HIGHLIGHTS

Research background

The progress on the laparoscopic technique and instruments has led to single-port laparoscopic surgery as a safe and feasible modality. However, in the field of liver surgery, technical difficulty has delayed its widespread adoption. Recently, several investigators have reported feasible results of single-port laparoscopic hepatectomy (SPLH) however, almost of them are case reports or small sized study.

Research motivation

Several studies have assessed the feasibility of SPLH in benign diseases such as left lateral sectionectomy and partial hepatectomy in spite of intrinsic technical limitations. However, most of them are for benign diseases and the study size is too small to determine the feasibility.

Research objectives

The aim of the present study is to investigate the technical feasibility and perioperative results of SPLH compared to the conventional laparoscopic surgery in a large volume center.

Research methods

Total enrolled patients were 246 and the data was collected from January 2008 to December 2015. The authors divided the surgical technique into two groups; SPLH and multi-port laparoscopic hepatectomy (MPLH). The authors performed laparoscopic liver resection for both benign and malignant disease. Major hepatectomy was done in the case that the disease free margin will be achieved without problems. The operative time, the volume of blood loss, transfusion rate, and the conversion rate to MPLH or open surgery was evaluated. The post-operative parameters included the meal start date after operation, the number of postoperative days spent in the hospital, and surgical complications was also evaluated.

Research results

In this study, the authors found that the operative results such as the operative time, the volume of blood loss, transfusion rate, and the conversion rate of the SPLH was not inferior to the MPLH. The post-operative parameters such as the meal start date after operation was even better than MPLH. It showed similar results in the analysis of the left liver surgery such as left hepatectomy and left lateral sectionectomy.

Research conclusions

The present study showed that SPLH is not inferior to MPLH in terms of surgical and oncological results after favorable patient selection. Furthermore, left liver lobe surgery, such as left lateral sectionectomy and left hepatectomy, is possible through single-port laparoscopic surgery without any significant deterioration in results compared to MPLH if it is performed by an experienced surgeon.

Research perspectives

In the future work, case controlled and/or large size prospective study will be needed.

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