A new option for laparoscopic spleen-preserving distal pancreatectomy: three cases with splenic artery preservation and resection of the splenic vein

Masataka Okuno 1,*, Yasuhiro Shimizu 1, Yoshiki Senda 1, Seiji Natsume 1, Shoji Kawakatsu 1, Seiji Ito 1, Koji Komori 1, Tetsuya Abe 1, Kazunari Misawa 1, Yuichi Ito 1, Takashi Kinoshita 1, Eiji Higaki 1, Hironori Fujieda 1, Yusuke Sato 1, Akira Ouchi 1, Masato Nagino 1 and Kazuo Hara 2

1Department of Gastroenterological Surgery, Aichi Cancer Center Hospital, Aichi, Japan
2Department of Gastroenterology, Aichi Cancer Center Hospital, Aichi, Japan
*Correspondence address. Department of Gastroenterological Surgery, Aichi Cancer Center Hospital, 1-1 Kanokoden, Chikusa-ku, Nagoya, Aichi 464-8681, Japan.
Tel: +81-52-762-6111; Fax: +81-52-764-2963; E-mail: m.okuno@aichi-cc.jp

Abstract
There are two techniques for a spleen-preserving distal pancreatectomy (SPDP): SPDP with splenic vessel preservation, and SPDP with splenic vessel resection. In some cases, although the splenic artery (SpA) can be preserved, the splenic vein (SpV) must be resected. We report the short- and long-term outcomes of three patients who underwent a new technique of laparoscopic SPDP with SpA preservation and SpV resection (SPDP-VRes). A grade B pancreatic fistula, which occurred in two patients, was successfully treated with drainage tube management. In all cases, the omental branches of the left gastroepiploic vein functioned as a drainage vein, and there was no splenomegaly, thrombocytopenia, or varix formation during the follow-up period (19 months to 5 years). Patients undergoing laparoscopic SPDP-VRes had no severe complications during the follow-up period; preserving the left omental branch is a key to this procedure. Laparoscopic SPDP-VRes might be a useful treatment option for patients undergoing SPDP.

INTRODUCTION
Spleen-preserving distal pancreatectomy (SPDP) has been performed in patients with benign or low-grade malignancies of the body and tail of the pancreas who do not require lymph node dissection. There are two variations of the SPDP: SPDP with splenic vessel preservation (SPDP-Pre) [1], and SPDP with splenic vessel resection (SPDP-Res, the so-called Warshaw technique) [2]. Advances in laparoscopic surgery have made it possible to perform complex cases as closed rather than open procedures [3–6]. Although we have attempted to perform laparoscopic SPDP-Pre, dissection between the splenic vessels and pancreatic parenchyma can be difficult because of tumor size, inflammation and/or adhesions. In such cases, we have changed laparoscopic SPDP-Pre to laparoscopic SPDP-Res, or occasionally to laparoscopic SPDP with splenic artery (SpA) preservation and splenic vein (SpV) resection (SPDP-VRes). Herein, we report the short- and long-term outcomes of laparoscopic SPDP-VRes in three cases.
A 31-year-old woman was diagnosed with a solid pseudopapillary neoplasm (SPN) based on endoscopic ultrasonography-guided fine needle aspiration (EUS-FNA) cytology. Contrast-enhanced computed tomography (CT) showed a 25-mm tumor with calcifications in the pancreatic body that widely contacted the splenic vein. Post-operative hospital stay was 35 days and the blood loss was negligible. The patient developed a grade B pancreatic fistula [7] which required drainage tube management. The patient was discharged on post-discharge day 35.

**Table 1.** Clinical features of three cases who underwent laparoscopic SPDP-VRes

| Case | Age, years | Gender | Diagnosis | Reason for resection of the SpV | Operative time, min | Blood loss, ml | Post-operative hospital stay, days | Major venous return routes from the spleen to SMV/PV | Platelet level, x10^4/μL | Spleen volume, cm³ | Long-term complications |
|------|------------|--------|-----------|---------------------------------|---------------------|----------------|-----------------------------------|---------------------------------|------------------|-------------------|----------------------|
| 1    | 31         | F      | SPN       | Close to the tumor              | 254                 | Little         | 35                                | LOB-ARCV                      | 27.1             | 195               | None                |
|      |            |        |           |                                  |                     |                |                                   | SGV-Stomach-LGV-GEV           |                  |                   |                     |
| 2    | 46         | F      | pNET      | Adhesion                        | 267                 | 20             | 37                                | LOB-MCV                       | 26.3             | 126               | None                |
|      |            |        |           |                                  |                     |                |                                   | SGV-Stomach-LGV               |                  |                   |                     |
| 3    | 38         | F      | MCN       | Close to the tumor              | 241                 | Little         | 9                                 | LOB-MCV-SPV                   | 15.4             | 133               | None                |

SPDP-VRes: spleen-preserving distal pancreatectomy with splenic artery preservation and splenic vein resection, F: female, SPN: solid pseudopapillary neoplasm, pNET: pancreatic neuroendocrine tumor, MCN: mucinous cystic neoplasm, SpV: splenic vein, SMV: superior mesenteric vein, PV: portal vein, LOB: left omental branch, ARCV: accessory right colic vein, SGV: short gastric vein, LGV: left gastric vein, GEV: gastroepiploic vein, MCV: middle colic vein.
Laparoscopic spleen-preserving distal pancreatectomy

Figure 2. (a) Contrast-enhanced CT shows a 25-mm tumor in the pancreatic body (arrowhead) that is in wide contact with the splenic vein (arrow). (b) 3D reconstruction image shows a dilated GEV and the arcade that is formed by the LOB and ARCV. (c) Schema of venous return in Case 1. The blood flow from the spleen flows into the portal vein through three main routes: LOB to ARCV; the SGV to the LGV via the stomach wall; and GEV. Postoperative Day 35. The histologic diagnosis was a SPN with infiltrative growth to the pancreatic parenchyma and contact with the SpV wall. The surgical margin was negative for tumor cells. A postoperative CT scan revealed that the omental branch of the LGEV, left gastric vein (LGV) and GEV were dilated. There were no gastric varices and no gastric wall enhancement (Fig. 2b). There was no SpA stenosis. The blood flowed from the spleen into the superior mesenteric vein (SMV) and portal vein (PV) via three main routes: the omental arcade to the accessory right colic vein (ARCV); the short gastric vein (SGV) to the LGV via stomach wall and the gastroepiploic arcade (Fig. 2c). The preoperative and post-discharge (47 postoperative days [PODs]) platelet levels were 27.1 and 17.7 x 10^4/μL, respectively. The pre- and post-operative (8 postoperative months [POMs]) spleen volumes measured by CT scan were 195 and 144 cm^3, respectively. The patient remains healthy without a recurrence 5 years postoperatively.

Case 2
A 46-year-old woman was shown to have hypoglycemia during a medical examination. She presented to our hospital for evaluation of worsening hypoglycemic symptoms. A CT scan of the abdomen did not reveal any abnormalities. Contrast-enhanced magnetic resonance imaging (MRI) showed a 5-mm tumor in the pancreatic tail which had a low-signal intensity on T1-weighted images and a high-signal intensity on T2-weighted images (Fig. 3a and b). EUS-FNA cytology indicated a pancreatic neuroendocrine tumor (pNET). An insulinoma was highly suspected and we performed a laparoscopic spleen-preserving procedure. There was a scar on the ventral surface around the tumor, which was thought to be caused by inflammation after the EUS-FNA. Although the SpA could be preserved because the SpA was not buried in the pancreatic parenchyma, it was difficult to separate the SpV from the pancreatic parenchyma around the scar because of adhesions and bleeding. The operative time was 267 min and the estimated blood loss was 20 cc. The patient developed a grade B pancreatic fistula [7], which required drainage tube management. The patient was discharged on Day 37 postoperatively. The histologic diagnosis was a pNET (10 mm in diameter) that did not contact the SpV and the surgical margins were negative for tumor cells. A postoperative CT scan revealed marked dilation of the omental branch of the LGEV (Fig. 3c). There was no SpA stenosis. The blood flowed from the spleen into the SMV via the left omental branch (LOB) through the middle colon vein. Although there was increased venous blood flow into the gastric fundus wall via the SGV and dilation of the LGV, no varices were observed. No right and LGEV arcade formed (Fig. 3d). The preoperative and post-discharge (47 PODs) platelet levels were 26.3 and 17.0 x 10^4/μL, respectively. Pre- and post-operative (5 POMs) spleen volumes were 126 and 145 cm^3, respectively. The hypoglycemic symptoms improved and she has been alive without a recurrence 4 years postoperatively.

Case 3
A 38-year-old woman was diagnosed with a mucinous cystic neoplasm (MCN) based on imaging studies. A CT scan showed a 35-mm cystic tumor in the pancreatic tail which had a low-signal intensity on T1-weighted images and a high-signal intensity on T2-weighted images (Fig. 4a and b). EUS-FNA cytology indicated a pancreatic neuroendocrine tumor (pNET). An insulinoma was highly suspected and we performed a laparoscopic spleen-preserving procedure. There was a scar on the ventral surface around the tumor, which was thought to
postoperative course was uneventful and the patient was discharged on day 9 after surgery. The histologic diagnosis was a MCN; there was no border between the SpV and cyst wall due to fibrosis. The surgical margins were negative for tumor cells. A postoperative CT scan revealed marked dilation of the omental branch of the LGEV without gastric varices (Fig. 4b). There was no SpA stenosis. The blood flowed from the spleen into the SMV via the LOB through the middle colon and splenic veins. No right and LGEV arcade formed (Fig. 4c). The preoperative and post-discharge (26 PODs) platelet levels were 15.4 and 13.0 x 10^4/μL, respectively. The pre- and post-operative (7 POMs) spleen volumes were 133 and 185 cm^3, respectively. The patient remains healthy without a recurrence 19 months postoperatively.

**DISCUSSION**

Reports on laparoscopic SPDP have been increasing [3–6] because of advances in laparoscopic surgery and recognition of the importance in preserving the spleen. The spleen has important roles in the immune system and in removing blood cells. In addition, resection of the spleen leads to overwhelming post-splenectomy infections (OPSIs). Although the incidence of OPSIs in adults is low, sepsis mortality rates as high as 50% have been reported [8].

Splenic vessel preservation may be the optimal way to preserve blood flow to the spleen, but the SpV must be resected during this process in some cases. The SpA usually passes through the cranial portion of the pancreas and there are a few branches from the SpA. Therefore, it is relatively easy to divide the pancreas and the SpA. Because the SpV usually passes through the groove behind the pancreatic body and tail and there are many small branches into the SpV, the SpV is relatively difficult to divide from the pancreas. Moreover, if there is pancreatitis and adhesions to the SpV, it is more difficult to divide the vein and pancreas without injury or bleeding. In addition, there are other reasons for surgical difficulty; specifically, tumors close to the SpV are a risk for residual lesions, perforation of the cystic wall and tumors that are too large to secure the field of view. In such cases, SPDP-Res or conventional distal pancreatectomy with splenectomy is generally indicated.

Because SPDP-Res is a relatively simple procedure compared with the SPDP-Pre, the SPDP-Res has a shorter operative time and less blood loss [9]. Splenic infarction and abscess of the conserved spleen are more frequent in SPDP-Res than SPDP-Pre [4, 5, 9, 10]. This finding may be due to insufficient blood flow from the short gastric and gastroepiploic arteries, which are usually preserved in the SPDP-Res. To avoid ischemia of the spleen, we have reported a new technique, the SPDP-VRes, in which the SpA is preserved and the SpV is resected. Indeed, there are no reports on this procedure.

Congestion of the spleen and the development of gastric varices is a concern when performing a SPDP-VRes. Blocking SpV flow and preserving the SpA is similar to a pancreaticoduodenectomy with combined PV resection for pancreatic cancer invading the PV/SMV confluence, which results in left-sided portal hypertension [11, 12]. To prevent left-sided portal hypertension after a pancreaticoduodenectomy with resection of the PV/SMV confluence, preserving multiple drainage veins as much as possible is considered efficacious [11, 13, 14]. When performing a SPDP-VRes, we always preserve the omental branches of the LGEV as an essential drainage vein, as well as the short gastric and LGEVs that are normally preserved in the SPDP. The LOB forms the arcade in the lower omentum with the right omental branch (the venous arch of Barkow) [15], and blood flows through the gastrocolic trunk or the middle colon vein to the PV. The preserved LGEV can also serve as collateral circulation, but in some cases an arcade with the right GEV is not formed. In the three cases presented herein, the GEV arcade was confirmed in only one case (Case 1) on postoperative examination. The preserved LOB functioned as an important drainage vein and there were no complications, such as thrombocytopenia, splenomegaly and varix formation, in all three cases who underwent SPDP-VRes during a relatively long-term follow-up.

In the previous reports of SPDP-Res and SPDP-Pre, the left omental vessels and the splenocolic ligament are divided [1, 2]. This certainly provides a better view of the splenic hilum, but it sacrifices the drainage vein of the left omental vein. Even if the left omental vein is preserved, the field of view of the splenic hilum can be obtained by properly retracting the stomach and left lateral segment of the liver to the right in the cranial direction. Preserving the LOBs is a key point in all SPDP procedures, especially in the SPDP-VRes because the LOBs function as an essential drainage vein.
CONCLUSIONS

SPDP-VRes may be a useful treatment option for patients who have tried to undergo SPDP-Pre. There were no serious complications during short- and long-term follow-up. It is important to preserve the omental branches of the LGEV to avoid spleen congestion.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

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REFERENCES

1. Kimura W, Inoue T, Futakawa N, Shinkai H, Han I, Muto T. Spleen-preserving distal pancreatectomy with conservation of the splenic artery and vein. Surgery 1996;120:885–90.
2. Warshaw AL. Conservation of the spleen with distal pancreatectomy. Arch Surg 1988;123:550–3.
3. Han HS, Min SK, Lee HK, Kim SW, Park YH. Laparoscopic distal pancreatectomy with preservation of the spleen and splenic vessels for benign pancreas neoplasm. Surg Endosc 2005;19:1367–9.
4. Jean-Philippe A, Alexandre J, Christophe L, Denis C, Masson B, Fernandez-Cruz L, et al. Laparoscopic spleen-preserving distal pancreatectomy: splenic vessel preservation compared with the Warshaw technique. JAMA Surg 2013;148:246–52.
5. Dai MH, Shi N, Xing C, Liao Q, Zhang TP, Chen G, et al. Splenic preservation in laparoscopic distal pancreatectomy: surgical strategy and late outcomes of splenic preservation. Br J Surg 2017;104:452–62.
6. Moekotte AL, Lof S, White SA, Marudanayagam R, Al-Sarireh B, Rahman S, et al. Splenic preservation versus splenectomy in laparoscopic distal pancreatectomy: a propensity score-matched study. Surg Endosc 2020;34:1301–9.
7. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, et al. The 2016 update of the international study group (ISGIPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 2017;161:584–91.
8. Rubin LG, Schaffner W. Clinical practice. Care of the asplenic patient. N Engl J Med 2014;371:349–56.
9. Wang L, Wu D, Cheng YG, Xu JW, Chu HB, Zhang GY, et al. Warshaw technique in laparoscopic spleen-preserving distal pancreatectomy: surgical strategy and late outcomes of splenic preservation. Biomed Res Int 2019;2019:4074369.
10. Partelli S, Cirocchi R, Randolph J, Parisi A, Coratti A, Falconi M. A systematic review and meta-analysis of spleen-preserving distal pancreatectomy with preservation or ligation of the splenic artery and vein. Surgeon 2016;14:109–18.
11. Ono Y, Matsueda K, Koga R, Takahashi Y, Arita J, Takahashi M, et al. Sinistral portal hypertension after pancreaticoduodenectomy with splenic vein ligation. Br J Surg 2015;102:219–28.
12. Mizuno S, Kato H, Yamaue H, Fujii T, Satoi S, Saiura A, et al. Left-sided portal hypertension after pancreaticoduodenectomy with resection of the portal vein/superior mesenteric vein confluence in patients with pancreatic cancer: a project study by the Japanese Society of Hepato-Biliary-Pancreatic Surgery. Ann Surg 2021;274:e36–44.
13. Yu X, Bai X, Li Q, Gao S, Lou J, Que R, et al. Role of collateral venous circulation in prevention of sinistral portal hypertension after pancreaticoduodenectomy: a single-center experience. J Gastrointest Surg 2020;24:2054–61.
14. Shihara M, Higuchi R, Izumo W, Yazawa T, Uemura S, Furukawa T, et al. Retrospective evaluation of risk factors of postoperative varices after pancreaticoduodenectomy with combined portal vein resection. Pancreatology 2020;20:522–8.
15. Ibukuro K, Ishii R, Fukuda H, Abe S, Tsukiyama T. Collateral venous pathways in the transverse mesocolon and greater omentum in patients with pancreatic disease. AJR Am J Roentgenol 2004;182:1187–93.