

Original article

**Laparoscopic spleen-preserving distal pancreatectomy
with and without splenic vessel preservation:
the role of the Warshaw procedure**

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Short running head: Laparoscopic spleen-preserving distal pancreatectomy

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Abstract

Background/Objectives: Laparoscopic spleen-preserving distal pancreatectomy (LSPDP) for low-grade malignant pancreas tumors was recently demonstrated. Although the procedure with splenic vessel preservation (SVP) is optimal for LSPDP, SVP is not always possible in patients with a large tumor or a tumor attached to splenic vessels. This study aimed to analyze the safety of two procedures: LSPDP without SVP, known as the Warshaw technique (lap-WT), and LSPDP with SVP (lap-SVP).

Methods: Seventeen patients who underwent a lap-WT and seven patients who underwent a lap-SVP were investigated retrospectively.

Results: The median follow-up duration was 45 (range 17–105) months. In the lap-WT and lap-SVP patients, the sizes of the tumors were 5 (1.3–12) and 1.5 (1–4) cm; the operative times were 304 (168–512) and 319 (238–387) min; the blood loss was 210 (5–3250) and 60 (9–210) gr; the length of the postoperative hospital stay was 15 (8–29) and 18 (5–24) days; the peak platelet counts were 37.2 (14.6–65.2) and 26.4 (18.8–41) $\times 10^4/\mu\text{L}$, and splenomegaly was observed in 10 (59%) and three (43%) patients, respectively. In both procedures, there was no local recurrence. In the lap-WT group, splenic infarctions were seen in four (24%) patients and perigastric varices were seen in two (12%) patients. All of these patients were observed

conservatively.

Conclusions: Both the lap-WT and lap-SVP were found to be safe and effective, and in cases in which the tumor is relatively large or close to the splenic vessels, lap-WT can be used as the more appropriate procedure.

Key words: pancreas tumor, splenic vessel preservation, laparoscopic distal pancreatectomy, Warshaw technique

Introduction

Spleen-preserving distal pancreatectomy (SPDP) is a suitable procedure for patients with benign or low-grade malignant pancreas tumors (1) because these patients are likely to survive for a long time, and therefore it is important to preserve their immunological function; in other words, to preserve the spleen. There are two spleen-preserving methods in SPDP: in one, the splenic artery and vein are preserved, and in the other they are excised (2–4). Although the preservation of splenic vessels is optimal for SPDP, it is sometimes difficult to preserve splenic vessels in patients with an unusually large tumor or a tumor attached to splenic vessels. SPDP with excision of the splenic artery and vein was first described in 1988 by Warshaw (5), in a report describing a technique that was successfully performed in 22 of 25 consecutive patients. This Warshaw technique (WT) spread widely as the best option for SPDP.

At the same time, laparoscopic surgical techniques have become well established in recent years, and several reports on laparoscopic distal pancreatectomy for low-grade malignant pancreatic tumors have been published (6–11). In the Warshaw technique, the postoperative splenic circulation is maintained by the collateral vessels via the short gastric vessels. Thereby, this blood flow induces gastric varices (12). Several research groups have described the risk of the development of gastric varices or splenic infarction linked to

the Warshaw technique (12–14), but splenomegaly and the elevation of platelet counts following the use of the Warshaw technique have not been reported in detail. In the present study, we describe both a way to preserve the splenic blood supply when performing the laparoscopic Warshaw technique (lap-WT) and our long-term results (including those concerning splenic circulation) in a comparison with laparoscopic SPDP with splenic vessel preservation (lap-SVP).

Materials and Methods

Between September 2005 and January 2013, a total of 24 patients diagnosed with benign or low-grade malignant pancreas tumors underwent laparoscopic SPDP in our Department of Surgery. Of those, 17 patients underwent lap-WT and the other seven patients underwent lap-SVP. The lap-WT procedure was indicated for relatively large tumors and for tumors located close to splenic vessels. The patients' characteristics are described in Table 1. The sizes of the tumors in the group of lap-WT patients were larger than those of the lap-SVP patients. In both groups, no tumor oppressed the splenic vessels and no collateral vessels developed preoperatively. Both procedures included hand-assisted laparoscopic surgery (HALS) and single-incision laparoscopic surgery (SILS).

We retrospectively analyzed the operative outcomes and the long-term outcomes (especially of splenic circulation) afforded by the two procedures. The platelet counts were evaluated on blood tests. The splenic volume was calculated on computed tomography (CT) scans using SYNAPSE VINCENT software (Fujifilm, Tokyo). The patients were followed up by CT scan within 3 months, at 6 months, 1 year after the operation, and once per year thereafter. We defined postoperative splenomegaly as when the splenic volume increased more than 120% compared to the preoperative volume. Perigastric varices with a venous dia.

> 5 mm were diagnosed on enhanced CT scan. All data are expressed as the median with range. The follow-up duration between two procedures was compared by the Mann-Whitney *U*-test using GraphPad PRISM6 for Mac.

Surgical techniques

Under general anesthesia, the patient was placed in the supine position. We used three 5-mm and one 12-mm working ports for the laparoscopic distal pancreatectomy. A 12-mm port at the umbilicus was also used for the 10-mm flexible laparoscope (Olympus, Tokyo). The port placement for laparoscopic pancreatic surgery using HALS and SILS has been reported (15,16).

In the lap-WT procedure, after pneumoperitoneum was achieved, the greater omentum was divided near the right gastroepiploic artery to widely reveal the anterior side of the pancreas body and tail. The splenicocolic ligament and gastrosplenic ligament were not divided, in order to maintain the blood supply to the spleen. After laparoscopic ultrasonography was performed to confirm the location of the tumor and to determine the resection line of the pancreas, the dissection of the pancreas was started at the inferior side of the pancreas near the resection line, and the pancreas was removed from the retroperitoneal space by rolling

the pancreas to the superior side.

The splenic artery was mobilized near the dissection line of the pancreas and divided by clipping both the proximal and distal sides; however, the splenic vein was not mobilized from the pancreas. An endoscopic linear stapler (End-GIA, Covidien, Norwalk, CT, USA) was used to resect the pancreas with the splenic vein (Fig. 1a). Thereafter the distal pancreas dissection from the retroperitoneal space was continued to reach the hilum of the spleen. In this process, we thought it was important not to dissect the splenocolic ligament, gastrosplenic ligament (including short gastric vessels), and left gastroepiploic vessels.

The structure consisting of these ligaments encircles the hilum of the spleen, and the pancreas was dissected along the dotted line shown in Figure 1b,c. The pancreas tail was then divided carefully so as not to damage the small vessels in the hilum of the spleen. The dissected pancreas was placed in an endoscopic retrieval bag and extracted from the umbilical wound. Lastly, we observed the color of the splenic surface to confirm the blood supply, using laparoscopic ultrasonography.

In the lap-SVP procedure, following the division of the greater omentum as in lap-WT, the splenocolic ligament and gastrosplenic ligament were divided. After the confirmation of the location of the tumor using laparoscopic ultrasonography, the dissection of the pancreas was conducted as in the lap-WT procedure. Not

only the splenic artery but also the splenic veins were mobilized from the pancreas. After the pancreas was resected using the endoscopic linear stapler, a distal pancreatectomy was performed as in the lap-WT procedure.

Results

The outcomes of each procedure are summarized in Table 2. All of the intended lap-SVP procedures were performed successfully without conversions to lap-WT procedures. In all patients who underwent the lap-SVP procedure, the patency of the splenic vessels was confirmed postoperatively on an enhanced CT scan. The median follow-up duration was 45 (range 17–105) months. The follow-up duration of the lap-WT group was significantly longer than that of the lap-SVP group (55 [23–105] vs. 38 [17–45] months, respectively; $P < 0.05$). In the lap-WT and lap-SVP groups, the median operative times were 304 (168–512) and 319 (238–387) min; the median operative blood loss was 210 (5–3250) and 60 (9–210) gr, and the median length of postoperative hospital stay was 15 (8–29) and 18 (5–24) days, respectively. There was no Grade B or C pancreatic fistula based on the International Study Group of Postoperative Pancreatic Fistula (ISGPF) (17), and no local recurrence following either procedure was observed.

The postoperative peak platelet counts in the lap-WT and lap-SVP patients were 37.2 (14.6–65.2) and 26.4 (18.8–41) $\times 10^4/\mu\text{L}$, respectively. Although the platelet counts in the lap-WT and lap-SVP groups rose to the peak levels on 12 (5–16) and 12 (5–17) postoperative days, respectively, they improved spontaneously as shown in Figure 2a. None of the patients needed antiplatelet agents.

Postoperative splenomegaly occurred in 10 (59%) lap-WT patients and three (43%) lap-SVP patients.

The transitions of postoperative splenic volume in the patients diagnosed with postoperative splenomegaly are

shown in Figure 2b. In all patients, no continuous increase in the spleen volume was seen. In the lap-WT

group, partial splenic infarctions were seen in four (24%) patients and perigastric varices were seen in two

(12%) patients. All four of the patients with splenic infarctions could be observed without any treatment (Fig.

3). In the two patients with perigastric varices, gastric submucosal changes were not detected on upper

gastrointestinal endoscopy.

Discussion

Distal pancreatectomy for malignant tumors of the body or tail of the pancreas requires a splenectomy. Splenectomy was reported to cause an overwhelming post-splenectomy infection in 1%–5% patients, with a mortality rate over 50% (18). Moreover, a splenectomy may raise the postoperative platelet count (19). Therefore, SPDP is commonly used for benign or low-grade malignant tumors of the body and tail of the pancreas. Use of the Warshaw technique is thought to increase the likelihood of spleen preservation with laparoscopic surgery because of its simplicity. However, the safety and feasibility of the Warshaw technique are still controversial, and no randomized controlled studies have been performed, to our knowledge (20,21).

Some authors have described the risk of the excision of splenic vessels (especially with regard to gastric varices) that the Warshaw technique presents. Miura et al. demonstrated the open Warshaw technique and reported that gastric varices were identified on CT in 70% (7/10) of their patients, with endoscopy revealing gastric varices in two of the seven identified on CT (13). Similarly, Tien et al. applied the open Warshaw technique and stated that perigastric varices were detected on CT in 29.7% (11/37) of their patients and that gastric submucosal varices were also found in 8.1% (3/37) of the patients (14).

Although our patient series was very limited in terms of the number of cases (n=25), perigastric varices were observed in only two patients who underwent the lap-WT procedure, and gastric submucosal findings were not detected by endoscopy in either group of patients. The difference in the results between the previous reports and the present study may be due to the use of the laparoscopic method rather than the open method. The lap-WT may be a more feasible way to preserve the blood supply to the spleen, because the laparoscopic technique can visualize the thinner vessels and can therefore avoid unnecessary vessel treatment. We were especially conscious not only of the preservation of the short gastric vessels but also of the splenocolic ligament and left gastroepiploic vessels (22). Laparoscopically we can see the hilum of the spleen from the front and can avoid the unnecessary treatment of vessels to preserve the blood supply to the spleen.

Tien et al. reported that postoperative splenomegaly following the Warshaw technique is associated with the incidence of perigastric varices (14). In the present study, both the lap-WT and lap-SVP procedures induced postoperative splenomegaly. Although the splenic vessels were preserved in the lap-SVP group, postoperative splenomegaly was observed in three patients (43%). Previous studies reported low-grade obliterations of splenic veins in 17.2%–74% patients who underwent lap-SVP (23,24). Those authors suggested that the causes of the obliteration of the splenic vein were the dissection of the splenic vein from

the pancreas and low blood pressure of the splenic vein. Our finding that the splenic enlargement occurred after both procedures suggested that not only the lap-WT but also lap-SVP might result in some degree of abnormalities of splenic circulation.

In contrast, Kohan et al. reported that some degree of splenic hypoperfusion was observed at 1 week after the operation in 63% (22/35) of patients who underwent lap-WT (25). In the present study, although lap-WT induced a splenic infarction in 24% (4/17) of the patients, all of the infarctions were focal and none required splenectomy. In all of these patients, the infarcted volume was less than 50% of the spleen and the infarctions were located mainly on the splenic hilum. These results suggested that our lap-WT procedure preserving not only short gastric vessels but also the left gastroepiploic vessels and splenocolic ligament could minimize the complications related to splenic circulation.

Tezuka et al. reported that SVP could reduce the postoperative elevation of the platelet count compared to distal pancreatectomy with splenectomy (26). They described that the postoperative platelet counts increased to maximum levels at 2 weeks after the operation in both patients who underwent an SVP and those who underwent a distal pancreatectomy with splenectomy. Although these early postoperative increases in the platelet count were induced by the inflammatory cytokines after the operations, the platelet

counts at 3 months after the distal pancreatectomy with splenectomy were higher compared to those after SVP because of the loss of the spleen (26, 27). Therefore, the late prolonged thrombocytosis might be related to the splenic function. A comparison between the WT and SVP has not been reported, to our knowledge. In the present study, we observed that the postoperative platelet counts increased to the maximum levels within 1 month after the operation and decreased to the preoperative levels thereafter in both the lap-WT group and the lap-SVP group. These results indicate that splenic function can be preserved by WT procedures as well as by SVP procedures.

In the present study, the operative blood loss in the lap-WT group was larger compared to previous results (20, 28). In the patients whose blood loss was more than 3200 mL, the splenic capsule was injured by a surgical instrument. However, the bleeding could be stopped laparoscopically. Moreover, despite the absence of grade B or C pancreatic fistula, the postoperative hospital stay of both groups was longer compared to the previous reports (20, 28). In Japan, university hospitals use the Diagnosis Procedure Combination (DPC) system (29). In cases in which patients diagnosed with a benign pancreatic tumor undergo a laparoscopic distal pancreatectomy, national health insurance covers the hospital stay for more than 2 weeks.

In conclusion, although the lap-WT procedure induced perigastric varices and splenic infarction in

12% and 24% of the patients, respectively, all of these patients could be managed conservatively under careful observation. In addition, although splenic vessel preservation is more suitable for maintaining the blood supply to the spleen in spleen-preserving distal pancreatectomy, we found that splenic preservation was successful even with the lap-WT. We consider that the lap-WT is especially suitable for benign or low-grade malignant tumors for which spleen preservation had previously been abandoned because of their large size or attachment to splenic vessels.

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Figure legends

Fig. 1. (a) In the lap-WT procedure, after the dissection of the splenic artery (white arrow), the pancreas with the splenic vein was resected with an endoscopic linear stapler. (b) The structure that encircles the splenic hilum. It consists of the splenocolic ligament (A), left gastroepiploic vessels (B) and gastrosplenic ligament (C). The splenic circulation is preserved by the blood supplied along these three routes. (c) The pancreas is dissected along the dotted line.

Fig. 2. The transition of postoperative platelet counts and splenic volume in the lap-WT and lap SVP procedures. (a) In both procedures, the platelet counts increased temporarily. (b) The transition of the splenic volume of the patients diagnosed with postoperative splenomegaly. In both groups, there was no continuous increase in splenic volume.

Fig. 3. CT scan of Patient 1 showing a partial splenic infarction. (a) One month after the lap-WT: the splenic infarction is shown as the non-enhanced area in the spleen (white arrow). Because the splenic infarction was

located on the splenic hilum and the patient had not presented any symptoms, we treated him conservatively at that time. (b) Three years after the initial operation: the splenic infarction had improved spontaneously.

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Fig. 1

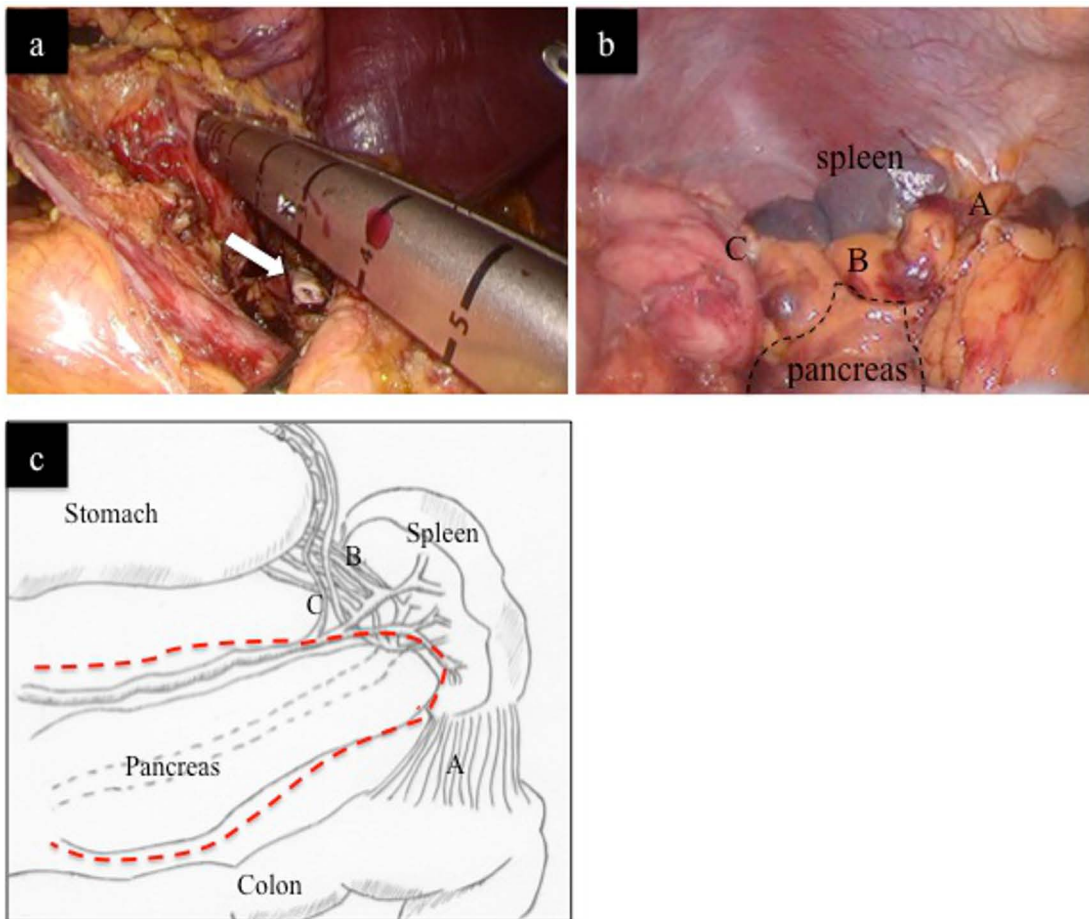


Fig. 2

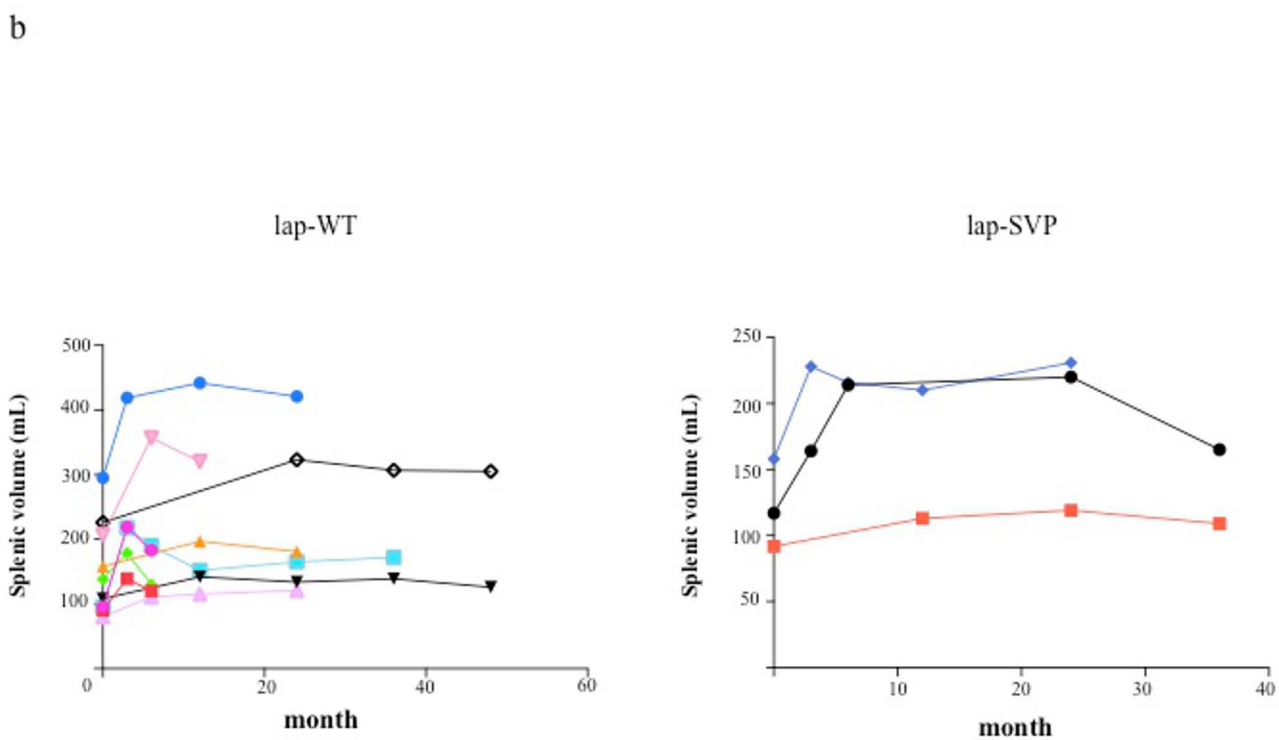
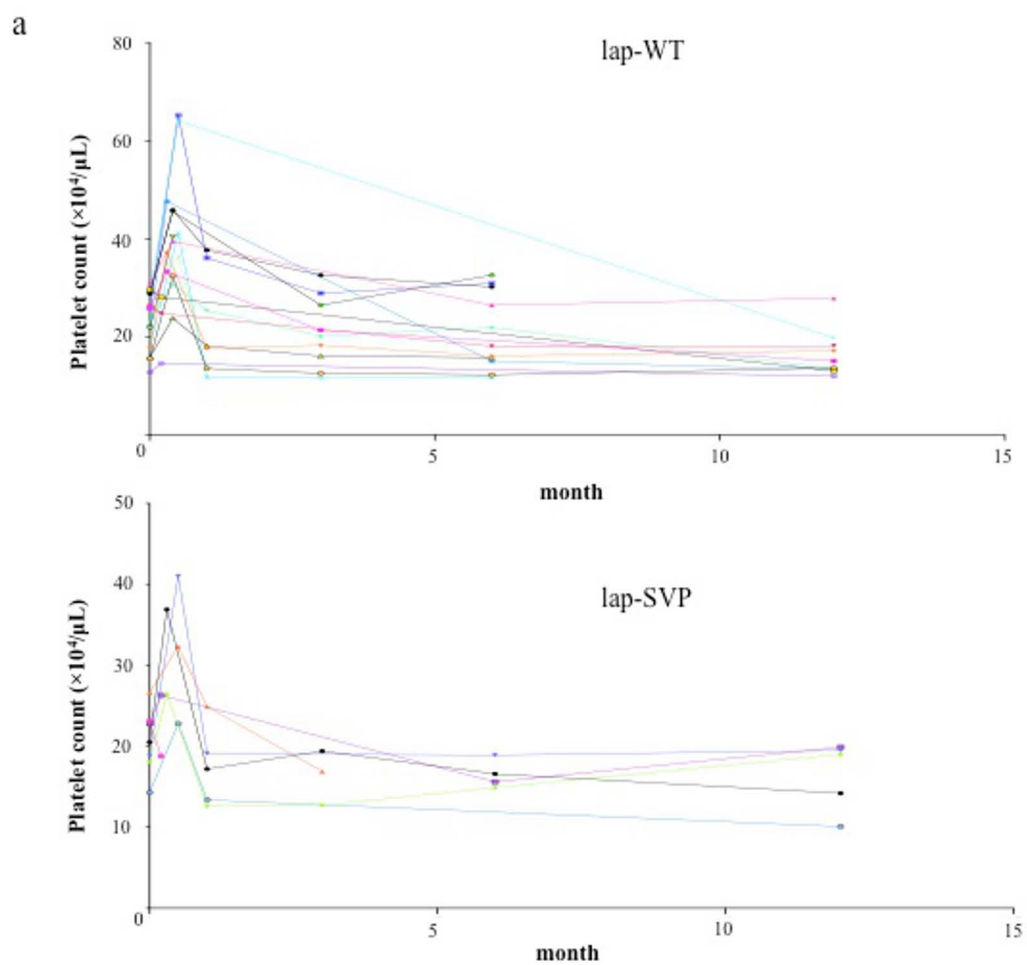


Fig. 3

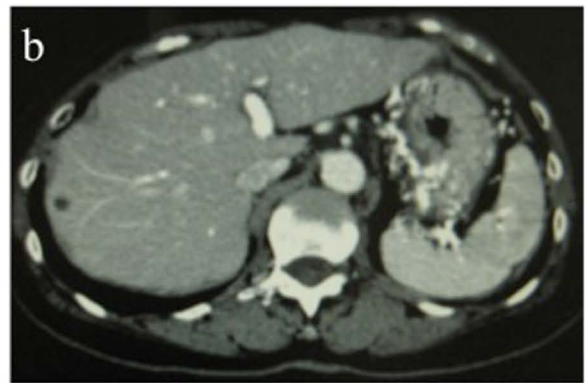
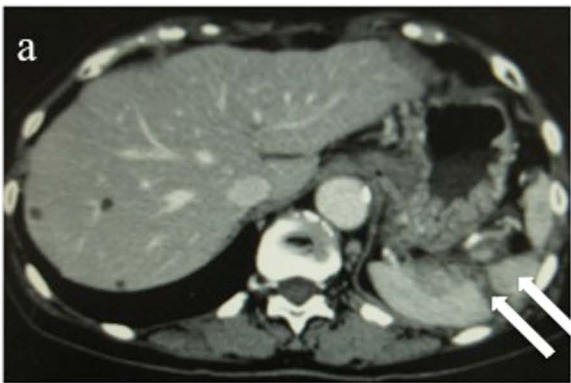


Table 1. The characteristics of the 24 patients with benign or low-grade malignant pancreas tumors

	lap-WT (n=17)	lap-SVP (n=7)
Gender (M/F)	3 / 14	4 / 3
Age (yrs)	49 (30–83)	70 (50–86)
BMI (kg/m ²)	22.3 (18.2–35.8)	22.8 (17.2–25.5)
Tumor size (cm)	5 (1.3–12)	1.5 (1–4)
Procedure (Lap/HALS/SILS)	5 / 10 / 2	4 / 1 / 2
Pathological diagnosis	Cases (malignancy)	
IPMN	3	1
MCN	4 (1)	1
SPT	3 (1)	1 (1)
SCN	2	0
Chronic pancreatitis	1	1
Metastasis	2	1
Others	2	2

lap-WT, laparoscopic Warshaw technique

lap-SVP, laparoscopic splenic vessels-preserving technique

BMI, body mass index

Lap, laparoscopic HALS, hand-assisted laparoscopic surgery

SILS, single incision laparoscopic surgery

IPMN, intraductal papillary mucinous neoplasm

MCN, mucinous cystic neoplasm SPT, solid-pseudopapillary tumor

SCN, serous cystic neoplasm

Table 2. The operative and long-term outcomes of patients who underwent lap-WT or lap-SVP

	lap-WT (n=17)	lap-SVP (n=7)
Follow-up duration (month)*	55 (23–105)	38 (17–45)
Operative time (min)	304 (168–512)	319 (238–387)
Blood loss (gr)	210 (5–3250)	60 (9–210)
Pancreatic fistula (Grade B, C)	0 / 17 (0%)	0 / 7 (0%)
Peak platelet count ($\times 10^4/\mu\text{L}$)	37.2 (14.6–65.2)	26.4 (18.8–41)
Postoperative days of peak platelet count (days)	12 (5–16)	12 (5–17)
Splenomegaly (%)	10 / 17 (59%)	3 / 7 (43%)
Splenic infarction (%)	4 / 17 (24%)	0 / 7 (0%)
Perigastric varices (%)	2 / 17 (12%)	0 / 7 (0%)
Hospital stay (days)	15 (8–29)	18 (5–24)
Local recurrence (%)	0 / 17 (0%)	0 / 7 (0%)

lap-WT, laparoscopic Warshaw technique

lap-SVP, laparoscopic splenic vessels-preserving technique

*: $P < 0.05$