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CASE REPORT

Robot-assisted partial splenectomy for benign splenic tumors: Four case reports

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Abstract

BACKGROUND

Robotic-assisted partial splenectomy (RAPS) is a superior approach for treating splenic cysts and splenic hemangiomas, as it preserves the immune function of the spleen and reduces the risk of overwhelming post splenectomy infection. Currently, there are no standardized guidelines for performing a partial splenectomy.

CASE SUMMARY

Four patients with splenic cysts or splenic hemangiomas were treated by RAPS. Critical aspects with RAPS include carefully dissecting the splenic pedicle, accurately identifying and ligating the supplying vessels of the targeted segment, and ensuring precise hemostasis during splenic parenchymal transection. Four successful RAPS cases are presented, where the tumors were removed by pretreating the splenic artery, dissecting and ligating the corresponding segmental vessels of the splenic pedicle, transecting the ischemic segment of the spleen, and using electrocautery for optimal hemostasis. Four patients underwent successful surgeries with minimal bleeding during the procedure, and there were no signs of bleeding or recurrence postoperatively.

CONCLUSION

Four cases confirm the feasibility and superiority of RAPS for the treatment of benign splenic tumors.

Key Words: Partial splenectomy; Robotic-assisted partial splenectomy; Splenic cyst; Splenic hemangiomas; Case report

Core Tip: Robotic-assisted partial splenectomy (RAPS) is a superior approach for treating splenic cysts and splenic hemangiomas, as it preserves the immune function of the spleen and reduces the risk of overwhelming post splenectomy infection. Currently, there are no standardized guidelines for performing a partial splenectomy. This paper reports four cases of benign splenic tumors managed successfully by robotic-assisted partial splenectomy. This article provides the first comprehensive account of the detailed surgical procedure. RAPS demonstrates notable advantages in the treatment of benign splenic diseases.

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INTRODUCTION

Splenic cysts and splenic hemangiomas are rare benign tumors. The reported incidence rate is 0.07% for splenic cysts and 0.02%-0.16% for splenic hemangiomas, with a higher prevalence among females[1,2]. Typically, there are no prominent clinical symptoms. These are usually discovered incidentally during routine medical examinations. However, when the tumor diameter is larger than 5 cm, there may be a palpable mass and pain in the left upper abdomen, with a risk of rupture. Therefore, for patients with symptoms or tumors larger than 5 cm in diameter, surgical treatment is strongly recommended[3].

In the past, the standard treatment for splenic cysts and splenic hemangiomas was splenectomy. However, recent studies have revealed a correlation between splenectomy and post operative complications such as infection, intra-abdominal abscess, portal vein thrombosis, pulmonary hypertension, thrombocytosis, and venous thromboembolism[4]. Due to the increasing recognition of the immune function of the spleen, spleen preservation has become a new trend in the surgical treatment of benign splenic diseases. Among the various methods, partial splenectomy is currently the preferred choice[5]. However, performing a partial splenectomy presents challenges, including a thin spleen capsule that is prone to bleeding, the presence of multiple branches of the splenic pedicle, and delicate vessel walls. The widespread use of the Da Vinci robotic surgical system has significantly improved surgical techniques by providing enhanced visualization and stability. This has led to a notable increase in the success rate of partial splenectomy. We report four cases of RAPS, which achieved favorable outcomes.

CASE PRESENTATION

Chief complaints

Case 1: A 14-year-old female, was admitted to the hospital after an enlarged splenic cyst was incidentally detected one week prior.

Case 2: A 40-year-old female, presented to the hospital due to progressive enlargement of a splenic hemangioma for one year.

Case 3: A 63-year-old female, was admitted to the hospital due to a four-month history of recurrent abdominal pain accompanied by thrombocytosis.

Case 4: A 40-year-old female, was admitted to the hospital with a complaint of an enlarged splenic cyst incidentally detected during a routine physical examination one year prior.

History of present illness

Case 1: Patient 1 experienced a sensation of bloating in the upper abdomen after meals for the past week.

Case 2: Patient 2 reported no symptoms; however, regular assessments indicated an increase in the size of the tumor.

Case 3: Patient 3 reported a history of recurrent pain in the upper left abdomen that had lasted for the past four months.

Case 4: Patient 4 had a similar history to patient 2.

History of past illness

All four patients had no history of abdominal trauma or travel outside the local area. They were systemically well.

Personal and family history

All four patients denied any family history of splenic tumors.

Physical examination

Abdominal examination of patient 1: The abdomen was soft, and a firm mass approximately 9 cm in size was palpated in the left upper abdomen, below the costal margin, with clear boundaries and no tenderness. The abdomen showed no tenderness to palpation, no rebound tenderness, and no muscle rigidity.

Abdominal examination of patient 2: Patient 2 was systemically well and had a soft abdomen without abdominal pain.

Abdominal examination of patient 3: On palpation, the abdomen was soft with mild pain in the upper left abdomen, below the rib margin. The abdomen showed no tenderness to palpation, no rebound tenderness, and no muscle rigidity.

Abdominal examination of patient 4: On palpation, a firm and well-defined mass measuring approximately 8 cm was palpable in the left upper quadrant, below the rib margin. The abdomen showed no tenderness to palpation, no rebound tenderness, and no muscle rigidity.

Laboratory examinations

Patient 1's, patient 2's and patient 4's blood tests revealed no abnormalities. The results of patient 3's blood test revealed a platelet count of 1084×10^9/L.

Imaging examinations

Patient 1's computed tomography (CT) scan revealed a round, non-enhancing low-density lesion measuring approximately 90 mm in the lower pole of the spleen, which was consistent with a splenic cyst (Figure 1A and B).

Patient 2's CT scan revealed multiple oval-shaped low-density lesions in the upper segment of the spleen, with the largest measuring approximately 52 mm. After contrast, the edges of the lesion demonstrated rings of enhancement, and, in the balance phase, they had slightly increased density, suggesting the presence of splenic hemangiomas (Figure 1C and D).

Patient 3's magnetic resonance imaging scan revealed a 40 mm well-defined mass in the lower pole of the spleen, which appeared as a low signal on T1 weighted images and a high signal on T2 weighted images. The signal intensity increased over time, and a splenic hemangioma was considered (Figure 1E and F).

Patient 4's CT scan revealed a round, non-enhancing low-density lesion measuring approximately 73 mm in the lower pole of the spleen, which was consistent with a splenic cyst (Figure 1G and H).

FINAL DIAGNOSIS

The final diagnoses of four patients were benign splenic tumors. Patient 1's diagnosis was splenic cyst. Patient 2's diagnosis was a splenic hemangioma. Patient 3's diagnosis was a splenic hemangioma. Patient 4's diagnosis was a splenic cyst.

TREATMENT

Under general anesthesia, the patient was placed in the right lateral position. RAPS surgery was performed with five ports in the upper abdomen (Figure 2). Under a 10 mmHg capnoperitoneum, the gastrocolic ligament was incised using an ultrasonic scalpel to expose the pancreas and spleen. The splenic artery was carefully dissected along the superior border of the pancreas, and then slung with nylon tape. The splenic hilum was exposed after the gastrosplenic ligament was divided. The ligaments around the segment to be pre-resected were divided, and the segment vessels of the pre-resected piece were cut. Once an ischemic line appeared on the spleen, the tumor was checked to ensure that it was localized within the ischemic line. Using an ultrasonic scalpel, the splenic parenchyma was dissected approximately 1 cm inside the inner edge of the ischemic line. Any bleeding points on the cut surface were cauterized using Maryland bipolar forceps or permanent cautery hooks. The splenic edge was treated with hemostatic gauze (Figure 3). The resected part of the spleen was placed into a specimen bag. The umbilical incision was subsequently extended to 2 cm, and the specimen bag was extracted from the body. The specimen was then fragmented by using tissue scissors for retrieval.

OUTCOME AND FOLLOW-UP

Four patients underwent successful surgeries; the operation duration and blood loss during the procedures are listed in Table 1.

The patients recovered smoothly after the operation and were discharged on the fifth or sixth postoperative days. Histopathology confirmed that there was no evidence of malignancy. Patient 1's pathology results indicated a primary splenic cyst (Figure 4). Patient 2's pathology result showed splenic hemangiomas (Figure 5B). Patient 3's pathology result

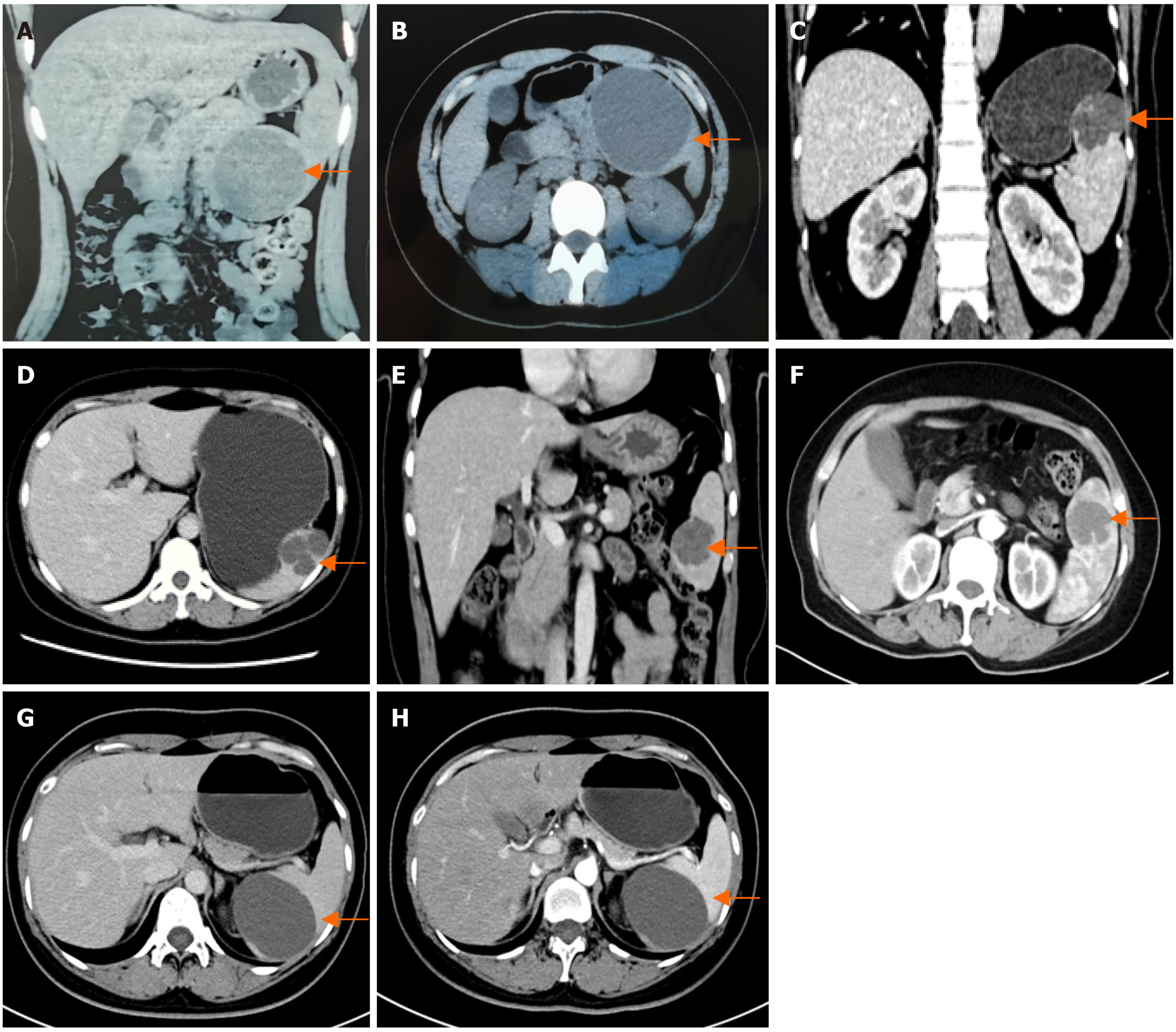

Figure 1 Imaging examinations of four patients. A and B: Computed tomography (CT) revealed a round, non-enhancing low-density lesion measuring approximately 90 mm in the lower pole of the spleen (arrows), which was consistent with a splenic cyst; C and D: CT revealed multiple oval-shaped low-density lesions in the upper segment of the spleen (arrows), with the largest measuring approximately 52 mm; E and F: Magnetic resonance imaging revealed a 40 mm well-defined mass in the lower pole of the spleen (arrows), which appears as a low signal on T1 weight and a high signal on T2 weight; G and H: CT revealed a round, non-enhancing low-density lesion measuring approximately 73 mm in the lower pole of the spleen (arrows).

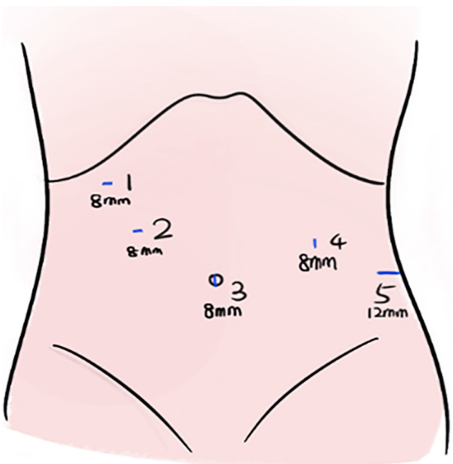

Figure 2 Schematic illustration of the port positions. Port 1 is for the Cadiere forceps; Port 2 is for the Maryland bipolar forceps; Port 3 is for the

laparoscope; Port 4 is for an ultrasonic scalpel or permanent cautery hook; and Port 5 is a port for assistance.

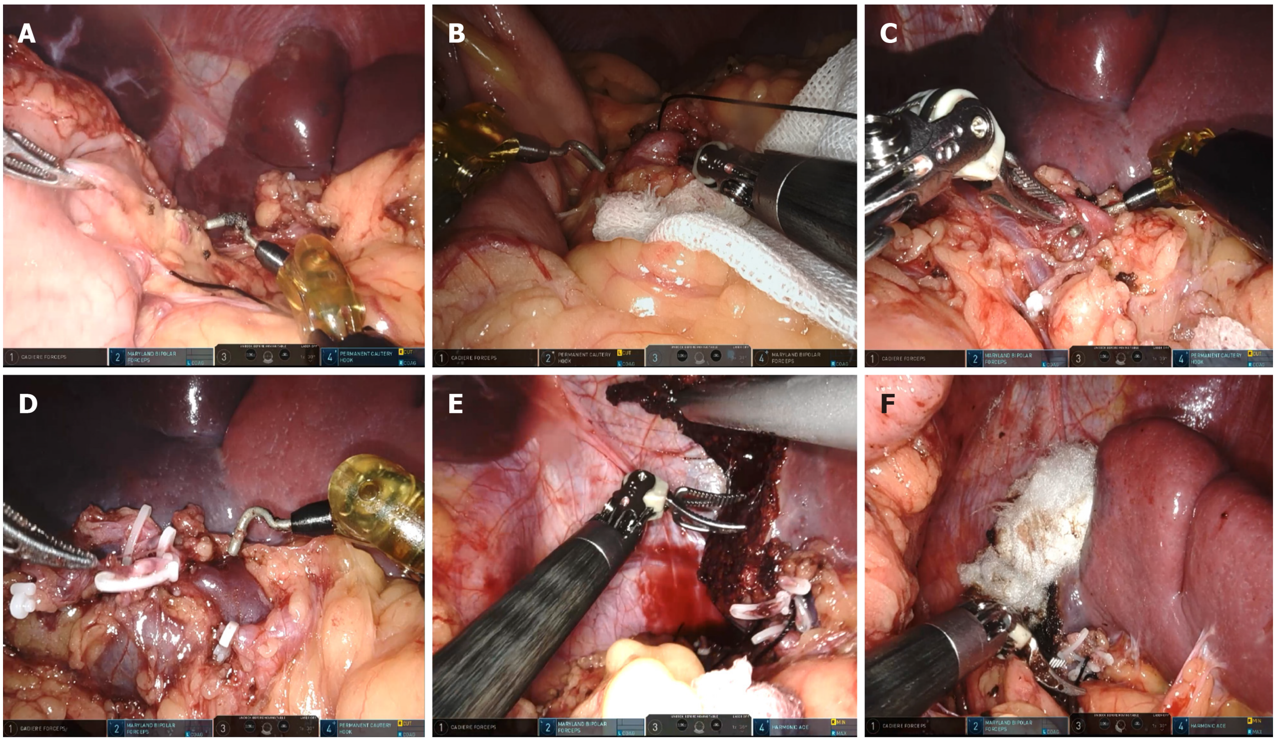

Figure 3 The detailed surgical procedure of robotic-assisted partial splenectomy. A: The gastrocolic ligament was incised to expose the pancreas and spleen; B: The splenic artery was slung with nylon tape; C and D: The splenic hilum was exposed, and the segment vessels of the pre-resected segment were cut; E: Bleeding points on the cut surface were cauterized using a permanent cautery hook; F: Hemostatic gauze was used on the splenic edge.

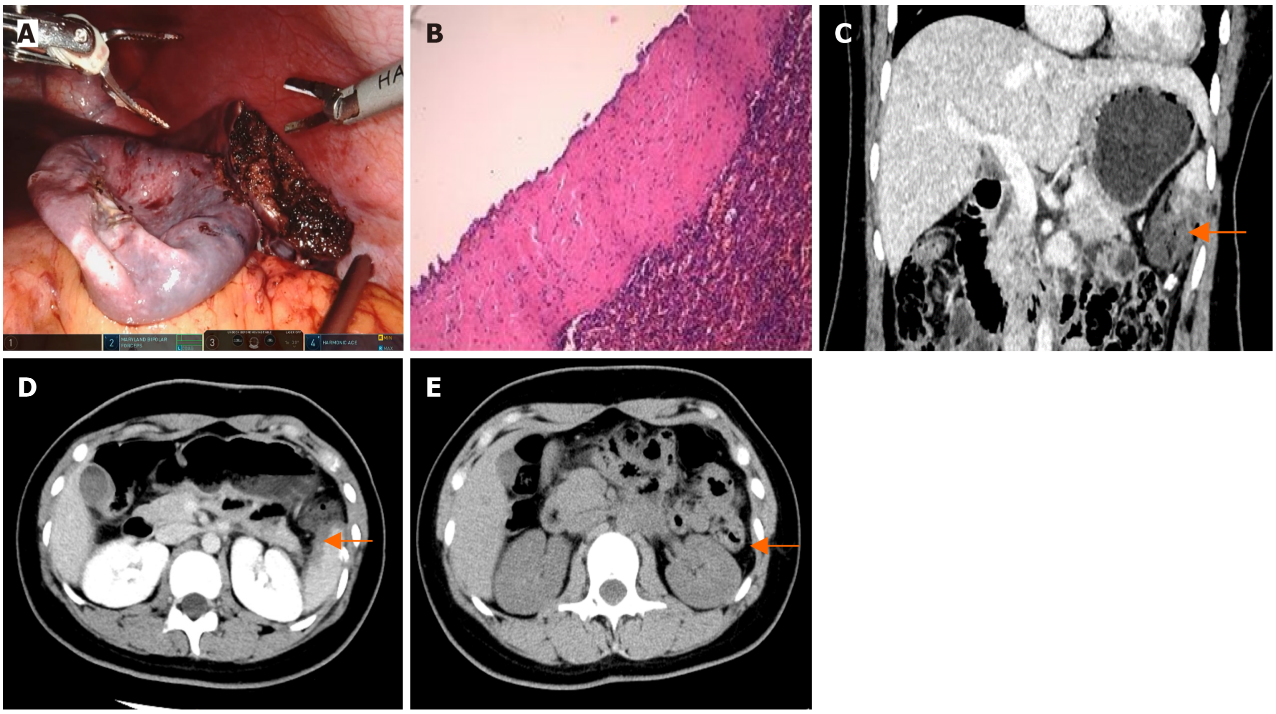

Figure 4 The patient 1's pathology result and postoperative computed tomography images. A: Resected specimen from patient 1. The contents of the cyst had already leaked out; B: Histopathological analysis and immunohistochemical examination of the resected specimen: Primary splenic cyst; C and D: Computed tomography (CT) images of patient 1 on the third day after surgery. There was some effusion around the spleen (arrows); E: A follow-up CT scan of patient

1 at six months post-surgery revealed that there was no tumor in the spleen.

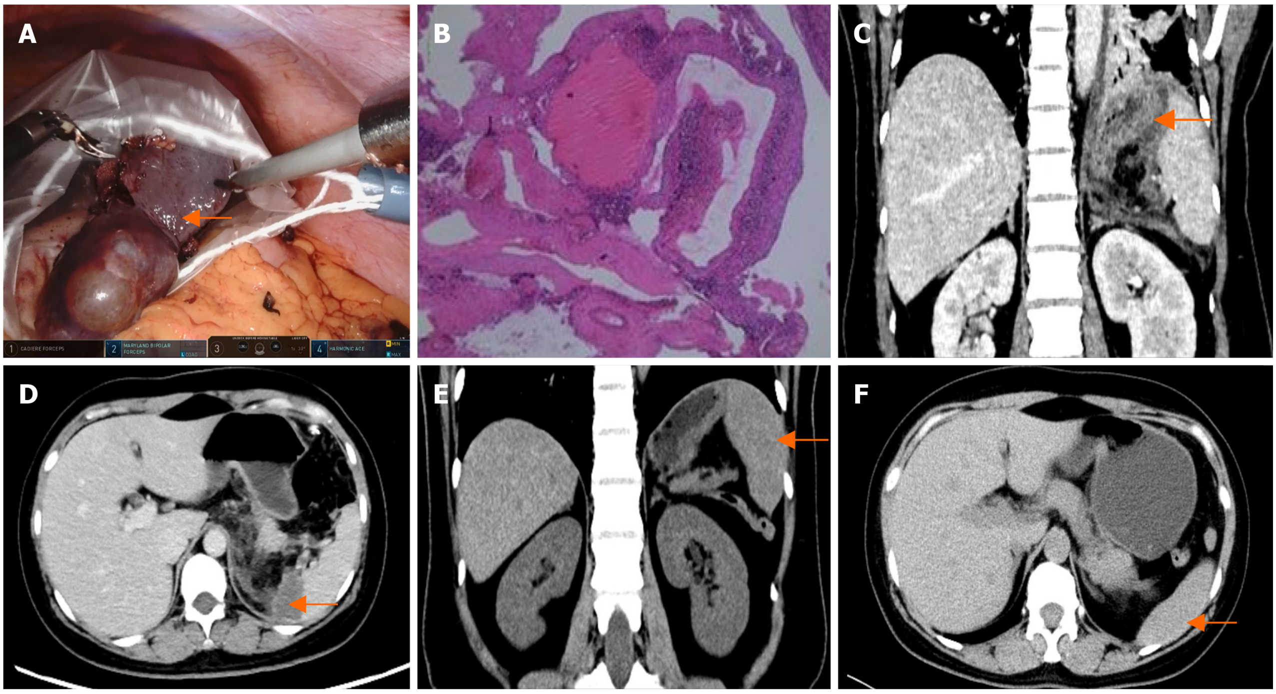

Figure 5 The patient 2's pathology result and postoperative computed tomography images. A: Resected specimen from patient 2; B: Histopathological analysis and immunohistochemical examination of the resected specimen: Splenic hemangiomas; C and D: Computed tomography (CT) images of patient 2 on the third day after surgery. There was some effusion above the spleen (arrows); E and F: A follow-up CT scan of patient 2 at six months post-surgery indicated that there were no tumors in the spleen (arrows).

indicated a splenic hemangioma (Figure 6B). Patient 4's pathology results revealed a splenic cyst (Figure 7B).

Four patients had CT scans on the third day after surgery, and the results revealed some effusion around the spleen (Figure 4C and D, Figure 5C and D, Figure 6C and D, Figure 7D). Blood tests revealed no significant abnormalities.

A follow-up CT scan six months after surgery for the four patients revealed no signs of tumor recurrence in the spleen (Figure 4E, Figure 5E and F, Figure 6E, Figure 7E).

DISCUSSION

Splenic cysts and splenic hemangiomas are relatively rare in humans. Small spleen cysts generally show no clinical symptoms and usually do not require treatment. However, if a cyst exceeds 5 cm in diameter, surgical intervention is necessary[6]. Splenic hemangiomas are the most common benign tumors of the spleen, with an incidence of 0.02%-0.16%, and they are more common in females[4]. Hemangiomas tend to grow slowly and have a low risk of malignant transformation, but there is a chance of spontaneous rupture. Once ruptured, massive hemorrhage can occur in the abdominal cavity. Therefore, early surgical intervention is advised, and total splenectomy is traditionally the recommended approach. With the advent of laparoscopic techniques, the first laparoscopic splenectomy was performed in 1992, highlighting its advantages over open surgery, such as reduced trauma, less pain, quicker recovery, and a lower risk of incision hernias[7]. As a result, laparoscopic total splenectomy has become the standard surgical method.

In 1952, King *et al*[8] were the first to report deaths following total splenectomy, noting severe infections that can occur afterwards. This led to the identification of overwhelming post splenectomy infection[8]. Since then, numerous studies have linked total splenectomy to complications such as postoperative infections, intra-abdominal abscesses, portal vein thrombosis, pulmonary hypertension, thrombocytosis, and venous thromboembolism.

With further research into the anatomy and function of the spleen, it has become clear that the phagocytic activity of splenic macrophages and the production of polysaccharide antibodies by B-lymphocytes are vital for infection defense [9]. Consequently, maintaining the immune function of the spleen is critical, with findings suggesting that preserving more than 25% of the splenic tissue can safeguard this function[9]. This revelation has brought partial splenectomy into the spotlight, and various reports have emerged.

Partial splenectomy has become a new trend in the surgical treatment of benign splenic diseases. This procedure is based on the segmental blood supply of the spleen. The splenic artery branches out into the splenic artery branches at the hilum of the spleen, with four types of branching patterns, including 1, 2, 3, and multiple branches, with the 2-branch and 3-branch types being the most common[10]. The arterial branches of the spleen form wedge-shaped segments that supply

Table 1 Operation duration and blood loss of four patients

	Operation duration (minute)	Blood loss (mL)
Patient 1	120	20
Patient 2	160	20
Patient 3	145	100
Patient 4	180	100

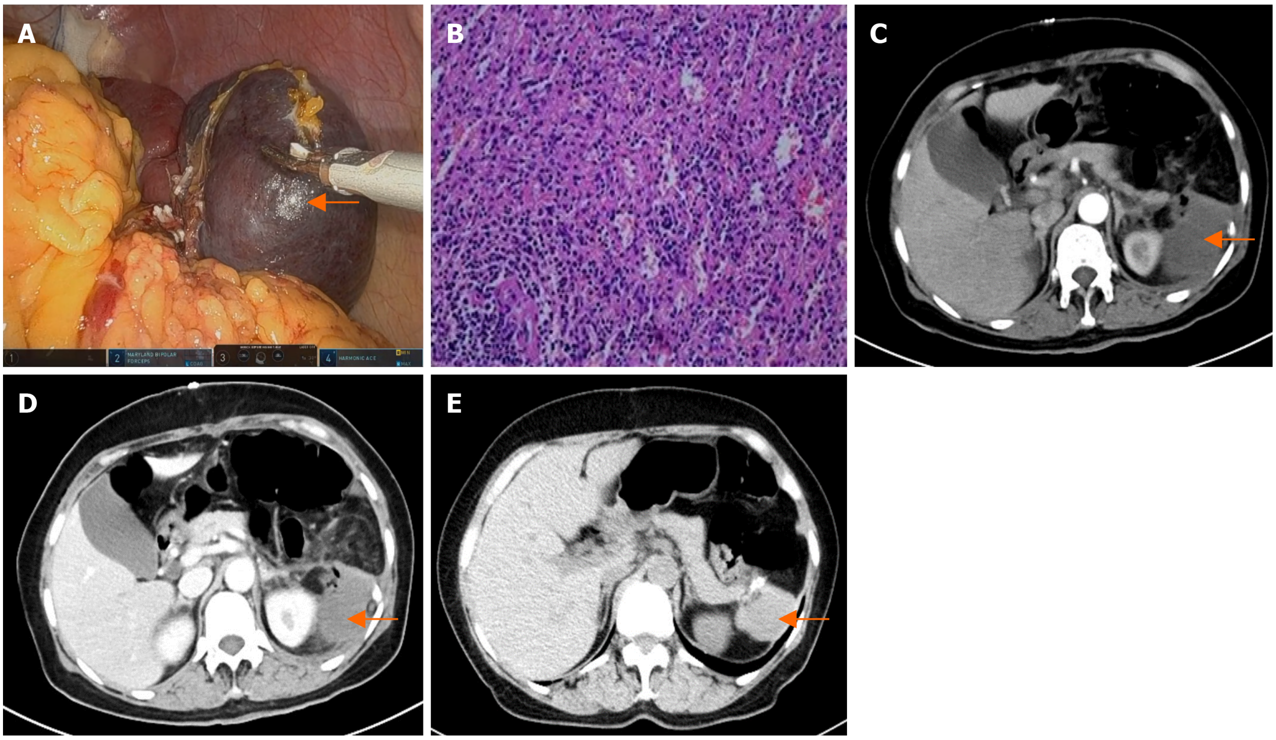

Figure 6 The patient 3's pathology result and postoperative computed tomography images. A: Resected specimen from patient 3; B: Histopathological analysis and immunohistochemical examination of the resected specimen: Splenic hemangiomas; C and D: Computed tomography (CT) images of patient 3 on the third day after surgery. There was some effusion above the spleen (arrows); E and F: A follow-up CT scan of patient 3 at six months post-surgery indicated that there was no tumor in the spleen (arrows).

blood to their respective segments. There are relatively ischemic planes between these segments[11]. By ligating the corresponding vessels at the splenic hilum and cutting the spleen 0.5-1 cm inside the ischemic line, segmental ischemia can be induced, allowing for safe removal of the desired portion of the spleen[12-14].

The challenges of partial splenectomy include anatomical identification of the splenic hilum vessels, precise identification and division of the blood supply to the pre-resected segments, and precise hemostasis during splenic parenchymal transection. To control intraoperative bleeding, various techniques have been used, including temporary occlusion with clamps, radiofrequency ablation, preoperative embolization, and microwave ablation[11,14,15]. Our team successfully used a hemostatic band at the splenic artery, allowing for easy traction and occlusion of the artery, effectively controlling bleeding during the procedure.

With respect to handling the splenic section, previous methods include the use of an ultrasonic scalpel, bipolar electrocoagulation, ligating clips, stapling devices, and bipolar radiofrequency electrodes for hemostasis[12]. Bing *et al*[4] utilized bipolar and ultrasonic techniques during surgeries for both dissection and hemostatic purposes[4]. Our team drew on various surgical experiences, implementing a tourniquet at the splenic artery to enable timely traction and occlusion for effective bleeding control. Notably, the vascular diameter within the spleen is relatively small. By using an ultrasonic scalpel in the right hand to cut vessels within 1 cm of the ischemic line, along with bipolar coagulation in the left hand, we can quickly achieve hemostasis without resorting to ligation clips, cutting devices, or sutures.

An enlarged umbilical puncture hole was used to extract the splenic specimen. Our team has gained experience in obtaining samples *via* single-incision laparoscopic cholecystectomy. We extended the umbilical incision to 2 cm, opened the umbilical ring, and removed the opening of the specimen bag. The splenic tumor was carefully cut into small fragments inside the bag, and the broken tissue specimen was extracted through the umbilical incision. Under direct visualization, we meticulously sutured the peritoneum and fascial layers of the umbilical incision, followed by suturing the umbilical skin back into its original position and concealing the incision within the umbilical fossa[16]. This meticulous

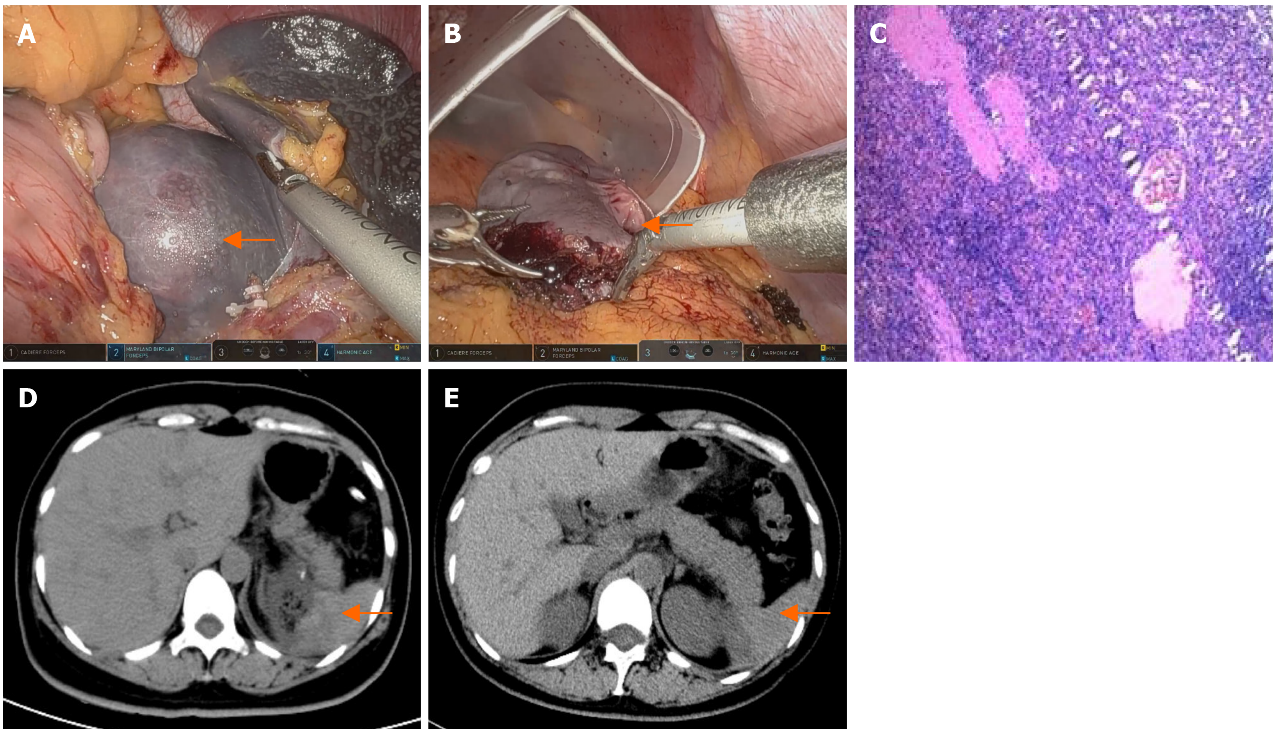

Figure 7 The patient 4's pathology result and postoperative computed tomography images. A and B: Resected specimen from patient 4; C: Histopathological analysis and immunohistochemical examination of the resected specimen: Splenic cyst; D: Computed tomography (CT) images of patient 4 on the third day after surgery. There was some effusion above the spleen (arrows); E: A follow-up CT scan of patient 4 at six months post-surgery indicated that there was no tumor in the spleen (arrows).

approach achieves a seamlessly concealed umbilical incision and minimizes the occurrence of incisional hernias postoperatively.

We completed four partial splenectomies with the assistance of the Da Vinci robotic surgical system. Robotic surgery has emerged as a superior minimally invasive technique, showing great promise in treating various conditions, including splenic surgery. In 2003, Talamini *et al*[17] were the first to use the Da Vinci robotic system for splenectomy[17]. The first case of robot-assisted partial splenectomy was reported by Vasilescu *et al*[18] in 2010.

Compared to laparoscopic surgery, robotic surgery significantly reduces the operation time, intraoperative blood loss, and overall incidence of complications during the perioperative period[19,20]. Research has indicated that the average operation duration of an open partial splenectomy is 120 minutes, that of laparoscopic surgery is approximately 135 minutes, and that of robotic surgery is 150 minutes. Patients who undergo robotic surgery typically experience an average postoperative hospital stay of 6.2 days and have fewer complications[21-24]. Importantly, there is no considerable difference in postoperative hospital duration between robotic and laparoscopic surgeries. In our study, Patient 1 underwent surgery lasting 120 minutes, with an estimated blood loss of approximately 20 mL. The patient successfully avoided conversion to open surgery and was discharged on the fifth postoperative day without any complications. Patient 2 had a surgical duration of 160 minutes, with approximately 20 mL of blood loss, avoided conversion to open surgery, and was discharged on the sixth day without complications. Patient 3 had a total operation time of 145 minutes, with approximately 100 mL of blood loss; no transfusion was necessary, and the procedure did not convert to open surgery, allowing the patient to be discharged on the sixth day without any issues. Patient 4 underwent surgery lasting 180 minutes, with approximately 100 mL of blood loss, requiring no transfusion and avoiding conversion to open surgery; the patient was discharged on the eighth day free of complications. These findings are consistent with those of prior studies.

The robotic surgery system offers several advantages. Firstly, it provides a higher magnification ratio, intuitive control, and a clear 3D surgical field, thereby minimizing collateral damage during the procedure[6]. Additionally, robotic arms have a better range of motion and can perform intricate maneuvers, allowing for more precise surgical techniques[21]. However, there are notable disadvantages to using the Da Vinci robot. Firstly, there is a lack of force feedback. Secondly, the cost of the robotic system is relatively high.

CONCLUSION

To summarize, robotic-assisted partial splenectomy demonstrates notable advantages in treating benign splenic diseases, significantly reducing surgical complexity. Nevertheless, the widespread adoption of robotic surgery is hindered by its high cost and limited insurance coverage. Additional clinical cases are necessary to further validate its superior benefits.

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FOOTNOTES

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