Original Article

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Liver exposure during laparoscopic right-sided hepatectomy *via* stretching of the ligamentum teres hepatis: A propensity score matching analysis

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SUMMARY: One of the challenges of laparoscopic liver resection (LLR) is the exposure of the surgical field. We propose a new surgical approach to better expose the right liver, stretching of the ligamentum teres hepatis (SLTH), and we evaluated its clinical feasibility and limitations through a study analyzing relevant cases. Clinicopathologic data on patients who underwent laparoscopic right partial hepatectomy (LRPH) at our center were retrospectively collected, and subjects were 276 patients with liver space-occupying lesions who met the selection criteria and who underwent the new surgical approach (SLTH) or the conventional surgical approach (no stretching of the ligamentum teres hepatis, or NSLTH). After 1:1 propensity score matching (PSM), 102 patients in each cohort were selected for further analysis. There were no significant differences in the operating time or the duration of postoperative hospitalization between the SLTH cohort and the NSLTH cohort. The duration of detachment of the hepatic parenchyma and the duration of hepatic portal occlusion were significantly shorter in the SLTH cohort than in the NSLTH cohort. The intraoperative blood loss in the SLTH cohort was significantly less than that in the NSLTH cohort. Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels were significantly lower in the SLTH cohort than in the NSLTH cohort on day 5 postoperatively. Results confirmed that SLTH is a simple, safe, effective, and highly reproducible technique for the treatment of LRPH. SLTH may help to perform LRPH by increasing the level of laparoscopic exposure of the right liver and reducing bleeding and operating time.

Keywords: laparoscopic right hepatectomy, stretching of the ligamentum teres hepatis, surgical approach

1. Introduction

Improvements in laparoscopic technology and equipment have facilitated an increasing number of complex laparoscopic surgeries (*1*). Laparoscopic techniques have gradually replaced conventional open approaches because of several advantages, such as smaller incisions, less pain, and quick postoperative recovery (*2-3*). Moreover, laparoscopic approaches provide the necessary precision for anatomic liver resection in terms of reducing tissue damage and intraoperative bleeding in an effort to reduce systemic trauma (*4*). In hepatobiliary surgery, sufficient attention has been paid to laparoscopic techniques and their use has been encouraged (*5*). The complexity and difficulty of laparoscopic liver surgery vary. Laparoscopic hepatectomy on the right side faces many challenges, including a poor surgical field, limited intraoperative movement of the liver, difficulty in selecting the surgical section, and hemorrhage control (*6*). These challenges often require more effort on the part of the assistant and surgeon to expose the liver, and relying solely on laparoscopic instruments to expose the liver is consequently more fatiguing and unstable (*7*). Exposure during laparoscopic right hepatectomy needs to be urgently addressed.

Many techniques for surgical field exposure have been used in clinical practice during laparoscopic right hepatectomy, such as changing the patient's position (*8-9*), adjusting the laparoscopic trocar layout (*10-11*), the liver hanging maneuver (*12-13*), and sterile glove pouching (*14-15*). However, these techniques all have certain limitations. For instance, a change in position, adjustment of the laparoscopic trocar layout, and the liver hanging maneuver cannot be performed at will. Sterile glove pouching is usually performed to a limited extent in laparoscopic surgery. Therefore, further screening is required for clinical use. Through continuous exploration and the practice of laparoscopic liver resection (LLR), the current authors explored an innovative procedure to expose the right side of the liver which they designated stretching of the ligamentum teres hepatis (SLTH). This procedure is performed as follows. After the right liver is dissected, the ligamentum teres hepatis is severed, and a traction thread is sutured at the stump. Then, tissue clamps are used to fix the traction suture, a hook needle is used to guide the traction suture outside of the body, and the suture can be fixed outside the abdominal wall. The right liver can be better exposed and rotated with the SLTH. As the authors' team gained proficiency and increasingly used hepatic ligament retraction, results indicated that the technique was very helpful for LRPH exposure, largely increasing the surgeon's space to maneuver and reducing the difficulty of exposure for the assistant. The aim of the current study was to introduce the SLTH and to evaluate its clinical feasibility and limitations.

2. Materials and Methods

2.1. General information

Data on all patients who underwent LRPH at the First Affiliated Hospital of Harbin Medical University from January 2015 to July 2022 were analyzed. The research ethics committee of Harbin Medical University approved this study in accordance with the Declaration of Helsinki (as revised in 2013). Clinical information and written informed consent were collected from all participants. Subjects were a total of 276 patients who underwent LRPH, including patients who underwent SLTH (n = 135, SLTH cohort) or not (n = 141, NSLTH cohort) during LRPH. All surgeries were performed by the same surgical team, and there were no differences in the learning curve between the two cohorts.

2.2. Selection criteria

Subjects were a total of 276 patients who met the following selection criteria: (1) patients with a single tumor located in the right lobe of the liver (segments 5-8); (2) patients who were Child–Pugh grade A or B and whose liver function was restored to grade A after short-term liver protection treatment; (3) patients with a retention rate of indocyanine green for 15 minutes of less than 20%; (4) patients free of tumor infiltration or metastasis; and (5) patients who had not previously undergone abdominal surgery (*16-17*).

2.3. Surgical procedure

All surgeries were performed by the same surgical team following surgical and oncological principles. Following general anesthesia with tracheal intubation, invasive arterial blood pressure and central venous pressure were monitored during the procedure. Patients were placed in the supine or semilateral position. The position was further adjusted with the operating table as needed. CO_2 pneumoperitoneum was performed to maintain intra-abdominal pressure at 14 mmHg (1 mmHg = 0.133 kPa). Five trocars were typically placed in the abdomen, and a 30-degree rigid laparoscope was used. Laparoscopic ultrasonography was used to locate the lesion and identify the important pipeline structures around the lesion. The round ligament and the falciform ligament were dissected until the secondary porta hepatis was revealed. The liver was completely mobilized by dissecting the ligaments around the liver. The appropriate fixation angle was selected by pulling the falciform ligament. The free ligamentum teres hepatis was reattached to the abdominal wall with a Hem-o-lok clip or endoscopic suture. The extent of removal was evaluated to determine whether the gallbladder could be preserved. The first hepatic hilar blood flow occlusion device was pre-placed through the foramen of Winslow to perform the Pringle operation. The liver parenchyma was transected with a harmonic scalpel (Ethicon Endo-Surgery, USA). After transection, the stump was clipped with a Hem-o-lok clip or titanium clip. Laparoscopically, the thick stump was closed with a linear cutting closure and sutured with Prolene 5.0 for hemostasis. The specimen was removed from the bag endoscopically. Bleeding from the incision was carefully stopped by bipolar coagulation, and the incision was repeatedly rinsed. After confirming that the section was free of bleeding or biliary fistulae, fibrin glue was uniformly sprayed on the liver wound. The traction clamp or suture line was incised with the harmonic scalpel and then removed *via* the port. A drainage tube was inserted, and the wound was closed in layers. The operating time, hepatic portal occlusion time, parenchymal resection time, and intraoperative blood loss were recorded. Preoperative and postoperative blood biochemical indices and the duration of postoperative hospitalization were recorded.

To eliminate confounding variables between the two cohorts, propensity score matching (PSM) analysis was performed. This analysis was used to match variables of baseline characteristics that differed significantly between the two cohorts. A matching caliper of 0.02 and 1:1 nearest neighbor matching were used.

2.4. Statistical analysis

Statistical analyses were performed using SPSS 24.0 (IBM SPSS, USA). The distribution of measurements was analyzed in each cohort. Normally distributed data were expressed as the mean ± standard deviation, and the two-sample independent *t*-test was used for intercohort comparisons; if the data did not follow a normal distribution, data were expressed using the median (interquartile range), and nonparametric tests (*Mann–Whitney U* test) were used for intercohort comparisons. Numerical data are expressed as frequencies (percentages), and the differences between the two cohorts were compared using the chi-square test. A *P* value < 0.05 was considered to indicate statistical significance.

3. Results

3.1. Baseline characteristics

First, the baseline characteristics of patients were compared, and significant differences between the two cohorts were noted in terms of BMI, Child–Pugh classification, and preoperative AST level (Table 1). The differences in these three indicators may affect the evaluation of the effectiveness of SLTH in surgery. Therefore, PSM analysis was used to select patients from the two cohorts at a 1:1 ratio. Ultimately, through PSM analysis, 102 patients were selected from each cohort and their baseline characteristics were compared. There were no significant differences in any indicator between the two cohorts of patients, thus eliminating the influence of baseline characteristics in the current study (Table 2).

Moreover, no major complications (Clavien–Dindo IIIa or worse) occurred in either cohort perioperatively, and no patients were transferred to the ICU or died perioperatively.

3.2. Perioperative surgical outcomes

Next, surgical indicators in the aforementioned patients were compared. Results indicated that the duration of hepatic parenchymal detachment and the hepatic portal occlusion time were significantly shorter in the SLTH cohort than in the NSLTH cohort, while intraoperative blood loss was significantly less in the SLTH cohort than in the NSLTH cohort. In addition, data revealed that there were no significant differences in the operating time or the duration of postoperative hospitalization between the SLTH cohort and the NSLTH cohort (Table 3).

3.3. Postoperative liver function

In addition, postoperative liver function in patients in both cohorts was compared. The alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels peaked on day 1 postoperatively and

Table 1. Comparison of patients' baseline characteristics

	SLTH cohort (*n* = 135)	NSLTH cohort (*n* = 141)	*P* values
Age (years)	49.42 ± 11.06	48.53 ± 11.06	0.504
Sex			
Male	64	66	0.921
Female	71	75	
Child–Pugh class			
A	124	138	0.045
B	11	3	
BMI (kg/m^2)	22.03 ± 2.37	21.42 ± 2.27	0.030
Pathological diagnosis			
Hepatocellular carcinoma	62	68	0.702
Hepatic hemangioma	73	73	
Alpha-fetoprotein (ng/mL)			
0-400	90	89	0.537
> 400	45	52	
Cirrhosis			
Yes	55	61	0.671
No	80	80	
Tumor location			
Segment 5	27	23	0.991
Segment 6	26	24	
Segment 7	34	36	
Segment 8	26	34	
Junction of segments 5-6	4	4	
Junction of segments 5-8	8	10	
Junction of segments 6-7	6	6	
Junction of segments 7-8	2	2	
Other	2	2	
Preoperative ALT	16.22 ± 4.67	16.29 ± 4.43	0.904
Preoperative AST	19.29 (3.78)	18.85 (3.31)	0.049

Table 2. Comparison of patients' baseline characteristics after PSM

	SLTH cohort (*n* = 102)	NSLTH cohort (*n* = 102)	*P* values
Age (years)	49.40 ± 11.48	48.33 ± 11.15	0.501
Sex			
Male	47	49	0.779
Female	55	53	
Child–Pugh class			
A	100	99	1.000
B	2	3	
BMI (kg/m^2)	21.67 ± 2.01	21.91 ± 2.20	0.405
Pathological diagnosis			
Hepatocellular carcinoma	45	44	0.888
Hepatic hemangioma	57	58	
Alpha-fetoprotein (ng/mL)			
0-400	69	68	0.881
> 400	33	34	
Cirrhosis			
Yes	40	38	0.773
No	62	64	
Tumor location			
Segment 5	23	18	0.964
Segment 6	22	20	
Segment 7	25	22	
Segment 8	19	25	
Junction of segments 5-6	3	4	
Junction of segments 5-8	4	5	
Junction of segments 6-7	3	4	
Junction of segments 7-8	2	2	
Other	1	2	
Preoperative ALT U/L	15.60 (6.60)	16.70 (4.70)	0.378
Preoperative AST U/L	19.34 (3.82)	19.17 (3.55)	0.360

Table 3. Comparison of perioperative surgical outcomes between the two cohorts after PSM

	SLTH cohort (*n* = 102)	NSLTH cohort (*n* = 102)	*P*
Operating time (min)	226.00 (130.00)	238.00 (114.00)	0.391
Parenchymal transection time (min)	102.00 (76.00)	148.00 (122.00)	< 0.001
Blood loss (mL)	100.00 (64.00)	120.00 (70.00)	0.006
Hospitalization (day)	10.00 (3.00)	10.00 (2.00)	0.783
Hepatic portal occlusion time (min)	25.00 (27.00)	40.50 (31.00)	< 0.001

Table 4. Comparison of postoperative liver function in the two cohorts after PSM

	SLTH cohort (*n* = 102)	NSLTH cohort (*n* = 102)	*P*
ALT (U/L)			
Day 1 postoperatively	277.9 (64.70)	289.40 (59.1)	0.076
Day 5 postoperatively	49.70 (4.80)	65.50 (4.60)	< 0.001
Day 7 postoperatively	16.05 (6.20)	17.50 (4.70)	0.057
AST (U/L)			
Day 1 postoperatively	302.19 ± 76.49	297.7 ± 67.53	0.714
Day 5 postoperatively	51.98 ± 17.22	60.77 ± 18.21	0.045
Day 7 postoperatively	15.97 ± 4.39	16.94 ± 4.52	0.203

did not differ significantly between the two cohorts. The ALT and AST levels in both cohorts gradually decreased. Notably, the ALT and AST levels were significantly lower in the SLTH cohort than in the NSLTH cohort on day 5 postoperatively. Seven days postoperatively, the ALT and AST levels in both cohorts had decreased to normal levels (Table 4).

4. Discussion

In LRPH, several methods, such as intraoperative position changes (*8*), adjustment of the trocar layout (*10-11*), and liver suspension and surgical glove techniques (*12,14*), have been widely used in clinical practice to expand the surgical field and reduce the difficulty of surgery. The liver hanging maneuver was first used in open right hepatectomy by Belghiti *et al*. (*18*). The specific procedure consisted of establishing a channel between the inferior vena cava and the liver parenchyma and then passing a pulling sling through, which was perforated between the right hepatic vein and the middle hepatic vein. By pulling the sling to help expose the deep portion of liver, compressing the intrahepatic vessels and guiding the direction of resection, the hanging liver maneuver can effectively shorten the operating time and reduce intraoperative bleeding. However, this technique involves certain surgical difficulties and risks. First, the anterior inferior vena cava is not visible, so surgical skill is required (*19*). Additionally, short hepatic veins are at risk of rupture. Second, this procedure is associated with considerable anatomic risk at the second hepatic hilum. Finally, the blind establishment of channels for tumors near the diaphragm may lead to tumor rupture (*20*). Thus, the conventional liver hanging maneuver is difficult to perform laparoscopically.

Therefore, an improved liver hanging maneuver was proposed (*12*). Instead of dissecting the hepatic vein at the second portal, the pulling sling is placed on the right side of the right hepatic vein after dissection of the deltoid ligament is completed. Moreover, the right adrenal gland and inferior vena cava were selected to avoid injury to the short hepatic vein. This technique significantly reduces the risk of surgery. These string-based techniques help to expose the liver, reduce bleeding, and shorten the operating time (*21*). However, many of the drawbacks of the liver hanging maneuver remain unavoidable during laparoscopic procedures. For example, the pulled sling occupies an already limited space and blocks the surgeon's instruments. The direction of the sling is limited by port positioning during laparoscopy and cannot meet the surgeon's requirements. In addition, applying sufficient pressure to the vasculature to occlude some of the blood flow, as is done in open surgery, is difficult.

More recently, surgical glove techniques have been used in laparoscopic right hepatectomy (*14,18*). This procedure consists of the following steps. After transection of the right deltoid ligament and the coronal ligament, water-injected gloves are placed behind the right liver. The pressure of the water capsule pushes the right liver forward and to the left, leading to the exposure of deep liver tissue. The advantages of this technique are the relative ease with which it is performed, the low level of risk, and the short preparation time. As the water capsule pushes the liver forward and to the left, it narrows the distance between the surgeon and the liver. This technique increases the exposure of the posterior hepatic field and the angle of operation. This technique is considered to reduce the duration of hepatic amputation and blood loss. The surgical glove technique seems to be more beneficial than conventional LRPH. When treating large tumors on the right side of the liver, however, the water capsule may further reduce the surgical field. Additionally, the liver is deformed by compression from the water capsule, which may lead to a change in the section surface after the removal of the water capsule.

Compared to the aforementioned techniques to increase the exposure of the right liver during laparoscopic surgery, the most striking features of SLTH are that it is simple and virtually risk-free. In LRPH, the space to manipulate the diaphragmatic surface of the liver is usually adequate due to the establishment of pneumoperitoneum, while the exposure of the hidden surface is difficult and unstable. This technique increases the space for the hidden surface of the right side of the

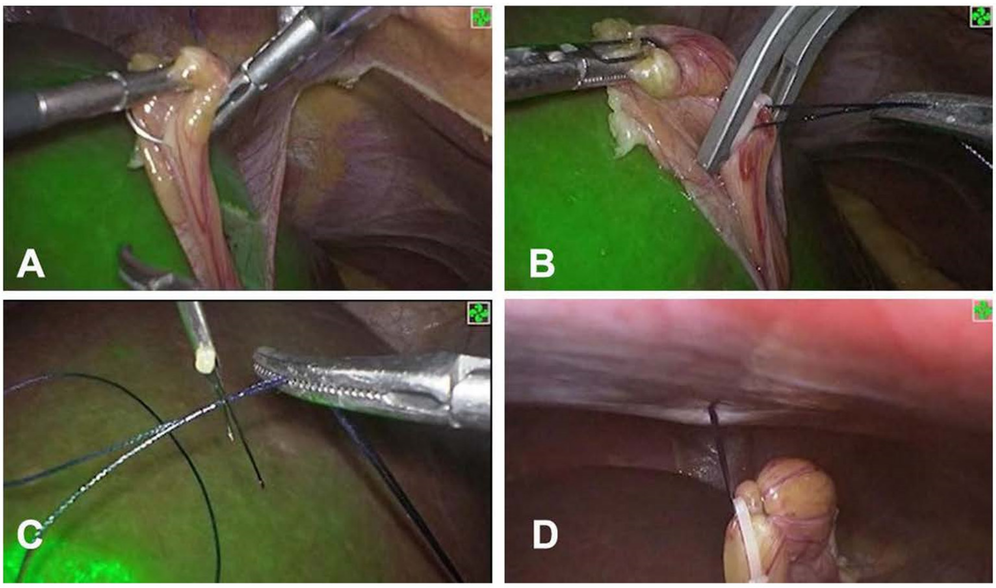

Figure 1. Stretching of the ligamentum teres hepatis. (A) A traction thread was sutured at the stump of the ligamentum teres hepatis. **(B)** Tissue clamps with fixed traction sutures. **(C)** A hook needle is used to guide the traction suture outside of the body. **(D)** External traction and fixation.

liver through suspension of the ligamentum teres hepatis so that the right side of the liver hangs in the abdominal cavity. Therefore, the assistant can more easily and stably assist the surgeon in exposing and transecting the right side of the liver. After liver dissection is complete, the right liver can be optionally rotated by pulling the ligamentum teres hepatis to select a more convenient surgical section. In addition, the sutured ligamentum teres hepatis is more solid than the sutured liver parenchyma, so the pulling strength is ideal and bleeding is rare.

Moreover, fixation of the ligamentum teres hepatis can better expose the hidden surface of the liver and facilitate observation of and surgery on deeper portions. As methods of detecting liver-related diseases improve, we will be able to detect smaller liver tumors earlier. Due to its lower risk and the ease with which it is performed, SLTH seems to be more suitable for small areas of liver resection.

The current study successfully used SLTH to increase the exposure of the liver in LLR. SLTH was feasible in all patients after screening. Compared to the NSLTH cohort, the SLTH cohort had a shorter duration of liver parenchymal detachment, a shorter hepatic portal occlusion time, and less intraoperative blood loss. Results indicated that the SLTH is a simple, safe, and effective surgical approach. This approach could increase the exposure of the right liver and reduce surgical difficulty, which may accelerate the early restoration of postoperative liver function.

This study had several limitations. First, identifying the ligamentum teres hepatis is difficult in patients who have undergone prior abdominal surgery. In these patients, the upper abdomen, and especially the liver, is strongly attached to the abdominal wall. Second, the liver has to be fixed multiple times in the event of multiple tumors. Third, the sample size was relatively small, and the follow-up was too short. Therefore, a larger sample size is needed and follow-up needs to be longer for further verification.

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