Intermittent Pringle Versus Continuous Half-Pringle Maneuver for Laparoscopic Liver Resections of Tumors in Segment 7

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Received: 16 April 2017 / Accepted: 15 January 2018 / Published online: 7 February 2018
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Abstract

Segment 7 is considered an unfavorable portion for laparoscopic hepatectomy because of technical difficulties in exposure and controlling bleeding. We compared intermittent Pringle with continuous half-Pringle maneuver in laparoscopic liver resections of tumors in segment 7. A retrospective analysis was conducted in a total of 36 consecutive patients with tumors in segment 7 undergoing laparoscopic liver resections between July 2011 and February 2016 (16 in the Pringle group versus 20 in the half-Pringle group). The two groups were well matched in baseline characteristics. The operative time (274.5 ± 34.3 versus 237.6 ± 41.8 min), overall declamping time (28.4 ± 8.6 versus 2.3 ± 2.5 min), and ischemic duration (69.7 ± 16.5 versus 52.7 ± 13.2 min) were significantly longer in the Pringle group ($P < 0.05$). The amount of intraoperative blood loss (612.5 ± 222.3 versus 417.4 ± 163.8 mL) and transfusion (335.2 ± 58.7 versus 224.8 ± 76.2 mL) was significantly greater in the Pringle group ($P < 0.05$). The Pringle group was associated with significantly lower postoperative albumin and higher C-reactive protein levels on postoperative days 1, 3, and 7 ($P < 0.05$). Laparoscopic hepatectomy for tumors in segment 7 can be performed safely and effectively with successful exposure of surgical field and proper hepatic blood flow occlusion. Continuous half-Pringle maneuver offers the advantages of less operative time and blood loss, less injury, and better recovery.

Keywords Laparoscopic liver resection · Segment 7 · Liver neoplasm · Pringle maneuver · Hemihepatic vascular inflow occlusion

Introduction

Until recently, laparoscopic liver resection of tumors at segment 7 was seen as a relative contraindication. Laparoscopic liver resection for tumors in this location is associated with difficulties in exposing the surgical field and controlling the bleeding. Injury of the large vessels in this area can lead to massive bleeding that is very difficult to control laparoscopically. With improvements in laparoscopic instruments and increasing experience in laparoscopy and liver surgery, more cases of

laparoscopic liver resection of tumors in segment 7 with favorable results have recently been reported [1–3].

Our department has performed laparoscopic liver surgery since 2008. After learning curve for laparoscopic liver resection, many laparoscopic complex liver resections have been performed in our department [4, 5]. We also approached posteriorly located tumors especially those in segment 7. Some useful techniques have been developed for the laparoscopic resection of tumors in segment 7 in our department, including using a custom-designed device to provide a better operative field and using continuous hemihepatic vascular inflow occlusion via an extra-Glissonian approach (half-Pringle maneuver) to perform a safer parenchymal transaction [5]. We herein analyzed our experiences with laparoscopic liver resections of tumors in segment 7 on exposing surgical field and bleeding control.

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Materials and Methods

Between July 2011 and February 2016, a total of consecutive 36 patients with tumors locating in segment 7 underwent

laparoscopic liver resections at the Third Department of Hepatobiliary Surgery, Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital, School of Medicine, University of Electronic Science and Technology of China. Of the total of 36 patients, 19 cases underwent laparoscopic tumorectomy (segmentectomy 7) and 17 cases underwent laparoscopic right posterior sectionectomy (bisegmentectomy 6–7). Sixteen cases were performed by intermittent Pringle maneuver (the Pringle group), and the other 20 cases were performed by continuous hemihepatic vascular inflow occlusion using extra-Glissonian approach (the half-Pringle group). The indications for both the two groups were determined based on the same criteria: (1) elective liver resection; (2) well-compensated chronic liver disease (Child-Pugh class A or B) without signs of severe portal hypertension (esophageal varices $\leq$ F2); (3) tumors which were located in segment 7; (4) tumor size $\leq$ 8 cm, and extent of partial hepatectomy was a segmentectomy 7 or bisegmentectomy 6–7; (5) no major vascular involvement; and (6) no concomitant surgical procedures except cholecystectomy.

Laparoscopic liver resection has become widely used worldwide due to its minimal invasiveness; however, the most favorable indication is the $\leq$ 5-cm-diameter solitary tumor in an anterolateral liver segment (2, 3, 4b, 5, and 6). Segment 7 is considered an unfavorable portion for laparoscopic liver resection because of technical difficulties caused by the difficult exposure, limited access, and lack of anatomical landmarks and potential difficulties in controlling bleeding. Recently, laparoscopic hepatectomy for lesions located in segment 7 has been reported by several authors with initial experience [1–3].

The preoperative workup consisted of a specified protocol including blood examinations, chest X-ray, spirometry, abdominal ultrasound, and contrast computed tomography scan. In selected cases, esophagogastroduodenoscopy or angiomagnetic resonance imaging was performed. Liver function was assessed by the Child's-Pugh grading. Laboratory blood tests included white blood cell (WBC), platelet (PLT), hemoglobin (HGB), alanine aminotransferase (ALT), aspartate transaminase (AST), albumin (Alb), serum total bilirubin (TBIL), international normalized ration (INR), prothrombin time (PT), HBsAg, antibodies to hepatitis C, serum alpha-fetoprotein (AFP), carbohydrate antigen 19-9 (CA19-9), carcinoembryonic antigen (CEA), and C-reactive protein (CRP).

All procedures were performed after informed consents were obtained. The data of preoperative clinical characteristics, intraoperative details, postoperative complications, and outcomes were collected prospectively and analyzed retrospectively. This study was approved by the Ethical Committee of the Sichuan Academy of Medical Sciences (Sichuan Provincial People's Hospital), and it followed the ethical guidelines of the 1975 Declaration of Helsinki.

Surgical Procedure

After general anesthesia, the patients were placed in the left semidecubitus position with the right side elevated approximately 30° – 45° . Generally, five ports were used. The first trocar (12 mm) was inserted at the right upper umbilicus for placement of a 10-mm 30° laparoscope. Four other trocars were inserted at the subxiphoid position (5 mm), at 5 cm superior to the umbilicus on the midline (12 mm), at 5 cm below the costal margin on the right midclavicular line (12 mm), and at 2 cm below the costal margin on the right axillary line (5 mm).

After placing all trocars successfully, the operating table was tilted slightly to the reverse Trendelenburg position. Exploration of the abdominal cavity was performed routinely. After full mobilization of the right liver, a custom-designed device (a water sac) was placed behind the mobilized right liver. The water sac made by a latex surgical glove was used as a pad to elevate the right liver. After the liver was flipped toward the left anteroinferior direction by the elevating of the water sac, the lesions in segment 7 and the predicted resection lobe (segment) of the liver were successfully exposed at the most convenient site for surgery. Routine intraoperative ultrasound was performed to confirm the extension of the tumor, the number of lesions, and their position in relation to the main hepatic structures. The area to be resected was marked by electrocautery.

For Pringle maneuver, after the avascular lesser omentum was divided, a tape was placed around the entire hepatoduodenal ligament and passed through a 16-Fr hard tube to enable performance of a Pringle maneuver. Both the two ends of the hard tube were connected by a 2-cm soft rubber catheter respectively. The internal end of the tube was close to the pedicle and the external end was extracorporeal. The external end passed through abdominal wall from umbilicus, allowing for easy external occlusion. When clamping, the external rubber catheter together with the tape could be clamped with a pean clamp to prevent gas leakage and tape slipping. Tightening of the tape and clamping of external rubber catheter would result in vascular inflow occlusion. Tightening or loosening of the tape would result in clamping or unclamping of the entire liver. Intermittent vascular occlusion was performed with cycles of 15/5 min of clamp and unclamp times.

For half-Pringle maneuver, the hilar plate was lowered, similar to the open technique as described by Hepp and Couinaud [6], to expose the confluence of the right and left portal pedicles by lifting the segment 4b of the liver upwards and incising the Glisson's capsule at its base. Without entering the liver substance, a space could be developed by bluntly dissecting between the liver substance and the hilar plate. The right portal pedicle was isolated en bloc and encircled with a tape to enable performance of a half-Pringle maneuver.

(Fig. 1a). Similar to the Pringle maneuver, tightening or loosening of the tape would result in clamping or unclamping of the right liver. The half-Pringle maneuver resulted in a visible line of ischemic demarcation along the main liver fissure (Cantlie line)(Fig. 1b).The hemihepatic vascular occlusion was continuous if the parenchymal transaction time was no more than 60 min, or else 5 min of reperfusion was required.

The parenchymal transection was performed by using the ultrasonic dissector (Harmonic Scalpel; Ethicon Endo-Surgery). Intraparenchymal control of the major vessels was obtained with titanium clips, vascular locks, or suturing using prolene sutures. Bipolar electrocoagulation was used for minor bleeding. Linear laparoscopic staplers (Echelon 60 ENDOPATH Stapler, Ethicon Endo-Surgery, LLC, Cincinnati, OH, USA) were used to transect the major vascular structures. A segmentectomy 7 (tumorectomy) was performed for smaller lesions in peripheral locations, while a bisegmentectomy 6–7 (right posterior sectionectomy) was adopted in larger lesions and in those located in the center of the posterior section (Fig. 2).The tumor was removed from a transverse incision (Pfannenstiel incision) at 3 cm superior to the pubic symphysis. The pneumoperitoneum pressure was induced at a pressure lower than 12 mmHg to reduce the risk of gas embolism, and the central venous pressure was kept below 5 mmHg during liver parenchymal transaction. Patients with unmanageable hemorrhage during laparoscopy were rapidly converted to laparotomy.

For tumors located in the segment 7, we suggested that a segmentectomy 7 (tumorectomy) was adopted for smaller lesions in peripheral locations, while a bisegmentectomy 6–7 (right posterior sectionectomy) was adopted in larger lesions or in those located in the center of the posterior section. During a segmentectomy or tumorectomy for tumors located in the segment 7, the poor operative field resulted in obtaining safe tumor margins and bleeding control [1]. The problem was solved as follows: The patients were placed in the left semidecubitus position with the right side elevated approximately 30°–45°. The operating table was tilted slightly to the reverse Trendelenburg position. A full mobilization of the right liver carried up to the

diaphragm was necessary as the first step of the procedure. Then, limited views could be largely overcome by using 30° laparoscope which could be moved among camera port and the two main working ports. This type of laparoscope allowed us to achieve a superior view of the resection line.

But the difficult access still makes transection of the parenchyma difficult. It is consistent to emphasize that laparoscopic partial hepatectomy is difficult to operate due to the limitation of the surgical area and the operating equipment [7]. Because of the limitations of using straight laparoscopic instruments, the transection line can be curved or angulated. However, resection in segment 7 is still challenging especially when using the conventional instruments. Several authors reported that intercostal trocars could be helpful to easily access the operative field and manipulate the instruments [3]. But the potential of the complications including intercostal vessel bleeding, pneumothorax, and the injury of the lung should be concerned.

Postoperative Management

All patients received the same postoperative care. Postoperative parameters of hepatic damage and recovery, including serum TBIL, ALT, AST, Alb, creatinine, PT, INR, and CRP were measured on postoperative days 1, 3, and 7. Abdominal ultrasound examination was performed on postoperative day 7.

Hepatic insufficiency was defined as a PT value more than 50% of normal and/or serum bilirubin more than 50 $\mu\text{mol/L}$ on postoperative day 7 and/or encephalopathy. Postoperative ascites was defined by an abdominal drainage output more than 500 mL/day, or required treatment. Perioperative mortality was defined as death within 90 days of surgery and death during the same hospital admission of surgery.

Statistical Methods

Results were expressed as mean $\pm$ standard deviation and were analyzed by paired-sample t (t') test. And the χ^2 test (with

Fig. 1 **a** The performance of a half-Pringle maneuver. **b** The Cantlie line of ischemic demarcation along the main liver fissure

Fig. 2 **a** The tumor is shown in the imaging location. **b** Complete resection of the tumor, the resection in Segment 6–7. **c** The tumor is shown in the imaging location. **d** Complete resection of the tumor, the resection only in Segment 7

continuity corrected χ^2 if the expected count was <5) or the Fisher exact test were appropriate for categorical data. All calculations were performed using the SPSS 19.0 statistical software. Results with P value <0.05 (paired-tailed test) were considered statistically significant.

Results

There were no significant differences between the two groups in terms of baseline characteristics, including preoperative clinical characteristics, tumor features, types of liver resection, and histopathology ($P > 0.05$) (Table 1). All patients were discharged in good condition, without massive hemorrhage, superficial and deep infection, and liver synthetic dysfunction. Of the total 36 cases, 2 were transferred from laparoscopic to open, as a result of uncontrollable bleeding (8.3%) (one in the Pringle group and one in the half-Pringle group). All of the patients underwent R0 resection, without margin invasion in both groups. The tumor-free resection margin was comparable between the two groups of patients ($P > 0.05$).

The mean operative time (274.5 ± 34.3 versus 237.6 ± 41.8 min, $P = 0.0075$), overall declamping time (28.4 ± 8.6

versus 2.3 ± 2.5 min, $P < 0.05$), and ischemic duration (69.7 ± 16.5 versus 52.7 ± 13.2 min, $P = 0.0016$) were significantly longer in the Pringle group than in the half-Pringle group. The mean amount of intraoperative blood loss was significantly greater in the Pringle group (612.5 ± 222.3 versus 417.4 ± 163.8 mL, $P = 0.0046$). As a result, there was a significantly greater volume of intraoperative blood transfusion in the Pringle group (335.2 ± 58.7 versus 224.8 ± 76.2 mL, $P = 0.0000$). In the half-Pringle group, the mean time taken to prepare the hemihepatic vascular inflow occlusion was 14.3 min (range, 7–22 min) (Table 2).

Postoperative Complications and Outcomes

In this study, both the two groups had no perioperative mortality. There was no evidence of intraoperative gas embolism in any of the patients. No bile duct injury occurred in either group. Postoperative hospital stay was similar in the two groups ($P > 0.05$). According to the Clavien-Dindo classification [8], two complications of postoperative bleeding (one in the Pringle group and one the half-Pringle group) were grade 3, and the other complications of the two groups were grade 1 or grade 2.

Table 1 Clinical characteristics of patients

	Pringle (<i>n</i> = 16)	Half-Pringle (<i>n</i> = 20)	<i>P</i> value
Sex			
M	9	11	0.9402
F	7	9	
Age (year)	47.3 ± 12.1	46.1 ± 10.7	0.7543
BMI	23.7 ± 3.9	24.1 ± 3.7	0.7549
WBC count (10 ⁹ /L)	5.8 ± 3.2	5.3 ± 2.8	0.6205
PLT count (10 ⁹ /L)	139.4 ± 71.8	145.8 ± 74.1	0.7956
HGB (g/L)	128.6 ± 21.2	121.8 ± 24.8	0.3899
Child-Pugh classification			
Grade A, <i>n</i>	11	12	0.5870
Grade B, <i>n</i>	5	8	
ALT (U/L)	48.7 ± 21.3	54.4 ± 26.6	0.4909
AST (U/L)	56.2 ± 23.2	52.1 ± 27.3	0.6357
TBIL (μmol/L)	16.4 ± 5.3	17.2 ± 6.2	0.6845
Alb (g/L)	34.7 ± 5.6	36.4 ± 5.8	0.3812
INR	1.02 ± 0.13	1.04 ± 0.15	0.6762
Creatinine (μmol/L)	68.4 ± 16.2	61.9 ± 21.4	0.3219
CRP (mg/L)	3.1 ± 2.8	2.8 ± 3.2	0.7696
Tumor size (cm)	4.1 ± 2.6	4.3 ± 2.8	0.8274
Patients with portal hypertension, <i>n</i>	1	2	0.8397

Note: *AST* aspartate transaminase, *ALT* alanine aminotransferase, *Alb* albumin, *TBIL* serum total bilirubin, *INR* international normalized ration, *HGB* hemoglobin, *WBC* white blood cell, *CRP* C-reactive protein

There were no significant differences in any type of complications and the overall operative morbidity ($P > 0.05$) (Table 3).

The postoperative liver functional status which was reflected by the postoperative changes of albumin, serum bilirubin, transaminase, and INR levels is shown in Table 3. No significant differences were observed in ALT and AST levels on postoperative days 1, 3, and 7 ($P > 0.05$). But the Pringle group was associated with significantly lower albumin levels on postoperative days 1, 3, and 7 ($P < 0.05$).

There were no significant differences in the bilirubin, INR, and creatinine levels between the two groups ($P > 0.05$).

The postoperative plasma concentration of CRP increased in both groups. The mean CRP levels were significantly higher in the Pringle group than in the half-Pringle group on POD 1 (36.3 ± 7.6 versus 28.4 ± 6.5 mg/L, $P = 0.0019$), POD 3 (94.9 ± 26.1 versus 76.3 ± 18.3 mg/L, $P = 0.0170$), and POD 7 (54.7 ± 8.1 versus 43.2 ± 7.7 mg/L, $P = 0.0001$).

Discussion

Laparoscopic liver resection is safe and may provide improved patient outcomes, compared to the open technique [9–12]. Long-term results show that oncological benefits of laparoscopic approach are similar to open surgery [12–14].

In our study, this difficulty could be largely resolved by a simple and safe technique. After full mobilization of the right liver, we placed a water sac behind the right liver. The water sac was used to elevate the right liver. Because of being lifted by the water sac, the liver could be flipped toward the left anteroinferior direction. The lesions in segment 7 and the predicted resection lobe (segment) of the liver were successfully exposed at the most convenient site for surgery. After adequately flipping the liver toward the left anteroinferior direction, the operative field became closer to the trocar site. It makes laparoscopic resection of this region safer and easier.

After successful exposure of the tumor in segment 7, bleeding remains the major concern during parenchymal transection [8, 15, 16]. Pringle maneuver is a traditional and the most commonly used method to decrease blood loss during parenchymal transection because of its effectiveness and simplicity. However, hemihepatic inflow occlusion has the advantages of no ischemic-reperfusion injury to the remnant liver, avoidance of splanchnic congestion, and better hemodynamic tolerability [17–19]. The intrahepatic Glissonian approach allows safe en masse control of the portal structures without prolonged dissection [20]. Its association with the half-Pringle maneuver results in less bleeding during parenchymal transection [21, 22].

Table 2 Intraoperative detail of patients

	Pringle (<i>n</i> = 16)	Half-Pringle (<i>n</i> = 20)	<i>P</i> value
Type of liver resection, <i>n</i>			
Segment VII	8	11	0.7652
Segment VI + VII	8	9	
Pathologic diagnosis, <i>n</i>			
Hepatocellular carcinoma	6	8	0.8785
Cholangiocarcinoma	1	2	0.8397
Metastases of colorectal carcinoma	2	3	0.7876
Hemangioma	7	7	0.5926
Nontumorous liver, <i>n</i>			
Normal	8	11	0.7652
Chronic hepatitis	3	4	0.7417
Cirrhosis	5	5	0.9668
Tumor-free resection margin			
> 1 cm	9	12	0.8206
0–1 cm	7	8	
Conversion to open liver resection, <i>n</i>	1	1	1
Operation time (range) (min)	274.5 ± 34.3	237.6 ± 41.8	0.0075
Overall declamping time(range) (min)	28.4 ± 8.6	2.3 ± 2.5	< 0.05
Ischemic duration (range) (min)	69.7 ± 16.5	52.7 ± 13.2	0.0016
Intraoperative blood loss (mL)	612.5 ± 222.3	417.4 ± 163.8	0.0046
Intraoperative blood transfusion, (mL)	335.2 ± 58.7	224.8 ± 76.2	0.0000

In our study, the mean operative time in the Pringle group was significantly longer. Tranchart [23] reported that in the patients that underwent laparoscopic liver resection for malignancy, operative time was the sole independent predictor of postoperative morbidity. Postoperative complication rate increases by 60% with each additional operative hour during laparoscopic liver resection [23]. Our study showed that the overall declamping time was significantly longer in the Pringle group. When declamping, it was very difficult to control bleeding by compression of the liver parenchyma in laparoscopic context [24], which caused the great amount of blood loss in declamping period. Greater amount of blood loss in declamping period ensued in the Pringle group because of a longer overall declamping time. When lesions locate in the right posterior liver, bleeding control is a great challenge to surgeons because of difficult access, difficult suturing for hemostasis, and a large transection area and its anatomic location. If bleeding could not be controlled successfully and rapidly in clamping period, it would be more difficult to control bleeding during the same time. Intermittent vascular occlusion was performed with cycles of 15/5 min of clamp and unclamp times. Bleeding was often difficult to be controlled successfully before the end of 15-min clamping period. If bleeding control was performed under a hurried and flustered condition, it might cause inadvertent ligation of the major

intrahepatic vessels, which was dangerous for cirrhotic patients because ischemic or congestive necrosis would occur in the remnant liver and might cause liver failure. In continuous hemihepatic vascular inflow occlusion, bleeding control could be accurately accomplished without hurry because the 60-min clamping period was long enough. The ischemic time in the Pringle group was significantly longer in our study. Ischemic-reperfusion injury could lead to postoperative morbidity. Less ischemic-reperfusion injury and blood loss caused patients in the half-Pringle group to have a significant better recovery, which was reflected by the difference of postoperative serum albumin and CRP between the two groups. Although no significant differences were observed in postoperative ALT and AST levels, the half-Pringle group was associated with significantly higher albumin levels on postoperative days 1, 3, and 7. CRP is the acute phase reactant mainly induced by IL-6 during tissue injury [25, 26]. According to our research, the inflammatory markers were less in the group undergoing half-Pringle group in comparison to that in the Pringle group, which demonstrated less surgical trauma in the half-Pringle group. Many centers have begun to explore the feasibility and safety of laparoscopic liver resection for both benign and malignant liver diseases [27]. However, this special technique has been published without RCTs and the existing data have not been systematically

Table 3 Postoperative complications and outcomes

	Pringle (<i>n</i> = 16)	Half-Pringle (<i>n</i> = 20)	<i>P</i> value
Postoperative complications			
Postoperative bleeding, <i>n</i>	1	1	1
Hepatic insufficiency, <i>n</i>	1	1	1
Surgical site infections, <i>n</i>	1	1	1
Ascites, <i>n</i>	3	3	0.8808
Pulmonary effusion, <i>n</i>	2	1	0.8397
Operative morbidity, <i>n</i> (%)	5 ^a (31.3%)	4 ^b (20.0%)	0.6985
Postoperative outcome			
POD 1			
ALT (U/L)	573.3 ± 131.8	585.4 ± 141.6	0.7944
AST (U/L)	607.6 ± 169.2	588.7 ± 161.3	0.7346
TBIL (mg/L)	1.25 ± 0.47	1.37 ± 0.50	0.4603
Alb (g/L)	26.6 ± 2.5	29.5 ± 2.8	0.0027
INR	1.14 ± 0.38	1.22 ± 0.31	0.4911
PT	13.5 ± 3.3	14.1 ± 3.7	0.6155
CRP	36.3 ± 7.6	28.4 ± 6.5	0.0019
POD 3			
ALT (U/L)	277.8 ± 98.8	283.6 ± 91.7	0.8565
AST (U/L)	311.4 ± 121.8	289.6 ± 131.3	0.6127
TBIL (mg/L)	1.57 ± 0.36	1.59 ± 0.40	0.8921
Alb (g/L)	29.3 ± 2.5	31.9 ± 3.1	0.0102
INR	1.23 ± 0.29	1.21 ± 0.34	0.8528
PT	13.8 ± 3.8	13.4 ± 3.4	0.7412
CRP (mg/L)	94.9 ± 26.1	76.3 ± 18.3	0.0170
POD 7			
ALT (U/L)	56.8 ± 27.4	50.9 ± 22.7	0.4844
AST (U/L)	71.4 ± 31.2	68.3 ± 28.4	0.7573
TBIL (mg/L)	1.19 ± 0.40	1.36 ± 0.42	0.2232
Alb (g/L)	30.3 ± 3.1	32.7 ± 2.8	0.0202
INR	1.11 ± 0.17	1.09 ± 0.24	0.7802
PT	11.8 ± 2.7	12.1 ± 3.1	0.7620
CRP	54.7 ± 8.1	43.2 ± 7.7	0.0001

^a Eight complications occurred in 5 patients^b Seven complications occurred in 4 patients

reviewed; the role of laparoscopic major liver resection remains unclear. Conventional open procedure still had advantages compared with laparoscopic procedure, such as surgical field, bleeding control and unnecessary damage [28].

In conclusion, even in poorly accessible segment 7, there are some limitations and particularities in the selection of laparoscopic surgery, but patients who were consistent with inclusion criteria were randomized. Laparoscopic liver resection could be performed safely and effectively in experienced hands, with successful exposure of surgical field and proper hepatic blood flow occlusion. Continuous half-Pringle maneuver offers the advantages of less operative time and blood loss, less injury, and better recovery compared to intermittent Pringle maneuver.

Author Contributions Yu Zhang and Xiangyu Lu have contributed equally to this work; Yu Zhang, Jian Xu, and Hongji Yang designed the study; Xiangyu Lu, Xiaofan Deng, Chen Kai, and Yunfei Chen collected the patient's clinical data; Jian Xu analyzed the data and wrote the paper.

Funding Information This study was supported by grants from Health Department of Sichuan Province, China, No. 130134 and Doctor Funding of Sichuan Academy of Medical Sciences.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

References

- Ishizawa T, Gumbs AA, Kokudo N, Gayet B (2012) Laparoscopic segmentectomy of the liver From Segment I to VIII. *Ann Surg* 256(6):959–964. <https://doi.org/10.1097/SLA.0b013e31825ffed3>
- Coles SR, Besselink MG, Serin KR, Alsaati H, Di Gioia P, Samim M, Pearce NW, Abu Hilal M (2015) Total laparoscopic management of lesions involving liver segment 7. *Surg Endosc* 29(11):3190–3195. <https://doi.org/10.1007/s00464-014-4052-2>
- Okuda Y, Honda G, Kurata M, Kobayashi S, Sakamoto K, Takahashi K (2014) A safe and valid procedure for pure laparoscopic partial hepatectomy of the most posterosuperior area: the top of segment 7. *J Am Coll Surg*. <https://doi.org/10.1016/j.jamcollsurg.2014.11.021>
- Zhang Y, Yang H, Chen Y, et al (2015) Totally laparoscopic associating liver tourniquet and portal ligation for staged hepatectomy via anterior approach for cirrhotic hepatocellular carcinoma. *J Am Coll Surgeons*. <https://doi.org/10.1016/j.jamcollsurg.2015.04.016>
- Zhang Y, Yang H, Deng X, et al (2015) Intermittent Pringle manoeuvre versus continuous hemihepatic vascular inflow occlusion using extra-glissonian approach in laparoscopic liver resection. *Surg Endosc*. <https://doi.org/10.1007/s00464-015-4276-9>
- Hepp J, Couinaud C (1956) Approach to and use of the left hepatic duct in reparation of the common bile duct. *Presse Med* 64(41):947–948
- Xiang L, Le Xiao JL, Chen J, Fan Y, Zheng S (2015) Safety and feasibility of laparoscopic hepatectomy for hepatocellular carcinoma in the posterosuperior liver segments. *World J Surg* 39(5):1202–1209. <https://doi.org/10.1007/s00268-015-2946-3>
- Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Santibañes E, Pekolj J, Slankamenac K, Bassi C, Graf R, Vonlanthen R, Padbury R, Cameron JL, Makuuchi M (2009) The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg* 250(2):187–196. <https://doi.org/10.1097/SLA.0b013e3181b13ca2>
- Twaij A, Pucher PH, Sodergren MH, Gall T, Darzi A, Jiao LR (2014) Laparoscopic vs open approach to resection of hepatocellular carcinoma in patients with known cirrhosis: systematic review and meta-analysis. *World J Gastroenterol* 20(25):8274–8281. <https://doi.org/10.3748/wjg.v20.i25.8274>
- Fuks D, Cauchy F, Ftéliche S, Nomi T, Schwarz L, Dokmak S, et al (2015) Laparoscopy decreases pulmonary complications in patients undergoing major liver resection: a propensity score analysis. *Ann Surg*. <https://doi.org/10.1097/SLA.0000000000001140>
- Siniscalchi A, Ercolani G, Tarozzi G, Gamberini L, Cipolat L, Pinna AD, Faenza S (2014) Laparoscopic versus open liver resection: differences in intraoperative and early postoperative outcome among cirrhotic patients with hepatocellular carcinoma—a retrospective observational study. *HPB Surg* 2014:1–7. <https://doi.org/10.1155/2014/871251>
- Yamashita Y, Ikeda T, Kurihara T, Yoshida Y, Takeishi K, Itoh S et al (2014) Long-term favorable surgical results of laparoscopic hepatic resection for hepatocellular carcinoma in patients with cirrhosis: a single-center experience over a 10-year period. *J Am Coll Surg* 219(6):1117–1123. <https://doi.org/10.1016/j.jamcollsurg.2014.09.003>
- Yoon S, Kim K, Jung D, Yu A, Lee S (2014) Oncological and surgical results of laparoscopic versus open liver resection for HCC less than 5 cm: case-matched analysis. *Surg Endosc* 29(9):2628–2634. <https://doi.org/10.1007/s00464-014-3980-1>
- Ahn KS, Kang KJ, Kim YH, Kim TS, Lim TJ (2014) A propensity score-matched case-control comparative study of laparoscopic and open liver resection for hepatocellular carcinoma. *J Laparoendosc Adv Surg Tech A* 24(12):872–877. <https://doi.org/10.1089/lap.2014.0273>
- Scatton O, Brustia R, Belli G, Pekolj J, Wakabayashi G, Gayet B (2015) What kind of energy devices should be used for laparoscopic liver resection? Recommendations from a systematic review. *J Hepatobiliary Pancreat Sci* 22(5):327–334. <https://doi.org/10.1002/jhbp.213>
- Otsuka Y, Kaneko H, Cleary SP, Buell JF, Cai X, Wakabayashi G (2015) What is the best technique in parenchymal transection in laparoscopic liver resection? Comprehensive review for the clinical question on the 2nd International Consensus Conference on Laparoscopic Liver Resection. *J Hepatobiliary Pancreat Sci* 22(5):363–370. <https://doi.org/10.1002/jhbp.216>
- Si-Yuan FU, Yee LW, Li G-G, Qing-he T, Ai-jun LI, Ze-ya PAN et al (2011) A prospective randomized controlled trial to compare Pringle maneuver, hemihepatic vascular inflow occlusion, and main portal vein inflow occlusion in partial hepatectomy. *Am J Surg* 201(1):62–69. <https://doi.org/10.1016/j.amjsurg.2009.09.029>
- Ni J-s, Lau WY, Yang Y, Pan Z-Y, Wang Z-g, Liu H, Wu M-c, Zhou W-p (2013) A prospective randomized controlled trial to compare Pringle maneuver, hemihepatic vascular inflow occlusion, and main portal vein inflow occlusion in partial hepatectomy. *J Gastrointest Surg* 17(8):1414–1421. <https://doi.org/10.1007/s11605-013-2236-z>
- Liang G, Wen T, Yan L, Li BO, Wu G, Yang J, Lu B, Chen Z, Liao Z, Ran S, Yu Z (2009) A prospective randomized comparison of continuous hemihepatic with intermittent total hepatic inflow occlusion in hepatectomy for liver tumors. *Hepato-Gastroenterology* 56(91–92):745–750
- Figueras J, Lopez-Ben S, Llado L, Rafecas A, Torras J, Ramos E et al (2003) Hilar dissection versus the “glissonean” approach and stapling of the pedicle for major hepatectomies: a prospective, randomized trial. *Ann Surg* 238(1):111–119. <https://doi.org/10.1097/01.SLA.0000074981.02000.69>
- Chen YJ, Zhen ZJ, Chen HW, Lai ECH, Deng FW, Li QH, Lau WY (2014) Laparoscopic liver resection under hemihepatic vascular inflow occlusion using the lowering of hilar plate approach. *Hepatobiliary Pancreat Dis Int* 13(5):508–512. [https://doi.org/10.1016/S1499-3872\(14\)60293-9](https://doi.org/10.1016/S1499-3872(14)60293-9)
- Herman P, Jaime K’g, Lupinacci R, Coelho F, Perini M (2013) Laparoscopic bisegmentectomy 6 and 7 using a Glissonean approach and a half-Pringle maneuver. *Surg Endosc* 27(5):1840–1841. <https://doi.org/10.1007/s00464-012-2681-x>
- Tranchart H, Gaillard M, Chirica M, Ferretti S, Perlemuter G, Naveau S, Dagher I (2014) Multivariate analysis of risk factors for postoperative complications after laparoscopic liver resection. *Surg Endosc* 29(9):2538–2544. <https://doi.org/10.1007/s00464-014-3965-0>
- Mizuguchi T, Kawamoto M, Nakamura Y, Meguro M, Hui TT, Hirata K (2015) New technique of extracorporeal hepatic inflow control for pure laparoscopic liver resection. *Surg Laparosc Endosc Percutan Tech* 25(1):e16–e20. <https://doi.org/10.1097/SLE.0b013e3182a4c0f4>
- Jiang G-Q, Chen P, Qian J-J, Yao J, Wang X-D, Jin S-J, Bai DS (2014) Perioperative advantages of modified laparoscopic vs open splenectomy and azygoportal disconnection. *World J Gastroenterol* 20(27):9146–9153. <https://doi.org/10.3748/wjg.v20.i27.9146>
- Muscari A, Collini A, Fabbri E, Giovagnoli M, Napoli C, Rossi V et al (2014) Changes of liver enzymes and bilirubin during ischemic stroke: mechanisms and possible significance. *BMC Neurol* 14:122
- Dagher I, Gayet B, Tzanis D, Tranchart H, Fuks D, Soubrane O, Han HS, Kim KH, Cherqui D, O’Rourke N, Troisi RI, Aldrighetti L, Bjorn E, Abu Hilal M, Belli G, Kaneko H, Jarnagin WR, Lin C, Pekolj J, Buell JF, Wakabayashi G (2014) International experience for laparoscopic major liver resection. *J Hepatobiliary Pancreat Sci* 21(10):732–736. <https://doi.org/10.1002/jhbp.140>
- Xu H, Liu F, Li H, Wei Y, Li B (2017) Outcomes following laparoscopic versus open major hepatectomy: a meta-analysis. *Scand J Gastroenterol* 7:1–8