Original Article

Lessons learned from follow up of spleen-preserving distal pancreatectomy with artery saving and vein sacrificing

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Background: The Warshaw method as a technique for spleen-preserving distal pancreatectomy (SPDP) carries the risk of splenic infarction following splenic artery ligation. This study introduces a modified Warshaw method, which preserves the splenic artery while sacrificing the splenic vein, and compares its outcomes with the traditional Warshaw method.

Methods: According to the bleeding status during vessel dissection, either the Warshaw method (group W) or the modified Warshaw method (group MW) was used. Guided by preoperative imaging, we utilized the planned modified Warshaw method (group PMW) when the splenic vein was embedded in the pancreatic parenchyma.

Results: Group MW demonstrated a lower incidence of splenic infarction and engorged gastric collaterals than group W (6.3% *vs.* 69.8%, P<0.001; 25.0% *vs.* 55.8%, P=0.003, respectively). There were no significant differences in perioperative changes of splenic volume between the two groups. Group PMW experienced less estimated blood loss than group W (71.9±59.13 *vs.* 357.9±447.72 cc, P=0.006).

Conclusions: The planned modified Warshaw method is an efficient and safe technique, resulting in lower estimated blood loss and favorable outcomes concerning splenic infarction and gastric collaterals than the Warshaw method without inducing congestive splenomegaly.

Keywords: Splenic vein; splenic infarction; splenic artery; pancreatectomy; laparoscopy

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Introduction

Splenic vessel-conserving spleen-preserving distal pancreatectomy (SPDP) was initially reported by Kimura *et al.* (1) Since then, SPDP has gained widespread acceptance as a standard procedure for addressing benign and low-grade tumors located in the body or tail of the pancreas. This SPDP approach aims to preserve immunologic and phagocytic functions of the spleen (2,3). Advance in laparoscopic instruments and techniques have empowered surgeons to preserve splenic vessels while performing laparoscopic SPDP (LSPDP) (4,5).

Nonetheless, preserving splenic vessels remains a challenging and time-consuming procedure due to the need for meticulous dissection of vessels from the pancreas parenchyma. Consequently, several studies have introduced

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the Warshaw method—an approach involving the sacrifice of the splenic artery and vein—as an alternative to the Kimura technique if the latter seems to be unfeasible, with comparable outcomes in terms of spleen preservation (6,7). However, the severance of the splenic artery and vein could precipitate splenic infarction. This is well known as a drawback of the Warshaw method, with reported incidence rates of 24–54.2%. Furthermore, the rate of those necessitating splenectomy due to splenic infarction can reach up to 5.9% (8-11).

In a previous study conducted at our center (Seoul St. Mary's Hospital, The Catholic University of Korea) (12), a modification of the LSPDP technique was introduced. This modification involves sacrificing the splenic vein while preserving the splenic artery. We referred to this approach as the modified Warshaw method (*Figure 1*). That study indicated that the incidence of splenic infarction, a primary drawback of splenic artery ligation, was significantly lower in patients who underwent the modified Warshaw method than in those who underwent the traditional Warshaw method. Nevertheless, concerns about the potential risk of splenic congestion or left-sided portal hypertension still persist in the long-term after adopting the modified Warshaw method. Indeed, most surgeons have intentionally ligated the preserved splenic artery due to concerns for splenic congestion following ligation of the splenic vein. However, we were doubtful about the necessity of intentionally ligating the preserved splenic artery as it could lead to splenic infarction.

Thus, the objective of this study was to analyze long-term outcomes of the modified Warshaw method, which involved sacrificing the splenic vein while preserving the splenic artery, in comparison with the Warshaw method. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-55/rc).

Highlight box

Key findings

- A modified Warshaw method, which preserves the splenic artery while sacrificing the splenic vein, offers safer distal pancreatectomy, reducing splenic infarction risk without increasing splenomegaly.

What is known and what is new?

- Preserving splenic vessels remains a challenging and time-consuming procedure due to the need for meticulous dissection of vessels from the pancreas parenchyma. Consequently, several studies have introduced the Warshaw method, an approach involving the sacrifice of the splenic artery and vein.
- However, the severance of the splenic artery and vein could precipitate splenic infarction. This is well known as a drawback of the Warshaw method, with reported incidence rates of 24–54.2%.

What is the implication, and what should change now?

- This method is expected to compensate for the shortcomings of existing methods, such as long surgery time, too difficult technically, or a lot of spleen infarction.

Methods

Patients

The present study performed a multicenter retrospective analysis of patients admitted to the General Surgery Department across multiple institutions who were scheduled to undergo LSPDP between November 2012 and February 2023. LSPDP was performed for benign to borderline pancreatic tumors located in the body or tail of the pancreas by 11 surgeons at five separate medical centers in Korea, affiliated with The Catholic University of Korea. Our center's basic principle for the initial approach to LSPDP is to utilize the Kimura technique, which involves preserving both the splenic veins and arteries (1). However, in cases where there was a risk of bleeding or if active bleeding occurred during vessel dissection from the pancreatic parenchyma, we transitioned to either the Warshaw method (group W) or the modified Warshaw method (group MW).

Furthermore, guided by preoperative imaging studies, if the splenic vein was found to be embedded in the pancreatic parenchyma or compressed by the tumor, which could increase the likelihood of vein tearing during dissection, we opted for only the modified Warshaw method, not the Kimura technique or the Warshaw method. This decision was made during the planning phase prior to surgery. Once in the operating room, we deliberately chose not to attempt venous preservation. Instead, we proactively ligated the vein just below the pancreatic neck or in the middle of the pancreatic body, while preserving the splenic artery. This planned approach was pioneered and adopted by only one of the 11 distinct pancreatic surgeons. We coined the planned modified Warshaw method (referred to as the PMW group).

Surgical procedures

Under general anesthesia, the patient was positioned in a supine position with legs apart and tilted to the right. After introducing five trocars, we accessed the lesser sac

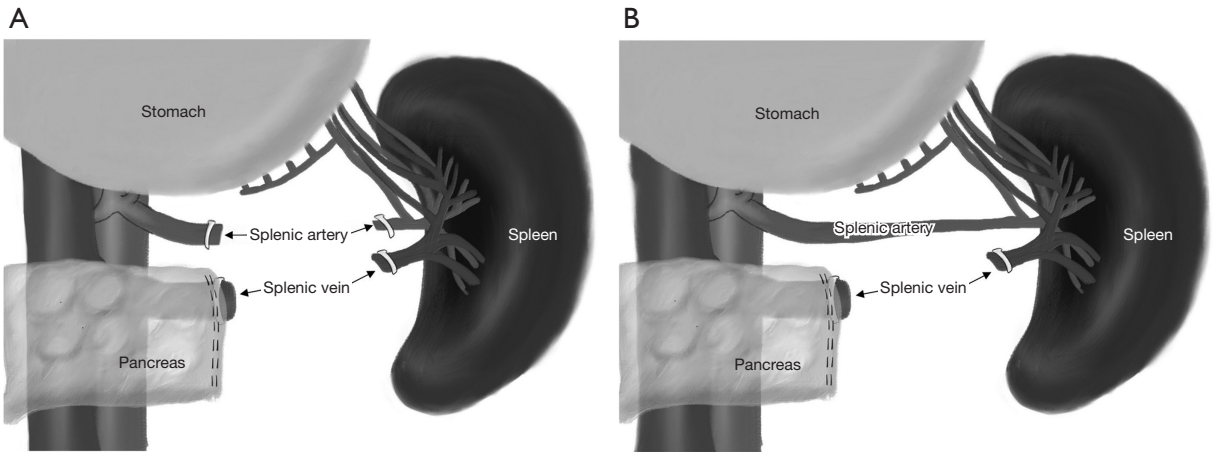

Figure 1 Schematic images for each surgical type: (A) the Warshaw method, involving the sacrifice of both the splenic artery and vein, and (B) the modified Warshaw method, preserving the splenic artery while sacrificing the splenic vein.

of the stomach and exposed the anterior surface of the pancreas from the posterior gastric wall. During this step, we concentrated on preserving main collateral vessels of the spleen, including the right gastroepiploic vessels on the right side of the pancreas and the left gastroepiploic vessels and the short gastric vessels on the left side. Following this, dissection progressed along the inferior border of the pancreas through the avascular plane. This maneuver unveiled the pancreas's posterior plane and facilitated the identification of both the splenic vein and the artery.

Upon separation of the pancreatic parenchyma from adjacent tissues, the pancreatic parenchyma was transected using a linear stapler (ENDOPATH™ ETS Articulating Linear Cutter, Ethicon Endo-surgery Inc., Cincinnati, OH, USA; The Signia™ powered stapler, or Endo GIA™ Ultra Universal stapler, Medtronic, Dublin, Ireland). As the dissection progressed toward the pancreatic tail, the splenic artery and the vein were either preserved or sacrificed using different techniques, such as the Kimura technique, Warshaw method, or the modified Warshaw method. The splenic artery and the vein were meticulously isolated from the body of the pancreas toward the spleen by delicately dividing small branches connecting splenic vessels and the pancreas employing a vessel-sealing device (LigaSure™ Maryland Jaw Thoracic Sealer/Divider with Nano-coating, Medtronic).

After completing these steps, the entire distal pancreas was extracted and the remaining pancreas stump was laparoscopically repaired using continuous sutures or reinforced by covering up with a bioabsorbable polyglycolic acid sheet (NEOVEIL®, Gunze International USA, Inc., Tokyo, Japan). We then positioned one or two drains near the pancreatic stump.

Warshaw method (sacrificing both splenic artery and vein)

Primary collateral vessels surrounding the spleen include short gastric vessels and left gastroepiploic vessels. These vessels typically course through the omentum to join the main splenic vessels near the splenic hilum. It is imperative to meticulously preserve these vessels in the Warshaw method since the main splenic vessels are sacrificed. Therefore, dissection should occur precisely at the border of the pancreatic tail. After ligating the splenic vein and the artery at the pancreatic tail, an assessment was carried out to check if the spleen's color had changed, with a change indicating potential infarction.

Modified Warshaw method (preserving splenic artery and sacrificing splenic vein)

In situations where inadvertent injury to the splenic vein occurred while attempting the Kimura technique, the splenic vein was ligated to control bleeding (group MW). In cases where a preoperative imaging study suggested that the splenic vein was embedded in the pancreas parenchyma or compressed by the tumor, intentional ligation of the splenic vein was carried out even before bleeding was expected (group PMW). When complete preservation of the splenic artery seemed achievable, dissection proceeded cautiously,

involving separation of the splenic artery from the pancreas. However, if an injury to the splenic artery or bleeding from the preserved splenic artery was detected during manipulation, an immediate transition to the Warshaw method was executed, which involved sacrificing the splenic artery.

Postoperative outcomes

Irrespective of the type of spleen-preserving method employed, all patients underwent the same postoperative clinical pathway. Routine oral feeding was resumed on the fifth postoperative day unless signs of pancreatic leakage were evident. Octreotide was administered if there was clinical evidence of a postoperative pancreatic fistula (POPF) under the judgment of the physician. Postoperative morbidities were evaluated and categorized using the Clavien-Dindo classification (13). POPF was defined in accordance with the revised criteria outlined by the International Study Group of Pancreatic Fistula (14).

For postoperative follow-up, contrast-enhanced computed tomography (CT) scanning or magnetic resonance imaging was conducted at 3 months post-surgery, followed by subsequent assessments every 3 or 6 months. We evaluated the occurrence of splenic infarction through intraoperative gross finding and imaging studies during the early postoperative period, specifically from postoperative days five to seven. The evaluation of splenic perfusion involved classifying it into four grades based on the percentage of total splenic volume affected by infarction: intact, grade 0; <50% infarction, grade 1; 50–99% infarction, grade 2; and 100% infarction, grade 3.

We evaluated whether gastric collaterals or splenomegaly occurred between 3 and 6 months after operation. A comparison of preoperative and postoperative images was performed to identify gastric collaterals engorgement and to determine whether they were preexisting or newly developed after surgery. Gastric collaterals with a diameter longer than 5 mm were defined as engorged gastric collaterals. Spleen volume was calculated using the formula of $30 + 0.58 \times L \times D \times T$ (cm^3), where L was the cranio-caudal distance between the first and last slices in the axial plane depicting the spleen, D was the largest measurable long-axis diameter in the axial plane, and T was the largest perpendicular dimension to D in the axial plane.

The current study was approved by the joint Institutional Review Board (IRB) of all five medical centers - The Catholic University of Korea (No. KC22RISI0488), and individual consent for this retrospective analysis was waived. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Statistical analysis

In the present study, differences in continuous data were assessed using Student's *t*-test, while differences in categorical variables were analyzed with Fisher's exact test or chi-square test. Descriptive statistics are presented as mean ± standard deviation. Statistical significance was considered at $P<0.05$. The primary outcome was emergence of postoperative splenic infarction or left-sided portal hypertension. The secondary outcome included parameters such as operation time and estimated bleeding loss during surgery. We examined demographic characteristics and postoperative outcomes in both MW and W groups, followed by a sub-group analysis comparing group PMW with group W. All statistical analyses were executed utilizing the SPSS statistical software package version 24.0 for Windows (SPSS, Inc., Chicago, IL, USA).

Results

Of the 426 patients who underwent laparoscopic distal pancreatectomy, 202 underwent LSPDP for benign-to-borderline pancreatic tumors located in the body or tail of the pancreas. Among this cohort, 28 patients were excluded for the following reasons: 16 patients had a history of upper abdominal operations, 4 required conversion to open distal pancreatectomy due to suspicion of malignancy, and 8 underwent other concomitant surgical procedures. Of the remaining 174 patients, 83 were able to undergo the Kimura technique.

Consequently, the study finally analyzed 91 patients, with 48 patients undergoing the modified Warshaw method (group MW) and 43 patients undergoing the Warshaw method (group W). Patient demographics and baseline clinical characteristics of both MW and W groups are presented in *Table 1*, revealing no significant differences between the two groups. *Table 2* shows a comparative overview of surgical outcomes for these groups.

Within group MW, 3 of a total 48 patients experienced splenic infarction that encompassed more than 50% of the total splenic volume. The incidence rate was 6.3%, which was significantly lower than that in group W, where

Table 1 Patient demographic and clinical characteristics among groups

Characteristics	Modified Warshaw (n=48)	Warshaw (n=43)	P value
Age (years), mean ± SD	56.2±16.59	54.2±15.68	0.50
Sex, N (%)			0.72
Male	15 (31.3)	12 (27.9)	
Female	33 (68.8)	31 (72.1)	
BMI (kg/m^2), mean ± SD	24.9±3.80	25.3±3.18	0.40
CCI, mean ± SD	2.0±1.85	1.8±1.50	0.23
ASA score, N (%)			0.79
1	14 (29.2)	12 (27.9)	
2	33 (68.8)	29 (67.4)	
3	1 (2.1)	2 (4.7)	
Follow-up duration (months), median [range]	24.6 [6.5–146.4]	28.9 [6.1–140.7]	0.32
Pathology, N (%)			0.08
IPMN	11 (22.9)	6 (14.0)	
NET	6 (12.5)	4 (9.3)	
SPN	6 (12.5)	7 (16.3)	
SCN	9 (18.8)	2 (4.7)	
MCN	4 (8.3)	11 (25.6)	
Pancreatitis	1 (2.1)	4 (9.3)	
Pseudocyst	0	1 (2.3)	
Others	11 (22.9)	8 (18.6)	
Tumor location[a], N (%)			0.07
Body	10 (20.8)	4 (9.3)	
Tail	37 (77.1)	34 (79.1)	
Body/tail	1 (2.1)	5 (11.6)	
Tumor size (cm), mean ± SD	3.7±2.00	4.0±2.50	0.27
Specimen length (cm), mean ± SD	9.1±2.75	8.9±2.54	0.36

[a], we classified the location of tumor per each case into the body or tail; if the boundary of mass exceeded over the left lateral border of aorta, it was regarded as the mass at tail of pancreas whereas the mass at body of pancreas if the mass was located within the left lateral border of aorta. SD, standard deviation; BMI, body mass index; CCI, Charlson comorbidity index; ASA, American Society of Anesthesiologists; IPMN, intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor; SPN, solid pseudopapillary neoplasm; SCN, serous cystic neoplasm; MCN, mucinous cyst neoplasm.

30 (69.8%) of 43 patients exhibited splenic infarctions with an extent exceeding 50% of the total spleen volume (P<0.001). The incidence of engorged gastric collaterals was significantly lower in group MW than in group W (25.0% *vs.* 55.8%, P=0.003).

Among the 48 patients in group MW, 16 underwent the planned modified Warshaw method (group PMW). *Table 3* presents a subgroup analysis comparing baseline characteristics between groups PMW and W. Notably, there were no significant differences in patient demographics observed between the two groups. Regarding surgical outcomes, group PMW exhibited a significantly lower

Table 2 Comparative analysis of surgical outcomes between two groups

Variables	Operation type		P value
	Modified Warshaw (n=48)	Warshaw (n=43)	
WOT (min), mean ± SD	154.1±48.99	169.3±55.80	0.64
EBL (cc), mean ± SD	216.25±281.4	357.91±447.7	0.07
Transfusion, N (%)	3 (6.3)	5 (11.6)	0.46
CR-POPF, N (%)	4 (8.3)	4 (9.3)	>0.99
B	2 (4.2)	4 (9.3)	
C	2 (4.2)	0	
Portal system: thrombosis, N (%)	2 (4.2)	2 (4.7)	>0.99
Splenic infarction, N (%)			<0.001
Grade 0 (intact)	39 (81.3)	9 (20.9)	
Grade 1 (<50% infarction)	5 (10.4)	4 (9.3)	
Grade 2 (50–99% infarction)	3 (6.3)	20 (46.5)	
Grade 3 (100% infarction)	0	10 (23.3)	
Splenomegaly, N (%)	2 (4.2)	3 (7.0)	0.66
Engorged gastric collaterals, N (%)	12 (25.0)	24 (55.8)	0.003
Morbidities, N (%)	18 (37.5)	16 (37.2)	0.29
Minor	14 (29.2)	11 (25.6)	
Major	4 (8.3)	5 (11.6)	
Mortality, N (%)	1 (2.1)	1 (2.3)	>0.99
LOS (days), mean ± SD	8.58±2.35	8.35±3.37	0.48

WOT, whole operation time; SD, standard deviation; EBL, estimated blood loss; CR-POPF, clinically relevant postoperative pancreatic fistula; LOS, length of hospital day.

incidence of splenic infarctions extending beyond 50% of the total splenic volume, with an incidence rate of 6.3% (1 out of 16 patients) compared to group MW with an incidence of 69.8% (P<0.001, *Table 4*). Furthermore, the development of engorged collaterals occurred significantly less frequently in group PMW than in group W (25.0% *vs.* 55.8%, P=0.03). The estimated blood loss was significantly lower in group PMW than in group W (71.9±59.13 *vs.* 357.9±447.72 cc, P=0.006). However, there was no significant difference in total operation time between groups.

Finally, an assessment of perioperative splenic volume was conducted for both groups MW and W (*Table 5*). There were no significant differences in preoperative splenic volume, postoperative splenic volume, or splenic volume shift before or after the operation between the two groups.

Discussion

In this study, SPDP with preserving splenic artery and sacrificing splenic vein, the modified Warshaw method, showed lower incidence of postoperative adverse events—specifically, splenic infarction and engorged collaterals—than the Warshaw method, which involved sacrificing both the artery and the vein. Meanwhile, there were no significant differences in whole operation time or estimated blood loss between the modified Warshaw method and the Warshaw method.

The Warshaw method has been introduced as a viable alternative to the Kimura technique due to the latter's requirement for a procedure that entails preserving spleen vessels, a process known to be time-consuming and associated with a high risk of massive bleeding (6,7). The Warshaw method could lead to complications such

Table 3 Patient demographic and clinical characteristics among groups (planned modified Warshaw *vs.* Warshaw)

Characteristics	Planned modified Warshaw (n=16)	Warshaw (n=43)	P value
Age (years), mean ± SD	48.75±15.73	54.21±15.68	0.82
Sex, N (%)			0.80
Male	5 (31.3)	12 (27.9)	
Female	11 (68.8)	31 (72.1)	
BMI (kg/m^2), mean ± SD	24.1±4.42	25.3±3.18	0.30
CCI, mean ± SD	1.1±1.55	1.8±1.55	0.95
ASA score, N (%)			0.56
1	6 (37.5)	12 (27.9)	
2	10 (62.5)	29 (67.4)	
3	0	2 (4.7)	
Follow-up duration (months), median [range]	14.5 [6.8–57.0]	28.9 [6.1–140.7]	0.052
Pathology, N (%)			0.43
IPMN	1 (6.3)	6 (14.0)	
NET	4 (25.0)	4 (9.3)	
SPN	2 (12.5)	7 (16.3)	
SCN	3 (18.8)	2 (4.7)	
MCN	2 (12.5)	11 (25.6)	
Pancreatitis	1 (6.3)	4 (9.3)	
Pseudocyst	0	1 (2.3)	
Others	3 (18.8)	8 (18.6)	
Tumor location[a], N (%)			0.35
Body	2 (12.5)	4 (9.3)	
Tail	14 (87.5)	34 (79.1)	
Body/tail	0	5 (11.6)	
Tumor size (cm), mean ± SD	4.1±1.95	4.0±2.49	0.46
Specimen length (cm), mean ± SD	8.8±2.47	8.9±2.54	0.95

[a], we classified the location of tumor per each case into the body or tail; if the boundary of mass exceeded over the left lateral border of aorta, it was regarded as the mass at tail of pancreas whereas the mass at body of pancreas if the mass was located within the left lateral border of aorta. SD, standard deviation; BMI, body mass index; CCI, Charlson comorbidity index; ASA, American Society of Anesthesiologists; IPMN, intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor; SPN, solid pseudopapillary neoplasm; SCN, serous cystic neoplasm; MCN, mucinous cyst neoplasm.

as splenic infarction, splenomegaly, or the development of perigastric collaterals resulting from ligating splenic vessels. Meanwhile, although the Kimura technique can preserve splenic vessels during operation, whether the patency of these preserved vessels is well-maintained postoperatively remains unclear. Previous studies have reported varying rates of patency for splenic vessels after LSPDP performed using the Kimura technique, ranging from 72.7% to 97.8% for the artery and from 22.7% to 86.2% for the vein (15-18).

In general, isolation of the splenic vein presents elevated challenges in more distal sections of the pancreas, where the vein is often firmly embedded within the pancreatic

Table 4 Comparative analysis of surgical outcomes between two groups (planned modified Warshaw *vs.* Warshaw)

Variables	Operation type		P value
	Planned modified Warshaw (n=16)	Warshaw (n=43)	
WOT (min), mean ± SD	137.7±39.98	169.3±55.80	0.45
EBL (cc), mean ± SD	71.9±59.13	357.9±447.72	0.006
Transfusion, N (%)	0	5 (11.6)	0.31
CR-POPF, N (%)	2 (12.5)	4 (9.3)	0.65
B	2 (12.5)	4 (9.3)	
C	0	0	
Portal system: thrombosis, N (%)	1 (6.3)	2 (4.7)	>0.99
Splenic infarction, N (%)			<0.001
Grade 0 (intact)	11 (68.8)	9 (20.9)	
Grade 1 (<50% infarction)	4 (25.0)	4 (9.3)	
Grade 2 (50–99% infarction)	1 (6.3)	20 (46.5)	
Grade 3 (100% infarction)	0	10 (23.3)	
Splenomegaly, N (%)	1 (6.3)	3 (7.0)	>0.99
Engorged gastric collaterals, N (%)	4 (25.0)	24 (55.8)	0.03
Morbidities, N (%)	5 (31.3)	16 (37.2)	0.54
Minor	3 (18.8)	11 (25.6)	
Major	2 (12.5)	5 (11.6)	
Mortality, N (%)	1 (6.3)	1 (2.3)	0.47
LOS (days), mean ± SD	8.44±1.55	8.35±3.37	0.32

WOT, whole operation time; SD, standard deviation; EBL, estimated blood loss; CR-POPF, clinically relevant postoperative pancreatic fistula; LOS, length of hospital day.

Table 5 Comparative analysis of splenic volume among groups according to the surgical methods

Variables	Modified Warshaw (n=48)	Warshaw (n=43)	P value
Preoperative SV (cc), mean ± SD	211.3±55.69	198.1±52.54	0.53
Postoperative SV (cc), mean ± SD			
1 month	251.9±75.89	260.4±87.33	0.59
1 year	240.0±96.20	239.6±74.36	0.27
Differences in splenic volume (cc), mean ± SD			
Post-pre-SV (1 month)	40.5±52.07	51.0±40.83	0.13
Post-pre-SV (1 year)	27.5±65.67	32.0±39.60	0.12

SV, splenic volume; SD, standard deviation.

parenchyma. In contrast, the splenic artery possessing greater thickness and elasticity compared to the vein exhibits a more favorable response to compression for achieving hemostasis, whereas compression can more readily result in vein rupturing. Consequently, the splenic vein is frequently sacrificed while the splenic artery is preserved.

Unlike most several surgeons who have intentionally ligated the splenic artery due to concerns about splenic congestion, Kim *et al.* (12) from our center newly introduced the modified Warshaw method. In this study, the modified Warshaw method presented favorable results in shortening the operation time from 193.1 minutes with the Kimura technique to 133.3 minutes and showed a lower incidence of splenic infarction at 4.8% compared to the Warshaw method which had a rate of 33.3%. Other previous studies have reported incidence rates of splenic infarction after the Warshaw method at 24–54.2% (8-11). In the current study, the incidence of splenic infarction exceeded 50%, with rates of 6.3% in group MW and 69.8% in group W.

Previous studies have reported that patients undergoing the Warshaw method have an incidence rate of 12–33% for perigastric varices and an incidence rate of 32.4% for splenomegaly. Nevertheless, none of these patients experienced gastrointestinal bleeding during the extended follow-up period (10,19). In our current study, the incidence of splenomegaly was 4.2% in group MW and 7.0% in group W. Theoretically, splenic vein occlusion can lead to spleen congestion and divert venous flow toward the short gastric or gastroepiploic veins, resulting in left-sided portal hypertension. Consequently, the development of gastric collaterals or splenomegaly might be a primary concern in group MW, which preserved the splenic artery while sacrificing the splenic vein, rather than in group W, which sacrificed both the artery and the vein. Contrary to expectations, our study found significantly fewer engorged gastric collaterals in group MW (25%) than in group W (55%). We assume that gastric collaterals engorgement could hypothetically develop as a compensatory result after splenic hypoperfusion. Furthermore, there were no differences in postoperative splenic volume changes in splenic volume before or after the operation between groups MW and W, indicating that the modified Warshaw method did not result in significant congestive splenomegaly.

In this study, among 48 patients of group MW, 32 patients unexpectedly underwent the modified Warshaw method converted from the Kimura technique due to splenic vein injury during dissection. The remaining 16 patients underwent the planned modified Warshaw method. We decided to sacrifice the splenic vein preoperatively if it appeared to be embedded in the pancreatic parenchyma or compressed by the tumor. This planned method was initiated based on the idea that the modified Warshaw method showed favorable results regarding splenic infarction and left-sided portal hypertension compared to the Warshaw method. In addition, the planned method might allow us to avoid unnecessary blood loss and shorten operation time by skipping meticulous dissection of the splenic vein from the pancreatic parenchyma compared to the Kimura technique.

Through subgroup analysis, we observed a significantly lower incidence of splenic infarction exceeding 50%, at 6.3% in group PMW compared to 69.8% in group W. Furthermore, in group PMW, engorged gastric collaterals developed significantly less, with a rate of 25.0% compared to 55.8% in group W. The incidence of splenomegaly in the two groups did not show significant differences, consistent with findings when group MW was compared with group W. Notably, while group MW showed no difference in estimated blood loss compared to group W, group PMW exhibited significantly lower estimated blood loss than group W.

A potential limitation of the current study was its retrospective nature, along with the fact that the planned modified Warshaw method was performed by a single surgeon. Furthermore, long-term follow-up regarding splenic infarction, its impact on potential spleen atrophy or dysfunction, and the possibility of infarction recovery over an extended period are necessary. We analyzed splenic infarction based on imaging studies conducted between the fifth and the seventh postoperative days. However, in most cases where splenic infarction occurred, patients showed recovery in long-term follow-up imaging studies. Additionally, establishing standard criteria for deciding when to employ the planned modified Warshaw method based on preoperative imaging studies is crucial. Further studies on perioperative outcomes of the planned modified Warshaw method should be conducted with larger sample sizes across multiple medical centers. Furthermore, the robotic approach to SPDP could be beneficial because of the meticulous dissection of the splenic vessels, which reduces the risk of bleeding. This is because it allows access through extensive angles with fully articulating instruments and provides a magnified three-dimensional view. As recent studies have focused on comparing the outcomes of laparoscopic and robot-assisted distal pancreatectomy,

additional studies comparing the outcomes of different techniques, including the modified Warshaw and Warshaw methods, in robot-assisted SPDP should be conducted.

Conclusions

SPDP with planned splenic vein ligation and splenic artery preservation is an efficient and safe method that can result in lower estimated blood loss compared to unplanned conversion to splenic vein ligation. This approach also can yield more favorable outcomes in terms of splenic infarction and gastric collaterals than the Warshaw method without causing significant congestive splenomegaly.

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Footnote

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