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Prevention and Treatment of Hemorrhage during Laparoscopic Splenectomy and Devascularization for Portal Hypertension

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Summary: This study was aimed to explore prevention and treatment of hemorrhage during laparoscopic splenectomy plus devascularization (LSD) for portal hypertension by modified and simplified operation. From June 2012 to June 2014, LSD was performed on 138 patients with portal hypertension. The patients were allocated into two groups: earlier stage (ES) group, in which 45 patients received traditional LSD from June 2012 to Sep. 2012; later stage (LS) group, in which 93 patients underwent modified LSD from Jan. 2013 to June 2014. Perioperative variables were compared between the two groups. Laparoscopic operations were successfully performed in all but two patients in ES group who were converted to laparotomy (total conversion rate: 1.4%). There was no perioperative death or reoperation, and all patients recovered and were discharged from hospital with no serious complications in the six months of postoperative follow-up. The average time in the ES group was longer than that in the LS group (335.1 min *vs*. 201.3 min, $P<0.05$). LS group outperformed ES group in terms of blood loss (705.4 mL *vs*. 910.4 mL, $P<0.05$). The average operation time to oral diet intake after surgery (40.5 h *vs*. 50.3 h, $P<0.05$) and postoperative hospital stay (7.4 d *vs*. 9.0 days, $P<0.05$) were much less in the LS group than in the ES group. The overall complication rate (4.3 % *vs*. 11.1 %, $P<0.05$) and conversion rate (0% *vs*. 4.4%, $P<0.05$) were lower in the LS group than in the ES group. It was concluded that prevention and treatment of hemorrhage are the key points of LSD for portal hypertension. By creating a tunnel above the splenic pedicle and a tunnel behind the lower esophagus, the simplified and modified LSD can reduce hemorrhage and improve success of surgery dramatically, and splenomegaly and severe varices are not contraindications.
Keywords: laparoscopy; splenectomy; devascularization; hemorrhage; portal hypertension

Portal hypertension is a common disease in China. Some patients of portal hypertension complicated with bleeding resulting from varicose veins in esophagus and proximal stomach and hypersplenism require surgical intervention. At present, shunt and devascularization surgeries are two basic surgical procedures except for liver transplant. Shunt procedures are more commonly used in Western countries, while devascularization procedures are more common in China. Splenectomy plus devascularization is the major operation for its effective control of bleeding with a little impairment of the liver and a low occurrence of encephalopathy[1, 2]. In recent years, as the progress of the laparoscopic techniques and accumulation of surgical skills, many scholars at home and abroad have made some explorations on patients with portal hypertension and splenomegaly. Some scholars completed the total laparoscopic operaion successfully[3–5]. In their research, laparoscopic splenectomy plus devascularization (LSD) is similar to or even better than the open operation in some cases in the overall efficacy, and has advantages of minimal incision, less postoperative pain, quicker recovery, shorter hospital stay, and fewer complications. For removal of normal to moderately enlarged spleens, laparoscopic splenectomy is the first choice[6–9], while it is much more difficult and risky for portal hypertension. Intraoperative hemorrhage is the major challenge and the major reason for conversion to laparotomy[10, 11]. How to prevent and control it is the key to success, however, few studies systematically discussed it. In this study, we explored measures to prevent and control the hemorrhage by modified and simplified operation procedures of LSD for portal hypertension.

1 MATERIALS AND METHODS

1.1 Demographic Data

All the 138 patients were diagnosed as having portal hypertension with secondary hypersplenism and bleeding due to esophageal gastric varices. They were classified into two groups: earlier stage (ES) group, including 45 cases in the earlier stage from June 2012 to Sep. 2012 receiving traditional LSD; later stage (LS) group, including 93 cases in the later stage from Jan. 2013 to June 2014 undergoing modified LSD. For liver cirrhosis in the ES group, 37 patients were classified as Child-Pugh A, 8 patients as Child-Pugh B, and no patients as Child-Pugh C. Of the 45 patients, 39 had liver damage caused by chronic hepatitis B, 5 had chronic hepatitis C-induced cirrhosis, and 1 had no history of hepatitis. While in LS group, there were 81 patients with Child-Pugh A cirrho-

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sis, 12 with Child-Pugh B cirrhosis, and no patient with Child-Pugh C cirrhosis. Of the 93 patients, 78 had liver damage caused by chronic hepatitis B, 10 had cirrhosis caused by chronic hepatitis C, and 5 had no history of hepatitis. All patients had splenomegaly and esophageal gastric varices, and their diameters of spleens ranged from 16 to 27 cm as shown in gastroscopy and three dimensional vascular imaging of computed tomography (CTV+CTA)[12] or magnetic resonance imaging (MRI) before surgery. The demographic data included in this study are listed in table 1.

Table 1 Characteristics of patients [(x±s), n]

Groups	Average age (years)	Gender (M/F)	Etiology (n)			Child-Pugh score (n)			Length of spleen (cm)
			HBV+ cirrhosis	HCV+ cirrhosis	Others	A	B	C	
ES (n=45)	44.7±5.1	31/14	40	4	1	35	10	0	19.1±1.7
LS (n=93)	44.5±5.4	63/30	81	10	2	70	23	0	18.9±1.8
P value	0.973	>0.05	>0.05			>0.05			0.891

HBV/HCV: hepatitis B/C virus; M/F: male/female

1.2 Operation Procedures

All the surgeries were performed by the same group of doctors. Patients were placed at the right lateral semireclining position and the operating table slightly tilted to the reverse Trendelenburg position. The intraabdominal pressure was maintained at 10–12 mmHg. The surgeon stood at the right side of operating table and 5 operative ports were used. A 10-mm trocar was placed at the right of umbilicus for a 10-mm 30-degree telescope camera; a 12-mm and a 5-mm main operative trocar were placed on the right midclavicular line above umbilicus and below the xiphoid, respectively; a 5-mm and a 12-mm accessory operative trocar were placed on the left midclavicular line and the left anterior axillary line below the lower pole of the spleen. Intraoperative posture and placement of trocars were adjusted according to the volume of the spleen.

Patients of ES group received traditional LSD. The gastrosplenic ligament was divided with the ultrasonic dissector, and splenic artery was dissected and ligated above pancreas. Spleen was mobilized starting at the lateral and posterior side by fully dividing the splenocolic, splenorenal and splenophrenic ligaments. Then the splenic pedicle was mutilated by a linear laparoscopic vascular stapler (Endo GIA, Covidien, USA). Finally, spleen could be resected after cutting off the remaining gastrosplenic ligaments and splenophrenic ligaments. After splenectomy, devascularization began by dissecting gastric fundus to identify the left crus of diaphragm and hepatogastric ligament was cut open to identify the right crus of diaphragm, and then the left gastric vessels were transected by Endo GIA. All branches toward 6–8 cm of the distal esophagus were dissected through the hiatus. Finally, the spleen was put into an impermeable retrieval bag and morcellated for removal by extending the incision on left midclavicular line to 2–4 cm, a drainage tube was placed in the left subphrenic space.

In LS group, modified LSD was performed. The gastrosplenic ligament (not including uppermost short gastric vessels) was divided with the ultrasonic dissector, and splenic artery was dissected and ligated above pancreas. Then spleen was mobilized starting at the lateral and posterior side by fully dividing the splenocolic, splenorenal and splenophrenic ligaments. After opening the anterior peritoneum between the upper pole of spleen and the splenic hilum, a tunnel could be created above the splenic pedicle. Then a linear laparoscopic vascular stapler (Endo GIA) crossed through the tunnel and mutilated the splenic pedicle by en bloc transecting the splenic arteries and veins. Finally spleen can be resected after cutting off the remaining splenogastric ligaments and splenophrenic ligaments. After splenectomy, devascularization was performed by dissecting gastric fundus to identify the left crus of diaphragm and expose the left and back side of esophagus. Then the hepatogastric ligament was cut open to identify the right crus of diaphragm and expose the right side of esophagus. A tunnel could be created behind the lower esophagus which enabled an Endo GIA to insert across it and transect the left gastric vessels en bloc. All branches toward 8–10 cm of the distal esophagus were dissected through the hiatus with the paraesophageal venous collaterals divided. Finally, the spleen was put into an impermeable retrieval bag and morcellated for removal by extending the incision on left midclavicular line to 2–4 cm, a drainage tube was placed in the left subphrenic space.

1.3 Statistical Analysis

The following perioperative variables of the patients were analyzed: operation time, estimated blood loss, the time to oral diet intake, postoperative complications (wound complications, abdominal hemorrhage, gastrointestinal bleeding, abdominal infection, pulmonary infection, pancreatic fistula, pleural effusion, lower extremity deep vein thrombosis, portal vein thrombosis, hepatic insufficiency, intestinal obstruction), postoperative hospital stay and conversion rate were compared. Data were compared using the t-test, Chi-square analysis, or Fisher's exact test, where applicable, and expressed as x±s. All statistical analyses were performed using the SPSS 19.0 for Windows. P<0.05 was considered statistically significant.

2 RESULTS

There were no differences in demographic data between the two groups to patients. The surgical results are shown in table 2. Success of laparoscopic surgery was achieved in all but 2 patients in the ES group (4.4%) who

required open laparotomy because intraoperative bleeding was hard to control by laparoscopic splenectomy. There was no conversion of laparoscopic to open surgery in the LS group. All the patients survived the surgery. The operation time was significantly longer in ES group than in LS group (335.1 min *vs*. 201.3 min, $P<0.05$). The estimated intraoperative blood loss was much more in ES group than in LS group (910.4 mL *vs*. 705.4 mL, $P<0.05$). The postoperative hospital stay of patients in LS group was shorter than that in ES group (7.4 days *vs*. 9.0 days, $P<0.05$). The time to oral diet intake in LS group was shorter than that in ES group (40.5 h *vs*. 50.3 h, $P<0.05$). The overall complication rate was much lower in LS group than in ES group (4.3% *vs*. 11.1%, $P<0.05$). In ES group, pancreatic fistula, abdominal hemorrhage, lower extremity deep vein thrombosis (DVT) and pneumonia were found in 1, 1, 2, and 1 patient(s), respectively. Conservative treatment was given to the patients with DVT and pneumonia, pancreatic fistula was drained under ultrasound guidance. The patients with abdominal hemorrhage were treated with blood transfusions. Of the patients in LS group, 2 patients developed asymptomatic portal vein thrombosis, 1 pleural effusion and 1 pneumonia. All patients recovered with no need for emergency surgical intervention. During a postoperative follow-up of 6 months, no serious complications such as recurrent variceal bleeding or liver failure occurred, and all the patients had an improved quality of life.

Table 2 Results and complications of patients [($x\pm s$), *n* (%)]

Groups	Operative time (min)	Estimated blood loss (mL)	Time to oral diet intake (h)	Postoperative hospital stay (days)	Overall complication rate, *n* (%)	Conversion rate, *n* (%)
ES (*n*=45)	335.1±40.3	910.4±83.5	50.3±7.2	9.0±0.8	5 (11.1)	2 (4.4)
LS (*n*=93)	201.3±35.1	705.4±75.3	40.5±8.3	7.4±0.7	4 (4.3)	0 (0)
P value	0.017	0.019	0.042	0.033	<0.05	<0.05

3 DISCUSSION

The laparoscopic splenectomy has become the first choice for resection of normal to moderately enlarged spleens. However, it is really more challenging for portal hypertension. The difficulties lie in exposure of operating field and control of bleeding. The most common reason for conversion to laparotomy is intraoperative bleeding, which would contaminate the operating field and make the laparoscopic surgery more difficult. Therefore, the crucial point is to prevent the hemorrhage, which is more important than to control it.

To solve the difficulties of the procedure and hemorrhage during the operation, we simplified and modified the operation of LSD in this study. Firstly, we created a tunnel above the splenic pedicle to ensure the safety of processing for massive splenomegaly. The key points lie in fully dissociation of the lateral and posterior of spleen and correctly opening of the anterior peritoneum between the short gastric vessels and the splenic pedicle; once finishing these two steps, a tunnel in the avascular area can be created above the splenic pedicle and the spleen can be then suspended with a silk thread or a catheter. The suspension and traction of spleen facilitate Endo GIA to cross through the tunnel easily and mutilate the splenic pedicle safely and completely by one cutting. Comparing to the traditional procedure of mutilation by Endo GIA without creating the tunnel in ES or the method of dissecting splenic vessels branch by branch, this modification enables the processing of the splenic pedicle much more safe and easy. In this study, all cases in LS group adopted this approach, and the tunnel could be created successfully even in the case of massive splenomegaly. Secondly, we created a tunnel behind the lower esophagus to ensure the safety of processing for varicose left gastric vessels. Devascularization was performed by dissecting gastric fundus to identify the left crus of diaphragm and expose the left and back side of esophagus. Then the hepatogastric ligament was cut open to identify the right crus of diaphragm and expose the right side of esophagus. A tunnel could be created behind the lower esophagus which enables an Endo GIA to insert through it and transect the left gastric vessels en bloc. Comparing to mutilation directly by Endo GIA without creating the tunnel in ES or the troublesome dissection of left gastric vessels branch by branch, this modification ensures the processing simpler and safer. In our study, we found that there always exists instinct anatomical space between crus of diaphragm and lower esophagus, no matter how severe the varices are, and the tunnel can be created successfully even in the case of severe varicosity and obesity. By our modified and simplified procedure, we reduced the risk of hemorrhage dramatically, and no conversion to laparotomy caused by the bleeding of the splenic pedicle or the left gastric vessels happened in our center.

In this study, success of LSD was achieved in all but 2 patients (total conversion rate 1.4%), lower than that in the literatures[3, 4, 10]. The 2 patients were both in the ES group. Compared to ES group, the results of LS group such as the operating time, the estimated intraoperative blood loss, the time to oral diet intake, the postoperative hospital stay and the overall complication rate were all much better. This is attributed much to the modification and simplification of the operation procedures. After accumulating enough experiences and establishing a standard procedure, LSD was conducted as a routine operation for the most patients with portal hypertension of LS in our center.

The indications for LSD are similar to those for open surgery. The absolute contraindications are cardiac, pulmonary or renal insufficiency and intractable coagulopathy which disable patients to tolerate general anesthesia, while older age, severe cirrhosis, past history of upper abdominal surgery, perisplenitis or splenic infarction are relative contraindications. The clinical

practice guidelines of the European Association for Endoscopic Surgery (EAES) suggest massive splenomegaly is a contraindication and a hand-assistant system is recommended[13]. In this study, the operation time prolonged and the estimated blood loss increased with enlargement of spleen and aggravation of varicosity in the early stage. With the modification and simplification of the operation procedures and the accumulation of experiences, the operative time was shortened and the estimated blood loss decreased gradually, no conversion needed in the later stage. Therefore, we suggest that splenomegaly and severe varicosity are not contraindications for LSD.

A detailed preoperative evaluation helps to reduce hemorrhage and complications caused by blind separation or poor physical status. Three dimensional vascular imaging of computed tomography (CTV+CTA) or MRV enables us to comprehensively understand the distribution of splenic vessels and varicose veins[12]. It is of significant value in assessing the risky and difficult points of operation and making strategies accordingly. Liver function should be assessed, and Child-Pugh A or B is preferable. Coagulation dysfunction should be improved. If platelet count is less than 20×10^9/L, one or two doses of the concentrated PLT suspension would be needed before operation[14]. In the case of serious bleeding or oozing during operation, it is more effective to transfuse concentrated PLT suspension and blood coagulation factors after ligation of splenic artery than preoperative transfusion.

The operative posture and the place of trocars are the crucial influential factors of exposure in laparoscopic operation. There are three postures commonly used in LSD: right lateral position, right oblique position and lithotomy position[15, 16]. Right lateral position is superior to right oblique position in dissociation of splenic ligaments, but inferior in processing the splenic pedicle and devascularization. For right oblique position, spleen can be exposed in various directions by the aid of gravity of spleen and the assistance of instruments, space of operation can be expanded remarkably. In our research, a satisfactory exposure of working space can be obtained in all cases by this approach, even in the case of massive splenomegaly. The sites, quantity and diameter of trocars should be selected based on the posture and the size of spleen, different instruments and operator's personal habits. Trocars are commonly inserted around umbilicus, below xiphoid and in the left and right upper abdomen, in 3 to 5 sites. Generally the trocars layout should abide by the basic principles. The sites should be located around the spleen hilum and distributed in fan-shape, 60° is the optimal angle for two interacting instruments. Puncture alone the line of observation port and operating field should be avoided. It should be ensured that there is sufficient distance between two sites to avoid mutual interference. For the patients with portal hypertension, trocars should be punctured cautiously to avoid injuring varicose abdominal vessels or enlarged spleen, especially the tortuous and expansive vessels in the ligamenta teres hepatis and umbilicus. The first observation port should be located on the right of umbilicus instead of above or below umbilicus. In the case of splenomegaly or severe varicosity in abdominal wall, open method to establish pneumoperitoneum is preferable, and the rest trocars should be punctured under direct vision.

Ligation of splenic artery enables the autotransfusion of spleen blood and reduces the blood supply of spleen and intraoperative bleeding. At the same time, the shrinkage of spleen increase working space and facilitate the operation. It is a very beneficial maneuver, especially for splenomegaly[17, 18]. In general, splenic artery is dissected superior to the pancreatic tail and ligated after great pancreatic artery to avoid ischemic injury of pancreas. It should be dissected cautiously to avoid damage to high-pressure and dilated splenic vein. The color change of spleen after ligation should be paid attention to, if change in color is not obvious or just partial, some branches of splenic artery are omitted and need to be located and ligated carefully. For most patients with portal hypertension, the dissection of splenic artery is often troublesome because of limited space and extensive collaterals. Hemorrhage can be caused by the injury to the dilated nourishing blood vessels in the splenic artery sheath, pancreatic branches of splenic artery, or the main splenic artery, which would hinder the subsequent procedures. Therefore, it is advisable to give up dissection in case of difficulty. Once bleeding, rapidly pressing hemostasis with gauze pads should be taken, and then the origin of bleeding can be found out and the bleeding will be stopped correspondingly. Bipolar electrocoagulation is effective to control the bleeding caused by injury of nourishing blood vessels on the splenic artery sheath or pancreatic branches of splenic artery. For the bleeding of the main splenic artery, it is recommendable to clamp the proximal and distal part of bleeder with absorbable clips respectively. In the case of massive hemorrhage hard to handle, conversion to laparotomy under oppression hemostasis is lifesaving and should be carried out in time.

In the case of splenomegaly with portal hypertension, the dilated spleen vessels with high pressure rupture easily and may result in unmanageable massive hemorrhage, the manipulation of the splenic pedicle is always the most risky part[19]. Different clinical centers have different approaches. According to the distribution of the terminal branches of splenic artery, the splenic pedicle can be divided into two types: the centralized type and the distributed type. The maneuver using Endo GIA to staple and mutilate the splenic pedicle directly is called the primary pedicle dissection, while the secondary pedicle dissection refers to separation and ligation of second branches of the splenic pedicle individually[20]. Currently there are 3 ways to manipulate the splenic pedicle in total laparoscopic surgeries: (1) Ligating the second branches of the splenic pedicle with clips or threads of silk: A study reported by Tan *et al*[21, 22] has introduced a method applying double ligation of proximal splenic vessel with a thread of silk and occlusion of distal part with a titanium clip, and they proved that it is feasible, effective and cheap; (2) manipulating the splenic pedicle with Endo GIA: it is simple, safe and effective, which make it the favorite method chosen by most doctors at home and abroad, though more expensive[20]; (3) processing the splenic pedicle with LigaSure vessel-sealing equipment: it has been developed for the safe closure of arteries up to 7 mm in diameter[23]. But the data for venous closure are rare, some study stated that it can be used to close veins up to 12 mm in diame-

ter[24] and can treat grades 3 and 4 of hemorrhoids[25]. For its prominent advantages of safe and reliable hemostatic properties and low thermal conductivity, it is widely used on patients with cirrhosis. Yao *et al*[26] demonstrated the safety and effectiveness of its application in devascularization on patients with portal hypertension in their randomized clinical trials, but some scholars[27] hold conservative and cautious attitudes, we also had no experience of processing the splenic pedicle with LigaSure in this study. More large-scale clinical researches are needed to study its safety in the processing of splenic vessels. In general, it is appropriate to adopt the technique of the secondary pedicle dissection for the distributed type; while for the centralized type, Endo GIA is more simple and effective. Surgeons should choose a safe and effective approach to achieve the optimal individual therapy according to the specific situation.

In this study, all the splenic pedicles are manipulated with Endo GIA successfully. It is crucial to completely mobilize the spleen and accurately estimate the length of the splenic pedicle. A complete mutilation with one cutting is optimal, another one or two nails would be needed if the mutilation is incomplete. When encountering resistance, Endo GIA should not be inserted forcibly. After the excision of spleen, the end of the splenic pedicle should be examined carefully, active bleeding can be controlled by Titanium clamps or absorbable clamps, oozing bleeding can be stopped by fibrin glue or bipolar electrocoagulation. When the spleen is tremendous and there are dilated vessels in the wide splenic pedicle, mutilation of the splenic pedicle with Endo GIA is unsafe and incomplete, which would probably cause the bleeding of the splenic pedicle or the upper branches of splenic artery.

The uppermost splenogastric ligament where stomach adjoins closely to spleen always contains varicose vessels with high pressure. It is the common bleeding second only to the splenic pedicle. The bleeding would interfere with the following procedure greatly and is hard to control for lack of space. In our study, it was dissected after manipulating of the splenic pedicle in all cases. It is recommendable to manipulate it with Endo GIA for the patients with severe varicose veins, it is simpler and safer.

In some cases, perisplenic adhesion caused by repeated perisplenitis or infarction of spleen would increase the difficulty and risk of the operation. Under these circumstances, the separation should be performed from the shallow to the deep, from easy to difficult. When the splenic pedicle is hard to expose as a result of adhesion or swollen lymph nodes, splenic ligaments could be separated first. Overemphasis on the second branches mutilation is inadvisable, and manipulation with Endo GIA is more simple and safe. On the contrary, if there is large amount of compact vascular adhesion around spleen, the separation of splenic ligaments is difficult, while the exposure of splenic hilum is relatively easy, retrograde splenectomy is recommendable. It is beneficial to process the splenic pedicle before splenic ligaments, which could not only improve the exposure of operative field, but also reduce intraoperative hemorrhage significantly. In case of rupture and hemorrhage on splenic capsular, hasty and blind clamp would aggravate rupture and bleeding, oppression with hemostatic gauze, gelatin sponge or spraying with biological fibrin glue is helpful. LigaSure or bipolar electrocautery is also useful haemostic instrument.

Tacit understanding cooperation is an essential guarantee of success; therefore, a stable surgical team is also very important to the laparoscopic surgery. In the later stage we established reasonable surgical procedures focused on the links of bleeding, and the surgical results turned out much better.

In conclusion, laparoscopic splenectomy plus devascularization for portal hypertension is a difficult and challenging operation with high risk. Intraoperative hemorrhage is the main risk, even in laparotomy. The difficult management of bleeding has always been the major reason for conversion to laparotomy. Therefore, how to prevent intraoperative hemorrhage is far more important than how to manage it. By creating a tunnel above the splenic pedicle and a tunnel behind the lower esophagus, the simplified and modified LSD can reduce hemorrhage and improve the predictability and controllability of the operation, and then can increase the success of laparoscopic operation. Splenomegaly and severe varices are no longer contraindications. For portal hypertension, LSD is a preferable option and should primarily be performed in all patients, if contraindications are ruled out.

Conflict of Interest Statement

The authors declare that there is no conflict of interest with any financial organization or corporation or individual that can inappropriately influence this work.

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