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Laparoscopic partial splenectomy with temporary occlusion of the trunk of the splenic artery in fifty-one cases: experience at a single center

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Abstract
Background Laparoscopic partial splenectomy (LPS) for splenic benign space-occupying lesions has been reported by many researchers; however, few studies have described methods to control intraoperative bleeding. Trustworthy experience in LPS with a satisfactory intraoperative hemorrhage control technique is therefore necessary. The current study aims to present our experience in LPS with temporary occlusion of the trunk of the splenic artery for controlling intraoperative bleeding with a large sample of 51 cases and to evaluate the safety, feasibility, and reproducibility of this technique.
Methods Fifty-one patients from August 2014 to April 2019 who underwent LPS in our institution were retrospectively analyzed. Surgical techniques were described in detail.
Results All patients had successfully undergone LPS with temporary occlusion of the trunk of the splenic artery. Conversions to open surgery, hand-assisted laparoscopic splenectomies, or blood transfusions were not needed. The operative time was 94.75 ± 18.91 min, the estimated blood loss was 71.13 ± 53.87 ml, and the volume of resected spleen was 34.75 ± 12.19%. The range of postoperative stays was 4–14 days. One female patient (2%, 1/51) suffered from postoperative complications. No perioperative mortality, incision infections, postoperative pancreatic fistulas (POPFs), splenic infarctions, or portal/splenic vein thromboembolic events occurred.
Conclusion LPS is an effective spleen-preserving surgery. Although there are many other bleeding control methods, temporarily occluding the trunk of the splenic artery was found to be a safe, feasible, and reproducible technique in LPS. The outcomes of this technique and the efficacy of splenic parenchyma preservation are acceptable.

Keywords Laparoscopic · Partial splenectomy · Space-occupying lesion · Splenic artery

Half a century ago, the spleen was considered an unnecessary and unessential organ, and total splenectomy was the routine surgery for spleen trauma or splenomegaly [1]. However, severe complications after total splenectomy, such as overwhelming postsplenectomy infections (OPSIs), portal/splenic vein thromboembolic events, pulmonary arterial hypertension, and immune responses to malignant tumors, gradually became major concerns among surgical communities [1–4]. According to the literature, patients suffer from asplenia and hyposplenic states after total splenectomy, which might damage the immune system and anti-infection functions of the human body over the life of the patient [2, 3, 5]. Basic science studies have demonstrated that T cells and B cells might contribute to preserving a spleen-dependent immune response following partial splenectomy [6, 7]. Some researchers have found that the volume/weight of the remnant spleen should not be less than 25% and should have adequate arterial perfusion to maintain its efficient functioning [8, 9]. Partial splenectomy has been more widely adapted in an effort to preserve splenic immune function.

Laparoscopic partial splenectomy (LPS) as an alternative to open surgery was first reported by Uranus in his

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pioneering work experimenting on animals in 1995 [10]; it was soon successfully applied to humans as a safe and effective surgery by Poulin [11]. However, due to the complicated blood supply of the spleen and challenging laparoscopic skills required in LPS, intraoperative hemorrhage became an obstacle to the comprehensive application of LPS. Therefore, methods to control intraoperative bleeding in LPS is a hot topic.

We perform a retrospective review of a cohort of 51 patients who underwent LPS from August 2014 to April 2019 at our institution. Median follow-up was 28 months (range 3–56 months). In the current study, we aim to share our experience with this procedure and to explore the safety, feasibility, and reproducibility of this intraoperative bleeding control technique.

Materials and methods

Patients

Fifty-one patients from August 2014 to April 2019 met the criteria for this study. All patients were postoperatively followed up after a median of 28 (range 3–56) months. No patients were lost to follow-up and there was no radiographic evidence of recurrence over the follow-up period. Every patient was routinely administered prophylactic antibiotics preoperatively 15 min before the start of LPS. Patient demographics, spleen size, lesion size, operative time, estimated blood loss, volume of the resected spleen, postoperative hospital stay, 1, 3, and 12 months postoperative CT scan, among others, were collected from inpatient or outpatient medical records. This study was approved by the Review Board of West China Hospital, Sichuan University. Written informed consent was obtained from all patients before the operation.

Indications

(1) Patients were diagnosed with benign space-occupying splenic lesions on ultrasonography or contrast-enhanced computed tomography after presenting with either abdominal pain or distention. The lesions were peripherally located in either the superior or inferior pole, and spleens were noted to be no larger than 20 cm; (2) preoperative serological tumor biomarkers such as alpha-fetoprotein (AFP), carcinoembryonic antigen (CEA), and carbohydrate antigen 19–9 (CA19-9) were normal; (3) no systemic coagulopathy; (4) no inflammation of the abdominal wall; (5) preoperative white blood cell count, hemoglobin, platelet count, preoperative prothrombin time (PT), and active partial prothrombin time (APTT) were in the normal range.

Contraindications

(1) Patients with malignant tumors at other sites, leading to high suspicion of metastasis in the spleen; (2) patients with systemic coagulopathy or abdominal wall infection; (3) massive splenomegaly > 25 cm and hypersplenism secondary to liver cirrhosis; (4) splenomegaly subsequent to hematologic and myeloid diseases.

Surgical techniques

Surgical technique was consistent across all patients. The patient was placed under general anesthesia and placed on a right semilateral decubitus position with the left side of the patient's body elevated 20 to 30 degrees. The operating table was tilted in a reverse Trendelenburg position. Pneumoperitoneum was established and maintained at a pressure level of 12–14 mmHg (1 mmHg = 0.133 kPa). Four ports were placed according to our previous description [12, 13]. Briefly, a 10 mm umbilical port was for the laparoscope and two 5 mm ports and one 12 mm port were the working ports. The peritoneal cavity was carefully inspected to exclude the presence of malignant tumors. An anterior approach with four-modular steps was adopted: (1) mobilization: the left side of the greater omentum up to the short gastric vessels was opened along the greater curvature by an ultrasonic scalpel, the lesser sac was entered and the portion of perisplenic attachments to be resected was mobilized near the spleen; (2) occlusion of the splenic artery and vascular dissection: the splenic hilum was exposed, and if an accessory spleen was found in the splenic hilum area, it was removed; the posterior peritoneum at the superior border of the pancreas in the lesser sac was opened, the trunk of the spleen artery was meticulously dissected and was temporary occluded by a laparoscopic bulldog clip for controlling the blood supply to the spleen (Fig. 1). The segmental branches of the

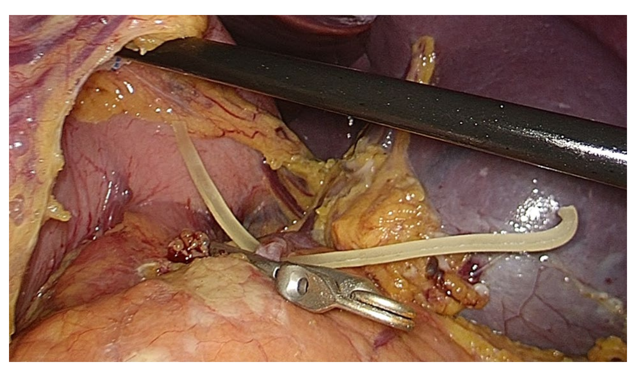

Fig. 1 Intraoperative figure demonstrates a laparoscopic bulldog clip is used to occlude the trunk of the splenic artery at the superior border of the pancreas

splenic artery and vein supporting the part of spleen to be resected were carefully mobilized with the lobar branches preserved. Each segmental branch was clipped with three hem-o-lok clips or ligated three times near the splenic hilum and then severed between the distal two clips or ligations. In this process, caution must be taken to keep the capsula pancreatis and pancreatic tail intact to avoid a postoperative pancreatic fistula (POPF). After devascularization of the part of the spleen to be resected, the bulldog clip was intermittently released, and a well-defined cyanotic demarcation line was clearly visualized on the splenic surface and was marked by electrocautery; (3) splenic parenchyma transection: the trunk of the splenic artery continued to be occluded, the tumor margin was determined to be ≥ 1 cm to the demarcation line by laparoscopic ultrasonography, and the splenic parenchyma, including the lesion at least 1 cm distal away from the ischemic line, was transected with an ultrasonic scalpel. The bulldog clip was released, the splenic cut edge was observed and adequate blood supply to the remnant spleen was ascertained. Oozing of the cut edge was controlled by bipolar electrocautery. Collagen fleece (Ethicon Inc., U.S.A) was used to seal the cut edge; (4) specimen retrieval: the specimen was introduced into a sterilized waterproof retrieval bag and was fragmented with forceps, the resulting blood was suctioned, and the bag was removed via the 12 mm port. A drain was placed near the splenic remnant in case of suspected injury to the pancreas. Then, pneumoperitoneum was evacuated, and the ports were sutured.

Table 1 Demographics and preoperative data

Variable	Mean ± SD, or median (interquartile range), or number (percentage)
Age, year	39 (13 ~ 66)
Gender	
Male	15 (29.4%)
Female	36 (70.6%)
Complaint	
Pain	20(39.2%)
Distention	31(60.8%)
Lesion location	
Upper pole	33 (64.7%)
Lower pole	18 (35.3%)
Splenic size, cm	13.57 ± 2.58
Range	10–25[a]
Lesion size, cm	5.54 ± 2.13
Range	2–11
Previous abdominal surgery	
Yes	2 (3.9%)
No	49 (96.1%)

[a]In this case series, an ingrown lesion at the upper middle pole was found in one male patient. The maximum longitudinal diameter of the lesion was measured up to 11 cm; however, approximately 3 cm normal spleen tissue was remained at the upper pole, which was difficultly to acquire a precise measurement of the maximum longitudinal diameter of the spleen size. We measured the maximum longitudinal diameter of his spleen size included the lesion up to nearly 25 cm; however, his remnant spleen was almost normal sized, so he was also included in this study

Results

Demographics and preoperative data

As shown in Table 1, 15 male (29.4%) and 36 female (70.6%) patients underwent LPS with the splenic artery occluding technique during the study period, with a median age of 39 (range 13–66) years. Of the 51 patients with a fast-growing mass, 20 (39.2%) patients had pain and 31 (60.8%) patients had distention at the upper left quadrant, 33 patients (64.7%) had lesions at the upper pole, and 18 patients (35.3%) had lesions at the lower pole. The maximum longitudinal diameter of the spleen was 13.57 ± 2.58 cm, and the maximum lesion size was 5.54 ± 2.13 cm. Two patients had had previous abdominal surgery.

Intraoperative data and postoperative outcomes

As shown in Table 2, two cases (3.9%) had undergone concomitant laparoscopic cholecystectomy (LC) for chronic cholecystitis. The Operative time was 94.75 ± 18.91 min, the estimated blood loss was 71.13 ± 53.87 ml, and the volume of resected spleen was 34.75 ± 12.19%。No conversion to open surgery or hand-assisted splenectomy occurred. Blood transfusions were not needed. The length of postoperative stay was 6.98 ± 2.26 days. Pathologic outcomes were nonparasitic cyst ($n = 20$, 39.2%), lymphangioma ($n = 14$, 27.5%), angioma/hemangioma ($n = 11$, 21.6%), littoral cell angioma ($n = 4$, 7.8%), chronic granulomatous ($n = 1$, 2%), and sclerosing angiomatoid nodular transformation ($n = 1$, 2%). With the exception of one female patient (2%, 1/51) suffering from splenic wound bleeding and pleural effusion, all patients recovered uneventfully. The diagnosis of wound bleeding was based on the observation of approximately 200 ml of bloody fluid from the drain tube on postoperative day 3; however, the patient was not symptomatic, her blood pressure remained stable and her hemoglobin was greater than 110 g/L. Abdominal ultrasound found no fluid collection in the peritoneal cavity, and the drain slowly became clear within two days of conservative treatment. In the meantime, her pleural effusion needed an ultrasound-guided percutaneous aspiration to relieve her dyspnea. There was no incidence of Perioperative perioperative

Table 2 Intraoperative and postoperative data

Variable	Mean ± SD, or median (interquartile range), or number (percentage)
Operation	
LPS	49 (96.1%)
LPS + LC	2 (3.9%)
Operative time, min	94.75 ± 18.91
Range	50–140
Estimated blood loss, ml	71.13 ± 53.87
Range	10–200
Volume of resected spleen, %	34.75 ± 12.19
Range	20–60
Postoperative stay, days	6.98 ± 2.26
Range	4–14
Pathology	
Lymphangioma	14 (27.5%)
Nonparasitic cyst	20 (39.2%)
Angioma/hemangioma	11 (21.6%)
Littoral cell angioma	4 (7.8%)
Chronic granulomatous	1 (2%)
SANT	1 (2%)
Complications	
Pleural effusion	1 (2%)
Post-operation bleeding	1 (2%)
POPF	0
Splenic infarction	0
Incision infection	0
Port/splenic thromboembolic events	0

SANT sclerosing angiomatoid nodular transformation, *POPF* postoperative pancreatic fistula, *LPS* laparoscopic partial splenectomy, *LC* laparoscopic cholecystectomy

mortality, surgical site infections, POPF, splenic infarctions, or portal/splenic vein thrombosis.

Follow-up data

All patients were followed up at the outpatient department 1, 3, and 12 months postoperatively by an upper abdominal CT scan according to our follow-up plan. All patients endorsed resolution of their presenting symptoms, and no disease recurrence was noted radiographically. In addition, no splenic artery pseudoaneurysm, strictures, or atresia were observed. Regeneration of the remnant spleen was seldom observed in this case series through the 12-month follow-up CT scan. After 12 months, patients were followed up through telephone interviews.

Discussion

Recognition of the pivotal role of the spleen has led surgeons to perform spleen-preserving surgery whenever possible. For some time, open partial splenectomy was a choice for splenic function preservation; however, it was associated with severe postoperative pain and cosmetic disadvantages. Splenic cyst fenestration was capable of conserving remnant splenic parenchyma as much as possible, but the recurrence rate was very high [14]. Based on these considerations, LPS, which has been applied in many high-volume minimal invasive centers for more than two decades, has been verified by many researchers as a safe, feasible, and reproducible surgery for spleen preservation in experienced hands [12, 13, 15–20]. Intraoperative hemorrhage, however, hindered its comprehensive application and was a cause of conversion.

In 2015, Han et al.performed temporary occlusion of the splenic artery on six patients to reduce bleeding of the wound in LPS; however, the device used to perform the occlusion was not present in their study [18]. Borie introduced a surgical technique in LPS that, similar to ours, needed to isolate the splenic artery along the upper border of the pancreas. However, unlike ours, he controlled the splenic artery by a vessel loop encircling the artery, which could be clipped when needed to afford temporary arterial occlusion [21]. Patrzyk and his colleagues used a detachable endoscopic vessel clip to temporarily clamp the main splenic artery and vein in three patients during LPS, and they concluded that the detachable endoscopic vessel clip could allow ideal control of bleeding [22]. Preoperative embolization [11, 22, 23] and intraoperative radiofrequency ablation [24, 25] were adopted by some researchers to control hemorrhage in LPS; however, the abdominal pain postembolization or the thick rim of necrotic tissue after ablation made these techniques less applicable. Hand-assisted laparoscopic partial splenectomy (HALPS) was reported by Okano as a safe and bloodless surgery for selected patients [26]. Balaphas et al. compared the safety, and feasibility of robotic-assisted partial splenectomy with LPS and found that robotic procedure may be an interesting technical option for reducing intraoperative hemorrhage [19]. However, the disadvantages of these techniques, such as extra incisions for HALPS or expensive costs for robotic procedure, have impeded popularization of these techniques. Although results of the aforementioned studies were favorable, their sample sizes were small and further studies are warranted.

According to Liu's research, each segmental artery supplies blood to the corresponding segment in a wedge shape, intersegmental planes are relatively avascular, and 95% of the trunk of the splenic artery is suprapancreatic

[27]. This anatomic knowledge of the splenic vasculature combined with our experience in vascular reconstruction in laparoscopic pancreaticoduodenectomy [28] made us try to apply a laparoscopic bulldog clip to occlude the trunk of the splenic artery at the superior border of the pancreas before the segmental branches were served. Bulldog clips are commonly used in laparoscopic surgeries to temporarily control the vasculature or the bile duct, and they can be placed or removed conveniently. This technique was able to provide a clear operative field, which facilitated the modular steps and reduced possibilities of damage to the splenic artery and the pancreas. In the present study, we successfully used a bulldog clip to occlude the trunk of the splenic artery prior to dissecting the segmental arteries and transecting the splenic parenchyma in 51 patients with LPS and found that this technique was simple and easy to master.

Teperman found that three hours of warm splenic ischemia would result in splenic necrosis in dogs and defined the safely occlusive time of the trunk of the splenic artery for humans as one hour, which allows sufficient time for most splenic surgical procedures [29]. We often completed dissecting the segmental branches and transecting the splenic parenchyma to be resected in no more than one hour, which was within the safe warm ischemic time proposed by Teperman. Although temporary occluding the trunk of the splenic artery in our study did not induce splenic infarction, concerns about whether occluding the artery might cause damage to the vasculature still existed. We followed up patients up to 12 months postoperatively by upper abdominal CT scan but found no pseudoaneurysms, strictures, atresia, or evidence of distal embolic events.. Based on these observational results, we prudently suggest that occluding the trunk of the splenic artery for up to one hour is safe.

Remnant splenic volume is related to the immune system and was determined by the volume of the resected spleen; however, consensus on how to measure the volume of the resected spleen had never been reached. Based on the suggestion proposed by the clinical practice guidelines of the European Association for Endoscopic Surgery (EAES), the volume of the resected spleen was estimated by the ratio of the total volume subtracted by the reserved volume to the total volume in the current study. The total volume was represented by the maximum longitudinal diameter, which was measured through preoperative CT scan imaging, and the reserved volume was shown by the maximum longitudinal diameter, which was measured intraoperatively using a sterile ruler [30]. In the present study, the remnant splenic volume was estimated to be 40% to 80%; in other words, the resected volume of the splenic parenchyma was 20% to 60%. On the basis of the volume/weight of the remnant spleen, which must not be less than 25% [8, 9], our remnant splenic volume was sufficient for maintaining immune and anti-infection functions.

Liu reviewed 44 studies from 1995 to 2018, which include 252 patients who had undergone LPS, and demonstrated that the ranges of operative time and estimated blood loss were 50–225 min and 0–1200 ml, respectively [16]. According to Liu's description, 3.5% (8/231) of patients needed blood transfusions, the conversion rate was 3.6% (9/252: 3 patients converted to open partial surgery, 1 patient converted to open total splenectomy, and 5 patients converted to laparoscopic total splenectomy). Postoperative complications were observed in 10.7% (27/252) with fluid collection as the most common postoperative complication, overall mortality was 0% (0/252), and the length of postoperative stay varied from 1 to 11 days [16]. In the current study, 51 patients had successfully undergone LPS with temporary occlusion of the trunk of the splenic artery. The range of operative time was 50–140 min, and the estimated blood loss was 10–200 ml, which were superior to those of most other studies. Therefore, dissecting and occluding the trunk of the splenic artery did not extend the operative time. Owing to the decreased splenic parenchyma bleeding, we spent less time in hemostasis, and accordingly, the operative time was reduced. Moreover, our results showed that conversion to other surgery or blood transfusions was not needed. The length of postoperative stay ranged from 4 to 14 days, and only one female patient (2%, 1/51) suffered from postoperative complications. Meanwhile, no perioperative mortality, incision infections, POPFs, splenic infarctions, or portal/splenic vein thromboembolic events occurred. Compared with Liu's results, our outcomes were acceptable.

Two patients suffered from recurrence of previous laparoscopic fenestration or laparoscopic partial incision surgery for spleen nonparasitic cysts in other institutions and had successfully undergone LPS in the current study. The operative times for these patients were 140 min and 125 min, respectively. However, by using our artery occluding technique, the estimated blood loss was 100 ml and 50 ml, respectively. Therefore, a previous laparoscopic splenic surgery was not a contraindication in our institution.

There were some limitations in the present study. First, this was a retrospective study. Second, the postoperative stay of 4 to 14 days was slightly longer for minimally invasive surgery, which was partly due to the Chinese Medical Insurance System. Patients were discharged after their incision had healed sufficiently. Third, this experience was from a single-center, and although our follow-up period was as long as 56 months, it was not long enough; whether OPSI after LPS will take place is unkown.

Conclusion

In summary, LPS is an effective spleen-preserving surgery. Although there are many other effective bleeding control methods, temporary occluding the trunk of the splenic artery in LPS was found to be a safe, feasible, and reproducible technique. The outcomes of this technique and the efficacy of splenic parenchyma preservation are acceptable. However, splenic benign lesions are rare entities, multicenter randomized collaborative studies and well-designed follow-ups are required to confirm these findings.

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Author contributions GO designed and wrote the study; YL and GO collected the data. YC, XW and HC analyzed the data. BP made the final approval of the version to be published.

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Compliance with ethical standards

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