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Revisiting vascular patency after spleen-preserving laparoscopic distal pancreatectomy with conservation of splenic vessels

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Abstract
Background We evaluated vascular patency and potential changes in preserved spleens after laparoscopic spleen-preserving distal pancreatectomy (SPDP) with conservation of both splenic vessels.
Methods We retrospectively analyzed the patency of conserved splenic vessels in patients who underwent laparoscopic or robotic splenic vessel-conserving SPDP from January 2006 to August 2010. The patency of the conserved splenic vessels was evaluated by abdominal computed tomography and classified into three grades according to the degree of severity.
Results Among 30 patients with splenic vessel-conserving laparoscopic SPDP, 29 patients with complete follow-up data were included in this study. During the follow-up period (median: 13.2 months), grades 1 and 2 splenic arterial obliteration were observed in one patient each. A total of five patients (17.2%) showed grade 1 or 2 obliteration in conserved splenic veins. Most patients (82.8%) had patent conserved splenic vein. Four patients (13.8%) eventually developed collateral venous vessels around gastric fundus and reserved spleen, but no spleen infarction was found, and none presented clinical relevant symptoms, such as variceal bleeding. There was no statistical difference in vascular patency between the laparoscopic and robotic groups ($P > 0.05$).
Conclusions Most patients showed intact vascular patency in conserved splenic vessels and no secondary changes in the preserved spleen after laparoscopic splenic vessel-conserving SPDP.

Keywords Spleen-preserving · Laparoscopic · Distal pancreatectomy · Vascular patency · Varix

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With recent advancements in laparoscopic instruments, experiences, and techniques, laparoscopic distal pancreatectomy is now regarded as a safe and effective treatment option for benign and borderline or low-grade malignant tumor of the pancreas [1, 2]. Traditionally, the spleen has always been removed together when distal pancreatectomy was performed because of its anatomic proximity with the distal pancreas and the mere technical comfort. However, more emphasis has been given to the significance of the spleen, not only in preventing infectious complications but also in providing a longer survival time with malignancy [3–5]. Recently every effort has been made to preserve the spleen when laparoscopic distal pancreatectomy is required to treat benign and borderline malignant pancreatic tumor.

In fact, since Kimura et al. [6] first reported splenic vessel-conserving spleen-preserving distal pancreatectomy (SPDP) for benign lesions of the pancreas, many surgeons began to focus on whether they can technically preserve the spleen. No studies have evaluated what happened to conserved splenic vessels and spleen after SPDP. However, Yoon et al. [7] recently published a very interesting paper about the patency of preserved vessels in patients who underwent laparoscopic splenic vessel-conserving SPDP. They reported a relatively high incidence of vascular obliteration, subsequent development of collateral vessels (varices), and infarction of the preserved spleen. They evaluated splenic vessel patency in 22 patients who underwent laparoscopic splenic vessel-conserving SPDP. Vascular obliteration in the preserved artery and vein was found in 6 (27.3%) and 17 patients (77.3%), respectively, within a month of the surgery, and in 3 (13.6%) and 13 patients (59.1%) 6 months or more after the surgery. Nine of ten patients (90%) with complete splenic vein occlusion developed a collateral circulation during the late postoperative phase. These observations are thought to be very important and have given many surgeons insight into the real clinical meaning of spleen "preservation" in laparoscopic distal pancreatectomy. Considering the high level of laparoscopic splenic vessel-conserving, SPDP is a time- and labor-consuming procedure [8, 9]. The high rate of vascular obliteration and its related secondary changes in preserved spleen represent the need for another surgical strategy in SPDP.

In this study, we evaluated the vascular patency of conserved splenic vessels and potential changes in preserved spleen based on follow-up computed tomography (CT) scan after laparoscopic SPDP with conservation of both splenic vessels to confirm whether the high rate of vascular obliteration is a general phenomena following laparoscopic splenic vessel-conserving SPDP.

Materials and methods

From January 2006 to August 2010, among those patients who underwent laparoscopic or robotic splenic vessel-conserving SPDP, we included patients with complete follow-up data in this study. All clinical data, including the patency of preserved splenic vessels, were assessed via retrospective analysis. All patients who received laparoscopic or robotic splenic vessel-conserving SPDP routinely underwent an abdominal CT scan before discharge, and regular CT scan assessments were performed at 6-month or 1-year intervals during outpatient clinic-based follow-up.

Laparoscopic or robotic splenic vessel-conserving spleen-preserving distal pancreatectomy

The patient was placed in the supine position on the surgical table and then shifted into the reverse Trendelenburg position with the left side up. The trocars used in laparoscopic cases were one 12-mm trocar for the camera, one 12-mm and two 5-mm trocars for the surgeon, and one 5-mm trocar for the assistant. In robotic procedures, we followed the operative technique as it was described in our previous reports [10–12]: a 12-mm trocar was placed below the umbilicus for the camera. Two 8-mm trocars for robot arms were placed in the right abdominal wall, another 8-mm trocar for robot arm was placed in the left abdominal wall, and a 12-mm trocar for the assistant was placed between the camera trocar and left robot arm trocar. After entering the lesser sac following division of the gastrocolic ligament, the direction of the dissection procedure was antegrade, in which the pancreas neck portion was first divided with an Endo-GIA® stapler (Tyco Healthcare, Norwalk, CT). Then, dissection of the splenic artery and vein from the pancreas parenchyma was performed toward the spleen, minimizing manipulation of the splenic vessels as much as possible. We did not retract the splenic vessels with vessel tape, but instead retracted the pancreas while making an effort to place the splenic vessels in the retroperitoneum during the operation as much as possible. We used an ultrasonic shear (Harmonic Scalpel®, Ethicon, Cincinnati, OH) and sometimes 5-mm metallic clips to control small tributary vessels between the pancreas and splenic vessels.

Computed tomography protocols

Images were obtained with a 16- or 64-channel multidetector CT scanner (Somatom sensation 16 or sensation 64; Siemens Medical Solutions, Forchhein, Germany). A precontrast scan was obtained before administration of contrast media. Using a bolus tracking technique, pancreatic parenchymal (or lateral arterial) phase was performed with a scan delay of 23 s after the Hounsfield Units (HU) of the abdominal aorta reached 100 HU. Portal venous phase was obtained with a scan delay of 25 s after the end of the previous phase. The CT parameters were as follows: 0.5-s rotation time, 120 kV, 240 mAs, 0.6-mm beam collimation, beam pitch = 1, and 3-mm slice thickness.

Assessment of patency of the splenic vessels and collaterals around the preserved spleen

We used the classification system of splenic vessel patency that was defined by Yoon et al. [7]. The patency of the splenic artery and vein were classified into three grades according to the degree of stenosis: intact (grade 0), partial occlusion or thrombosis (grade 1), and total occlusion or unidentified (grade 2; Fig. 1A, B). The degree of the collateral vessels was classified into three grades: no collateral vessels (grade 0), partial collateral vessels (grade 1), and

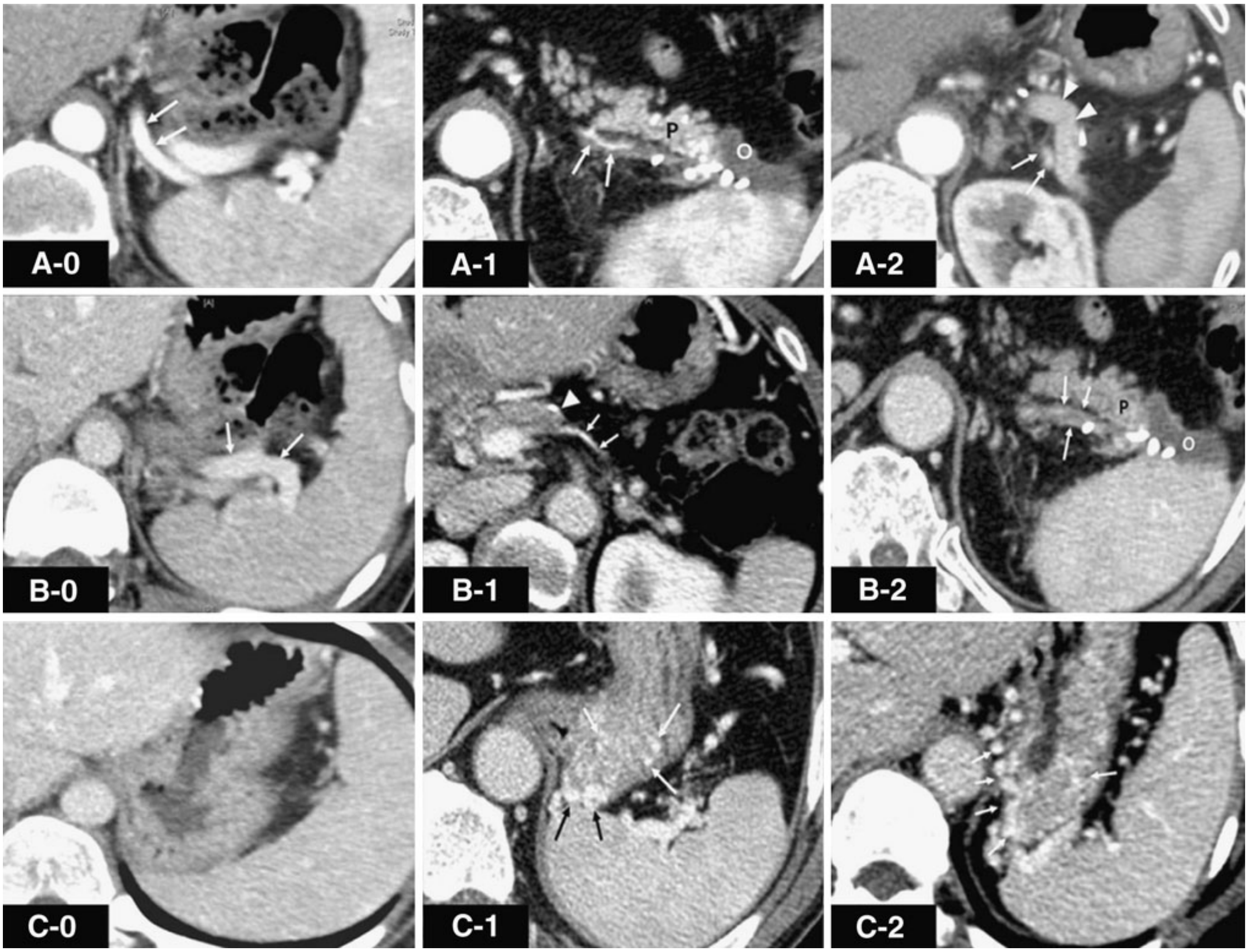

Fig. 1 Grading system of vascular patency and collateral vessels. **A** Splenic artery patency (G0, G1, G2). **A-0** Grade 0 patency: splenic artery (*arrow*) is well conserved (grade 0). **A-1** Splenic artery (*arrow*) is partially stenotic status (grade 1). **A-2** Splenic artery (*arrow*) is near totally obstructed (grade 2), otherwise, splenic vein (*arrowhead*) is intact. **B** Splenic vein patency (G0, G1, G2). **B-0** Splenic vein (*arrow*) was well preserved (grade 0). **B-1** Splenic vein has partially stenotic status (grade 1). The *arrowhead* indicates the resection margin of the pancreas. **B-2** Splenic vein (*arrow*) is totally obstructed. **C** Degree of collateral vessels (G0, G1, G2). **C-0** There were no collateral vessels (grade 0). **C-1** Gastric fundal varix is newly developed after surgery (grade 1). **C-2** More prominent gastric fundal and perigastric venous engorgement was observed (grade 2). *P* remnant pancreas; *O* fluid collection on resected site

prominent collateral vessels (grade 2; Fig. 1C). Two radiologists came to a consensus in assessing the degree of splenic vessel stenosis with a retrospective review of the CT scan.

Results

General characteristics

During the study period, a total of 74 patients underwent minimally invasive (laparoscopic or robotic) distal pancreatectomy. However, 37 patients were excluded because they also underwent splenectomy, due to malignancy and difficulty in spleen preservation. An additional seven patients were excluded, because the spleen was preserved using a combined segmental resection of both splenic vessels (Warshaw procedure). Therefore, 30 patients with laparoscopic or robotic splenic vessel-conserving SPDP were considered for this study; however, 29 patients with complete follow-up CT study were ultimately included (follow-up rate: 96.6%). Patient characteristics are described in Table 1.

Perioperative outcomes and CT follow-up

Robotic splenic vessel-conserving SPDP was performed in 16 patients, whereas the laparoscopic approach was used in 13. The mean operation time was 287.8 ± 121.6 min. The mean length of hospital stay was 7.1 ± 2.2 days. Grade B

Table 1 Patient characteristics

	Frequency, median ± standard deviation
Age (year)	47.6 ± 14.4
Gender (female:male)	16:13
Diagnosis	
Solid pseudopapillary tumor	7
Serous cyst tumor	6
Neuroendocrine tumor	5
Intraductal papillary mucinous tumor	5
Mucinous cyst tumor	4
Chronic pancreatitis	1
Intrapancreatic accessory spleen	1
Length of resected pancreas (cm)	8.4 ± 3.7
Surgical approach (laparoscopic:robotic)	13:16
Operation time (min)	287.6 ± 121.6
Length of hospital stay (days)	7.1 ± 2.2
POPF[a] (grade B)	2

[a] *POPF* postoperative pancreatic fistula, defined according to the International Study Group on Pancreatic Fistula [17]

postoperative pancreatic fistula was observed in two patients (6.9%), who recovered with conservative treatment. No perioperative mortality was noted (Table 1).

The median short-term period of CT scan assessment was 5.3 (range, 2–12) days, and the median long-term period during outpatient clinic-based follow-up was 13.2 (range, 3.3–34) months.

Conserved splenic artery patency

We did not find any splenic artery obliteration in preoperative CT scans. One case of grade 1 and one case of grade 2 splenic arterial obliteration were observed during the early postoperative period. These vascular obliterations continued to the late postoperative period without change. Twenty-seven patients (93.1%) showed grade 0 patency in conserved splenic artery during the follow-up period (Fig. 2).

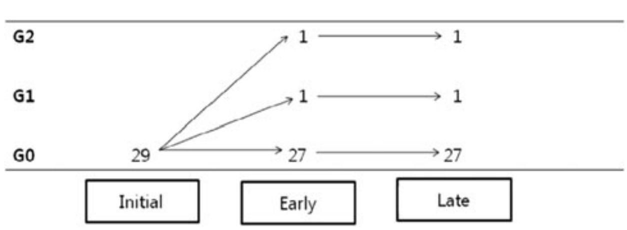

Fig. 2 Conserved splenic artery patency according to follow-up period. Note that none of the obliterated changes in conserved splenic arteries were resolved to lower grades (G1 or G0) during the follow-up period

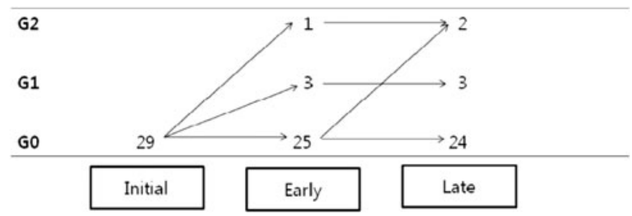

Fig. 3 Conserved splenic vein patency according to follow-up period. Similar to the splenic artery, note that none of the obliterated vessels were resolved to lower grades (G1 or G0) during follow-up period, but one additional patient developed G2 venous obliteration later during the follow-up period

Conserved splenic vein patency

There was no splenic vein obliteration on the preoperative CT scan. During the early postoperative period, grades 1 and 2 splenic vein obliteration were observed in three and one patients, respectively. During the follow-up period, these changes in vascular obliteration continued to the late postoperative period, but one additional patient with grade 0 patency in the early period developed grade 2 obliteration in the conserved splenic vein. Finally, a total of five patients (17.2%, three of grade 1 and two of grade 2) showed partial or complete obliteration in the conserved splenic vein. Twenty-four patients (86.2%) showed grade 0 patency in the conserved splenic vein during the follow-up period (Fig. 3).

Spleen and collateral circulation

Four patients (13.8%, one of grade 1 and three of grade 2) eventually developed collateral venous vessels around the gastric fundus and reserved spleen. However, no spleen infarction was found, and none presented clinically relevant symptoms, such as variceal bleeding during the follow-up period (Fig. 4).

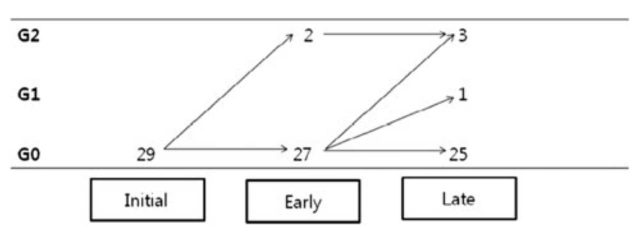

Fig. 4 Perigastric collateral vessels according to follow-up period. There seems to be a time lag between the development of perigastric collateral vessels and splenic vein obliteration, but most patients with splenic vein obliteration developed perigastric collateral vessels during the late follow-up period (4/5 patients). Note that one additional patient with newly developed splenic venous obliteration (G2) showed G2 perigastric collateral vessels during the late follow-up period, suggesting that long-term follow-up should be considered for patients with splenic vessel-conserving SPDP

Table 2 Vascular patency rate between two different surgical approaches

	Laparoscopic ($N = 13$)	Robotic ($N = 16$)	*P* value
Arterial obliteration			
No (G0)	11	16	0.192
Yes (G1, G2)	2	0	
Venous obliteration			
No (G0)	10	14	0.632
Yes (G1, G2)	3	2	
Collateral development			
No (G0)	10	15	0.299
Yes (G1, G2)	3	1	

Vascular patency rate and video re-evaluation in laparoscopic and robotic SPDP

The incidence of vascular obliterations was compared according to approach (laparoscopic vs. robotic). We observed two arterial obliterations in the laparoscopic group and none in the robotic group. Venous obliteration was found in three patients of laparoscopic group and two patients of robotic group. Collateral venous engorgement was observed in three patients in the laparoscopic group and in one patient in robotic group. However, in all of the above findings, there were no statistical differences between the two groups (Table 2).

When reevaluating the recorded video of patients with obliteration in conserved splenic vessels, it was suggested that it was related to frequent bleeding and vascular manipulation during the procedures due to chronic pancreatitis, anatomic causes, or limited experience. It was noted in one patient that overly close and long activation of the ultrasonic shears near the conserving splenic artery may have been related to vascular obliteration (patient 3; Table 3).

Discussion

Unlike the previous report by Yoon et al. [7], our data showed a relatively lower rate of vascular obliteration after laparoscopic or robotic splenic vessel-conserving SPDP. Even in cases with vascular obliteration, its related secondary changes (collaterals and varices) did not cause clinical problems during the follow-up period. Therefore, the high rate of vascular obliteration in conserved splenic vessels and secondary changes in the preserved spleen may not be general phenomena after laparoscopic splenic vessel-conserving SPDP.

Technically, when performing minimally invasive (laparoscopic or robotic) splenic vessel-conserving SPDP, we tried to remove the pancreas by placing both splenic vessels in the retroperitoneum and minimize vascular manipulation during dissection of the pancreas off the splenic vessels. We do not apply vessel tape for traction of splenic vessels during dissection of the pancreas from these conserving vessels in an effort to reduce potential vascular damage. Yoon et al. [7] suggested two potential mechanisms to raise the occlusion rate of the splenic vein over that of the splenic artery. First, the splenic vein is so densely adherent to the pancreas that more manipulation is required during dissection of the splenic vein from the

Table 3 Recorded video assessment in patients with vascular obliteration in conserved splenic vessels

Patient	Age/gender	Diagnosis	Vascular obliteration	Surgical modality	
				Laparoscopic	Robotic
1	44/Female	SPT	Vein (G1)	Bleeding, too much vascular manipulation (first case of splenic vessel-conserving LSPDP)	
2	67/Male	NET	Artery (G1)	Bleeding	
			Vein (G2)	Bleeding	
3	56/Male	SCA	Artery (G2)	Too closely activating ultrasonic shears to conserving splenic artery	
4	45/Female	MCA	Vein (G2)		Chronic pancreatitis → bleeding, too much vascular manipulation
5	41/Female	SPT	Vein (G1)		Pancreas behind splenic hilum → bleeding, too much vascular manipulation
6	61/Female	MCA	Vein (G1)	Chronic pancreatitis, pancreas behind splenic hilum → bleeding, too much vascular manipulation	

SPT solid pseudopapillary tumor, *LSPDP* laparoscopic spleen-preserving distal pancreatectomy, *NET* neuroendocrine tumor, *SCA* serous cyst adenoma, *MCA* mucinous cyst adenoma pancreas. Second, the splenic vein is more susceptible to thrombosis and inflammation [13–15] due to lack of muscle and elastic fibers, lower blood pressure, and lower speed than artery.

In our observation, two patients had grade B postoperative pancreatic fistula, but they did not show any obliterated conserved splenic vessels during the follow-up period. This may have been due to the limited number of patients, so we should pay attention to the potential reasons for conserved vascular obliteration in future clinical practice. Actually, when we carefully reviewed the recorded videos of patients with vascular obliteration, most cases were related to frequent bleeding during the operation, and many vascular manipulations were required for splenic vessel conservation, especially the splenic vein because splenic vein, which is densely adherent to the pancreas due to its specific anatomic relationship, such as pancreatic tail behind splenic hilum and chronic pancreatitis associated with pancreatic pathology (Table 3). These findings are thought to support the potential mechanism suggested by Yoon et al. [7] for vascular obliteration following splenic vessel-conserving SPDP. In addition, one patient with splenic artery obliteration suggested that activating the ultrasonic shear too close to the conserving artery might provoke thermal damage of the vessel and subsequently cause stricture and obliteration.

Gianduzzo et al. [16] reported that the activated blades of the ultrasonic shear may potentially cause thermal injury to the cavernous nerves. The tips of the activated blades of the ultrasonic shear may attain temperatures exceeding 150°C, and the activated blades of the ultrasonic shear required 40 s to cool from the peak temperature exceeding 150°C to less than 60°C. They demonstrated the degree of lateral thermal spread from ultrasonic shear using thermographic mapping and histologic confirmation of adjacent tissue around the dissection field. The median thermal lateral spread of ultrasonic shear was 6.42 mm, which may cause thermal injury to the artery to be one of the potential mechanisms for arterial obliteration.

Theoretically, the robotic surgical system has several advantages in performing minimally invasive surgery. A three-dimensional magnified view and seven degree articulating movement without tremor enable the operator to handle the tissue and organ with precise manipulation. It has been introduced to overcome the critical limitations of conventional laparoscopic techniques; however, most surgeons have already overcome the limitations of laparoscopic surgery by accumulating experience and instruments. In this study, we compared the vascular patency rate between two different minimally invasive approaches (laparoscopic vs. robotic) based on the hypothesis that robotic surgical system would be beneficial in patency of conserved splenic vessels, but there are no significant statistical differences in vascular patency of conserved splenic vessels between the two groups (Table 2). Regardless of approach, vascular obliteration is apparently related to frequent bleeding and excessive vascular manipulation during the procedure due to anatomic difficulties and chronic inflammation between the splenic vessels and pancreas parenchyma. This may suggest that the methodological differences of minimally invasive surgical techniques, laparoscopic or robotic, are not that important in keeping vascular patency following splenic vessel-conserving SPDP as long as surgeons stick to the surgical principle of minimizing vascular manipulation and bleeding. Therefore, it is thought that deciding upon a laparoscopic technique based on experience is more important for lowering the vascular obliteration rate than considering the several merits of robotic surgical system in minimally invasive surgery.

One of five patients in the present study and 3 of 13 patients in the previous study by Yoon [7] showed that obliteration in conserved splenic vessels can develop even long after surgery, and most patients (4/5 patients) with obliterated conserved splenic vein ultimately developed perigastric collateral vessels during the follow-up period. Therefore, it is highly recommended that long-term follow-up be conducted after splenic vessel-conserving SPDP. This is very important because splenic vessel-conserving laparoscopic SPDP is usually performed for benign or borderline tumors, for which long-term follow-up is thought to be unnecessary. Yoon's [7] previous original study and present observations suggest that there is an important message in our daily practice of minimally invasive surgery, and certainly give significant motivation to think about the quality of surgical techniques for function-preserving minimally invasive surgery. In fact, we admit that surgical interest has apparently been focused only on the technical feasibility of SPDP.

It is necessary to interpret the current results carefully, because this study has unavoidable critical limitations. It is basically a retrospective study, so a selection bias must be involved. The CT protocol, especially, may differ between institutions and determination of vascular obliteration is solely subjective according to radiologists.

In conclusion, conserved both splenic vessels are mostly patent, and the clinical impact of vascular obliteration-related changes in preserved spleens is so limited that laparoscopic splenic vessel-conserving SPDP is still a safe and recommendable technique. However, if the dissection for conserving splenic vessels is expected to be difficult and requires frequent vascular manipulation for splenic vessels conservation, it would be beneficial to convert to Warshaw's procedure when considering potential vascular obliteration and its secondary changes in a preserved spleen following splenic vessel-conserving SPDP. This case-specific selective approach to minimally invasive

SPDP cannot only increase the quality of surgery, but also the patients' life expectancy. Continuous attention needs to be paid to this issue based on more careful and long-term follow-up results.

Disclosures Drs. Ho Kyoung Hwang, Young Eun Chung, Kyoung Ah Kim, Chang Moo Kang, and Woo Jung Lee have no conflicts of interest or financial ties to disclose.

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