6 Single Incision Laparoscopic Splenectomy (SILS)

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6.1 Background

Laparoscopic splenectomy is widely applied in clinical practice currently [1]. However, the operative technique and key points of single incision laparoscopic splenectomy (SILS) are different from those of laparoscopic splenectomy. Meanwhile, the spleen has abundant vascularity and brittle texture and is vulnerable to hemorrhage, which leads to difficulties in operation [2]. In 2009, Barbaros [3] firstly reported successful SILS in two patients with immune thrombocytopenic purpura (ITP). Since then, some scholars have reported cases of successful use of SILS for splenic diseases successively [4, 5]. In 2011, Second Department of General Surgery, Shengjing Hospital, Affiliated to China Medical University completed the first case of SILS for traumatic splenic rupture in the world [6]; in 2020, it performed transumbilical SILS combined with esophagogastric fundus pericardial vasectomy for cirrhotic portal hypertension and reported this operation on international journal firstly [7]. In 2013, Fan Ying et al. conducted a systematic meta-analysis and drew a conclusion that SILS has much more viability and safety compared with multi-incision laparoscopic splenectomy, with a better cosmetic result [8]. With the development of laparoscope and its technology, there is an increase in articles reporting SILS.

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6.2 Indications and Contraindications

SILS was first used for the treatment of diseases of the blood system, especially for the treatment of ITP [9]. With the improvement of surgical skills and the usage of high-definition laparoscope, ultrasonic scalpel, and Endo-GIA stapler, the indications of SILS have been widened gradually. Currently, the indications of SILS are considered as follows.

6.2.1 Indications of SILS

1. Traumatic splenic rupture
2. Splenic benign tumors such as hemangiomas and hamartomas
3. Splenic cyst
4. Hematological system diseases, e.g., hereditary spherocytosis, refractory immune thrombocytopenic purpura, and autoimmune hemolytic anemia (AIHA)
5. Cirrhotic portal hypertension, with normal-sized spleen

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6.2.2 Relative Contradictions of SILS

1. Pathological spleen led by portal hypertension. The Medical Center of Loyola University Chicago has listed portal hypertension with pathological spleen as a contradiction of SILS [10]. Some scholars believe that it is safe and effective to perform LS for portal hypertension with pathological spleen [11].
2. Splenomegaly. Some scholars consider that it is a contradiction for LS if the spleen with an interpole length of 25 cm or one that crosses the midline or enters the pelvis [12].
3. Severe perisplenitis, vascular or anatomical disorder

6.2.3 Absolute Contradictions of SILS

1. Aged patients, with other underlying diseases, intolerant to surgery
2. Severe impairment of blood coagulation, which is difficult to correct in medicine
3. Splenic malignant tumors, pregnancy splenic abscess, etc.

In a word, the indications of SILS should be handled according to the experience and skill of the surgeon, and it is critical to guarantee a safe surgery with less or no complications [13].

6.3 Preoperative Assessment and Preparation

Preoperative assessment and preparation mainly include skin preparation, biochemical examination, gastrointestinal preparation, and medicine preparation.

6.3.1 Skin Preparation in the Field of Operation

Before the operation, shave the hair above the pubis and clean the umbilical region, in order to reduce the probability of local infection in the incision.

6.3.2 Routine Biochemical Tests

Examine the blood routine, coagulating time and prothrombin time, to understand the coagulation status of the patient. If the patient's platelet (PLT) is less than 20×10^9/L, preoperative infusion of whole blood or 4–16 U platelet suspension should be carried out to prevent intraoperative hemorrhage or wound bleeding.

6.3.3 Gastrointestinal Preparation

Patients should have fasted for 12 h and have been deprived from water for 4 h preoperatively to prevent the occurrence of asphyxiation, aspiration pneumonia, and postoperative ventosity due to intraoperative nausea and vomiting. Insert gastric tube and carry out continuous gastrointestinal decompression preoperatively and evacuate gastric contents to remit flatulence.

6.3.4 Medicine Preparation

Patients with immune thrombocytopenic purpura should be administrated with hydrocortisone 3 days before surgery at a dose of 100–300 mg/day, to prevent the occurrence of hemolysis crisis; patients with liver cirrhosis should be provided with proper treatment to protect liver and correct hypoproteinemia and liver function. If patients are suffering from ascites, the operation can be performed after ascites retrogression.

6.4 Surgical Procedures

6.4.1 Surgical Position and Surgeon Position (Fig. 6.1)

Surgical position: After the success of general anesthesia, outstretch the patient's upper limbs both sides horizontally and lower limbs

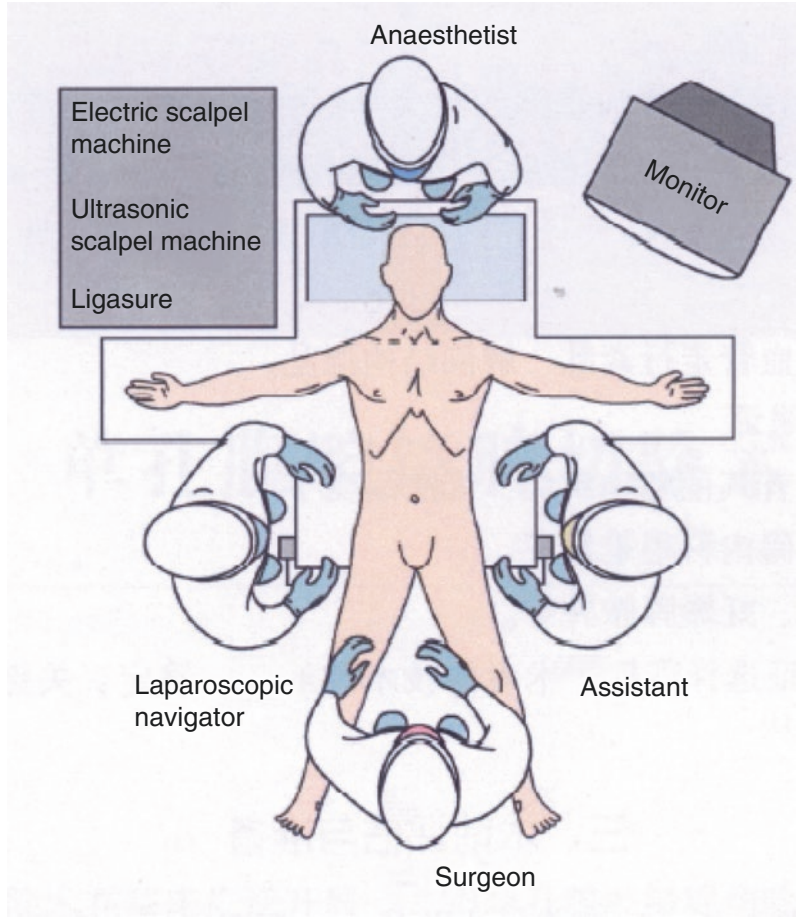

Fig. 6.1 Surgical position and surgeon position

for 30–45°, and pad the left shoulder-back for about 15–20°.

Surgeon position and device placement: The surgeon stands between the legs of the patient, the laparoscopic navigator usually stands on the right side of the patient, and the assistant stands on the left side; the monitor is placed to the outside of the patient's left shoulder. Compared with porous incision, SILS is more difficult to perform, with fewer devices used, so it is necessary to use body position and gravity to expose the field.

6.4.2 Main Steps

1. Place the trocar and establish the pneumoperitoneum. Make an incision about 2 cm long through the umbilical region, keeping the fascia layer intact and avoid air leakage during the pneumoperitoneum. After successful pneumoperitoneum, perform puncture with 10 mm trocar at the bottom of the incision, insert the laparoscope to confirm the feasibility of single-incision laparoscopic surgery. Then place 5 mm trocar and 12 mm trocar on the upper edge of the surgical incision, arranging the three trocars in an inverse triangle (Fig. 6.2). Then, insert grasping forceps, ultrasonic scalpel, or LigaSure into 5 mm trocar and 12 mm trocar, respectively, for tissue separation and coagulation [14]. Set CO_2 pneumoperitoneum pressure at 12–14 mmHg.
2. Dissect the spleen. First, dissociate the gastrocolic ligament to expose the pancreas. Continue to dissociate the splenogastric ligament, and cut off the short gastric vessels with ultrasonic scalpel. Then dissociate the splenocolic ligament by ultrasound scalpel, avoiding

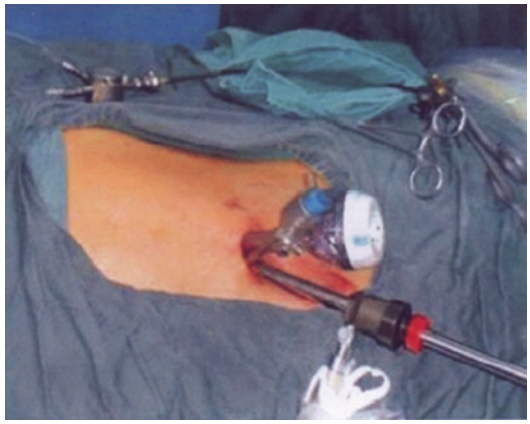

Fig. 6.2 Trocar of SILS arranged into an inverse triangle

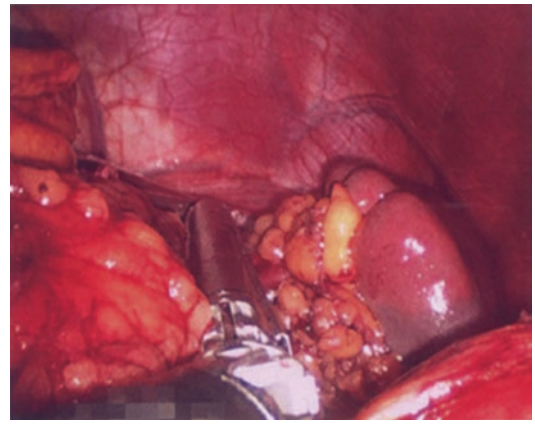

Fig. 6.3 Cut off the ligated splenic pedicle by Endo-GIA under laparoscope

the accidental injury of transverse colon. Cut off the splenocolic ligaments, lift up the lower pole of the spleen to expose the splenorenal ligament behind the splenic hilus, and then cut it off by ultrasonic scalpel safely. Finally, dissociate the splenophrenic ligament upward with ultrasonic scalpel.

3. Dispose of splenic pedicle. Use ultrasound scalpel with LigaSure to carefully dissociate the peritoneum of the splenic hilum, and then expose the pancreatic tail and protect it. Dissect the splenic pedicle at the splenic hilum after dissociating in the front of the pancreatic tail. Place a 60 mm linear Endo-GIA through a 12 mm trocar to close the splenic pedicle (Fig. 6.3), to complete hemostasia and splenectomy. In patients with splenomegaly or with difficulty in exposing or dissecting splenic pedicle, hand-assisted laparoscopic splenectomy can be used in laparoscopic splenectomy, to dispose of the splenic arteries and veins and remove the spleen under direct vision.
4. Take specimen. Place the spleen into the sample bag placed via 12 mm trocar. Due to the limitation of single-incision laparoscope, load the spleen into the sample bag with the change of body position (Fig. 6.4). This process requires skilled laparoscopic technique and

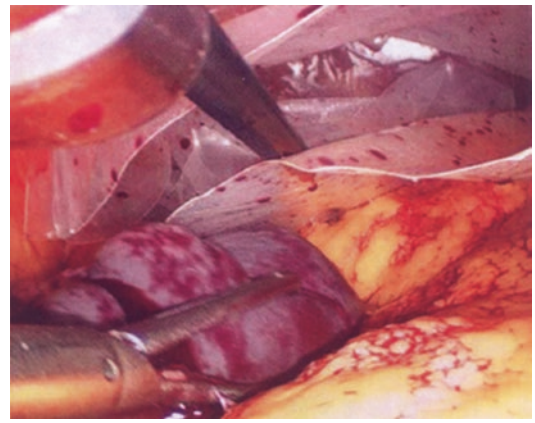

Fig. 6.4 Load splenic tissue into the sample bag

sufficient patience. Tighten the mouth of the specimen bag, clamp it, and drag it into the trocar. Pull it out together with the trocar. Expand the mouth of the specimen bag, and extract splenic tissues in batches by sponge forceps.

5. Place the drainage tube. Rinse locally and suck the abdominal hemoperitoneum. Detect whether there is bleeding or leakage, and after the check of the gauze and other instruments, retain a drainage tube in the spleen fossa, which should be extracted through the umbilical cord (Figs. 6.5 and 6.6).

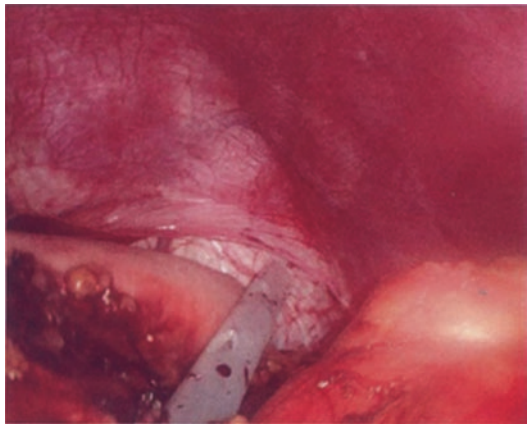

Fig. 6.5 Placement of the drainage tube: retaining a drainage tube in spleen fossa

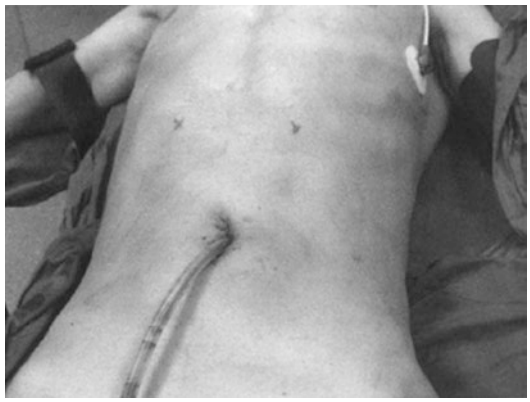

Fig. 6.6 Placement of the drainage tube: drainage via the umbilical cord

6.5 Key Surgical Techniques

6.5.1 Techniques for Dissociation of the Spleen via Single-Incision

The dissociation of the perisplenic ligaments is an important step in the process of SILS. We should pay attention to the following points [15]:

1. The dissociation of the upper pole of the spleen and the splenophrenic ligament is a difficult part, given the fact that the spleen is adjacent to the gastric wall and the diaphragm, with short gastric vessels running inside, which is difficult to be exposed, and the operating space is narrow. If handled improperly, bleeding and gastric wall and diaphragmatic injury can be caused. If the gastric distension occurs, take out gastric contents via gastric tube; lift the upper pole of the spleen gently with aspirer by left hand, making that there is moderate tension between spleen, the stomach fundus, and the diaphragm; then dissect the serous layer of the splenogastric ligament by ultrasonic scalpel to release the ligament and expand the gap; dissociate short gastric vessels; and after the clear exposal, clip and cut off the short gastric vessels by vessel clips and ultrasonic scalpel, respectively, so as to avoid the injury of the stomach and the spleen. For the patients with portal hypertension, cut off varicose veins by vessel clips in avoidance of intraoperative and postoperative bleeding.
2. Some patients with portal hypertension have severe retroperitoneal varicose veins. When operating on such patients, perform as close as possible to the spleen during the process of dissociating the splenorenal ligament, for avoiding incorrect surgical layer. After entering the anterior renal space, avoid massive bleeding caused by the injury of retroperitoneal varicose veins.

6.5.2 Treatment of Splenic Artery

After dissociating the perisplenic ligaments, look for and identify the splenic artery at the upper margin of the distal pancreas and ligate it after its dissociation, which is a critical step especially in patients with portal hypertension. After the ligation of splenic artery, due to the lack of the splenic perfusion, the texture of the spleen becomes soft, with its slightly reduced size and the reduction of the hemorrhage it would be, making the operation easier and facilitating the later steps. If it

is difficult to find the splenic artery at the upper margin of the distal pancreas, follow the common hepatic artery and dissociate to the left to identify the splenic artery.

6.5.3 Treatment of Splenic Hilum

Treatment of splenic hilum is one of the difficulties during the SILS, and there are a variety of surgical plans in the medical centers at home and abroad, which can be summarized into two categories:

1. Ligament of secondary branches of splenic pedicle. Use silk thread or vascular clip to clip the trunk and branches of the splenic artery and vein in order, and then ligate the splenic pedicle completely.
2. Ligament of primary branches of splenic pedicle. Create tunnels on the front and rear of the pancreatic tail near the splenic hilus, and then use Endo-GIA to ligate splenic vessels completely.

The first method is to dissect and cut off splenic vessels, respectively, with a precise and reliable hemostasis, but it is more time-consuming; for the patient with obesity, tortuosity, and expansion of splenic vessels, and with peri-pancreatic tail adhesions, this method for dissecting vessels is more difficult to be carried out, and it is more vulnerable to hemorrhage in the process of dissection. Thus, it is advisable to apply the second method on such patient, for its sufficiency on dissecting and its avoidance on injuring pancreatic tail and stomach. In addition, the thickness of the staple cartridge is selected according to the thickness of the tissue. For example, if the splenoportal tissue is more abundant and wider, with tortuous splenic vessels, the whole tissue can be ligated with silk thread first and then cut with Endo-GIA after the spleen pedicle is narrowed in order to ensure the ligamental effect. It should be emphasized that it is vital to confirm whether the staple cartridge is not clipped on vascular clip, suspension band, gauze strips, and so on before starting the Endo-GIA, so as to avoid poor closure leading to massive hemorrhage [16–18].

6.5.4 Techniques for Specimen Removal

After the total splenectomy, put the specimens into a disposable sample bag, remove it from the splenic fossa, wash the wound surface with warm saline, and check the presence of bleeding and pancreatic lesions again. Meanwhile, the presence of surrounding accessory spleen should be checked. Apart from the complete removal of the malignant splenic specimens, other types of spleen specimens can be chopped before removed. It should be noted that different sizes of sample bags can be selected according to the size of the specimen, and the bag should be anti-tension to avoid the splenic implantation after the rupture of the specimen belt, which will affect the surgical effect.

6.6 Special Intraoperative Circumstances and Handling Skills

6.6.1 Intraoperative Hemorrhage

The spleen is deeply located with brittle texture and abundant blood supply, which can easily lead to bleeding during laparoscopic splenectomy. If there is an accidental hemorrhage during the operation, stay calm at first, use a small gauze strip to compress the bleeding site, and then identify and handle the bleeding site carefully after cleared by an aspirator. If the hemorrhage is difficult to be dealt with under laparoscope, it shall be transferred to hand assistance or open surgery. Timely transferring to open surgery does not mean the failure of laparoscopic surgery, but the better maintenance of the patient's life based on the principle of "life first." In order to prevent bleeding during laparoscopic splenectomy, the following methods can be summarized after consulting a large number of domestic and foreign literatures [19–22]:

1. Strictly control the indications of surgery, and check the preoperative coagulation function routinely.
2. During the operation, the patient should be carefully operated with clear anatomical layers and operative fields to prevent iatrogenic hemorrhage. During the operation, the force to pull perisplenal ligament should be moderate with the correct method. The spleen cannot be directly clamped; instead, place gauze blocks on the head of the aspirator and use the aspirator to expose the spleen by poking, carrying apart, pushing, elevating, and any other gentle way. Usually, during the operation, dispose of the perisplenic ligament first, then the short gastric vessels, and last the splenic pedicle. A few relevant articles suggest that it is not necessary to cut off the short gastric vessels completely at one time if there is difficulty in disposing of the short gastric vessels; after handling the spleen pedicle, cut off the remaining short gastric vessels [20].
3. Ultrasound scalpel is mainly used for dissociation and dissection during the operation. The ultrasonic scalpel has many advantages such as convenience to use, high operation accuracy, good coagulation function, clear separation of surrounding tissues, low probability of accidental injury to surrounding tissues, and so on.
4. Timely transfer to open surgery during the operation does not mean the failure of the operation; instead, it is good for the better maintenance of the patient's life based on the principle of "life first."
5. The drainage tube placed in the splenic fossa after surgery can timely detect the splenic pedicle bleeding, which makes decisive measures to carry out to dispose of bleeding and to save patient's life in time.
6. The operative field should be fully exposed intraoperatively, and the surgical operation should be carried out step by step. Attention should be paid to the possible presence of the accessory spleen, which must be removed simultaneously if detected.

6.6.2 Adjacent Organ Injury

Given the unclear tissue exposure during the operation, the nearby stomach and colon might be injured or perforated. According to the intraoperative conditions, primary suture or building fistula is selected.

6.7 Postoperative Management and Prevention and Treatment of Complications

6.7.1 Routine Postoperative Care

1. The patient should be kept in a supine position after the operation. In order to prevent the patient's vomit from blocking the trachea, the patient's head can be turned to one side.
2. Closely observe the patient's vital signs, measure blood pressure, respiration, and pulse every hour, and constantly monitor the patient's temperature and oxygen saturation. Observe the patient's change of mental state and psychological and physical appearance.
3. Observe the patient's abdominal signs, paying attention to whether the patient has abdominal pain or distension.
4. After the postoperative recovery of intestinal function, remove the gastric tube; instruct the patient to gradually intake liquid and/or semiliquid food. Due to the less traumatic of laparoscopic splenectomy, it has marginal impact on the human gastrointestinal system; thus the recovery of gastrointestinal function is rapid, the gastric tube can usually be removed a day or so postoperatively. Many patients will develop nausea in the short term after the operation, which is due to the use of pneumoperitoneum and anesthesia intraoperatively; intramuscular injection of metoclopramide can be applied.
5. Closely observe the incision and abdominal drainage tube. Observe whether there is seepage or bleeding at the incision; replace the

dressing on time to keep the incision hygienic. Observe the quantity and quality of the abdominal drainage fluid, record the drainage volume each hour on the day of operation, and take notice on the patency of the drainage tube. If there's active hemorrhage or oozing of blood in abdominal cavity, drainage fluid will increase; detect and treat it timely. The drainage tube can be removed when the drainage fluid is reduced to less than 20 mL/day.

6.7.2 Common Postoperative Complications and Their Prevention and Treatment

Previous studies have shown that the occurrence of complications of open splenectomy ranges from 5% to 60%, mainly including hemorrhage, pancreatic tail injury, and pulmonary complications, while the incidence of complications of splenectomy for patients with splenomegaly and splenic malignancy ranges from 40% to 60% [23, 24]. With the popularization of laparoscopic splenectomy, the incidence of complications is significantly lower than that of open splenectomy due to the minimally invasive, high-definition, enlarged operative field and delicate and gentle operation. However, the complications of laparoscopic splenectomy cannot be completely avoided due to the complicated anatomy and variability of the spleen, especially the pathologic spleen coincides with coagulation dysfunction and ultra-splenomegaly.

1. Gastric fistula, intestinal fistula, and pancreatic fistula. The internal injuries are not only caused by puncture cannula or pneumoperitoneum needle, but also related to surgical operation. Improper use of electric cauterization can cause iatrogenic gastric, colon, and pancreatic injuries [25]. If the dissection of splenocolic or splenogastric ligament is too close to the colon, the thermoelectric effect produced by cautery hook can cause gastric and colon injury, resulting in delayed gastrointestinal perforation. When the gastric wall is clamped, it can cause the ischemia and necrosis of the gastric wall, resulting in gastric fistula. Given the pancreatic tail is close to the spleen, if the dissociation of splenic vessels is far away from the splenic hilus, the pancreatic tail will be easily damaged, causing pancreatic fistula. Electrocoagulation hemostasis at the splenic hilum under non-direct vision may cause severe bleeding; therefore, in electrocoagulation, electrotomy, clipping, and cutting off of the splenogastric, splenocolic, and splenophrenic ligaments, the maintenance of a certain tension is needed. Such procedure should change into mobilization of lower pole of spleen should close to spleen, do not damage the colon, stomach, or diaphragm [26]. In the dissection of splenic hilum, the sharpness dissection via ultrasonic knife should be adopted as much as possible to prevent the tearing of the spleen capsule. Pay attention to checking serum amylase postoperatively, to timely detect and handle pancreatic injury [27].
2. Postoperative bleeding. Postoperative bleeding should be disposed of immediately if found; secondary operation (endoscopy or laparoscopy) is needed if non-surgical treatment to hemorrhage cannot control bleeding.
3. Thrombosis in mesenteric blood vessels, deep vein of lower limbs, or spleen-portal vein. Thrombosis is a complication with low incidence; the reason may be associated with platelet rising velocity [28, 29]; therefore, constantly monitoring the change of platelet and coagulation is needed, and if it is necessary, use medication to regulate platelet and coagulation, which helps to reduce the incidence of the complication of thrombosis. If the platelet increases to 600×10^9/L, medication can be appropriately used to reduce the counting of platelets. Assisting patients on off-bed activity is an effective way to prevent thrombosis. If thrombosis occurs in lower limbs, nurses should instruct patients to lie down and elevate the affected limb.
4. Postoperative fever and infection. Most of the patients will have fever within 3 days after operation. There are two causes of rising body temperature, one is splenic fever, which can be diagnosed if infective diagnoses are

excluded, then carry out antipyretic treatments. Generally, liver function plays a more important role in splenic fever, it is important to detect and improve liver function perioperatively. In the second case, if the body temperature exceeds 39 °C (102 °F) and lasts for more than 3 days, the occurrence of postoperative infection should be taken into accounts. Postoperative splenic fossa fluid infection is prone to occur; in this case, find the infection sources out in time, and appropriate usage of antibiotics and puncture drainage should be used for treatment. Some patients will also suffer from pulmonary, incision, and abdominal cavity infection postoperatively. For the prevention of pulmonary infection, patients should be informed to pay attention to respiratory function exercise before surgery, atomization inhalation treatment should be carried out twice a day postoperatively, and guide patients to cough effectively. Abdominal infection is usually caused by peritoneal effusion; drainage tube should be placed in the splenic fossa to extract the effusion in time. Take good care of the skin around the orifice of the drainage tube. Timely change of dressing can keep the incision dry and clean.

5. Complications related to accessory spleen. Velanovich et al. [30] reported that five cases of patients with hematology disease underwent laparoscopic accessory splenectomy due to the presence of accessory spleen after splenectomy, of which two cases were significantly improved. The occurrence rate of accessory spleen is 15–20%; among the patients with hematology disease, such probability is as high as 30% [31]. CT and ultrasound examination should be completed preoperatively; the exploration should be carried out first after the laparoscopy enters the abdomen, and the accessory spleen should be resected when it is found. It would be difficult to find the accessory spleen after splenectomy for the accessory spleen is mainly on the splenic hilum, pancreatic tail, omentum, mesentery, and perisplenic ligament. During hand-assisted laparoscopic splenectomy, the accessory spleen could be found with finger with sensitive tackle to prevent omission. When the specimen is being taken out, the legacy of the accessory spleen or autologous transplantation of splenic tissue fragments may lead to surgical failure. Due to its own limitations, SILS is more likely to cause omissions if there is slightly negligent. During the operation, put splenic specimens into the bag. Then fasten the mouth of the bag, which should be put out of the abdominal wall, and finally cut up the specimens with gyno uterine rotation cutter or break it with oval forceps, remembering that the sample bag should be avoided to be perforated.

6.8 Hot Topics and Future Prospects

6.8.1 Advantages of SILS

Traditional LS makes four incisions in the patient's umbilicus and upper abdomen, while SILS only makes a 3 cm incision in the fold of the umbilicus. After healing, due to the cover of the fold of the navel, the surgical scar is almost difficult to be detected, which has an obvious psychological comfort on patients, especially on young and unmarried patients.

6.8.2 Disadvantages of SILS

Given the parallel arrangement between the equipment and the mutual interference between surgeon and laparoscopic navigator in SILS, surgical instruments cannot be fully unfolded, which leads to an apparent "chopsticks effect" and a higher difficulty compared to LS, so its indication has certain limitation, especially in the early stages of the operation; patients with no abdominal surgery history and no obesity with normal-sized spleen and strong desire of beauty simultaneously are suitable to such operation. This technique has a unique learning curve, requiring good cooperation between the laparoscopic navigator and the surgeon, lessening inter-

ference with surgical instruments while ensuring a clear view. Therefore, the requirements for the surgical are stringent.

6.8.3 Future Prospects

SILS is safe and feasible if its indications and contradictions are handled properly [32]. At home and abroad, the research for robot-assisted splenectomy will be much more mature; the multiangular rotation of the robot arm can overcome the "chopsticks effects" in a single-incisional operation. A few large- and medium-sized hospitals have put it into clinical use gradually, which will then be carried out by primary hospitals. Presently, the top priority is given to train a large number of skilled endoscopic surgeons, followed by the continuous development of advanced laparoscopic equipment to keep up with the development of surgical needs. It is believed that with the continuous development of society, science and technology, the continuous update of laparoscopic instruments, and the continuous deepening of LS research, SILS will play a greater role in the research and clinical application of splenic surgery.

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