Randomised controlled trial

INTERNATIONAL JOURNAL OF SURGERY

OPEN

Interim analysis of short-term outcomes after laparoscopic spleen-preserving distal pancreatectomy with or without preservation of splenic vessels: a randomised controlled trial

Qiangxing Chen, MD[a,b,c], Yangzhi Fu, MM[a,b], Yongbin Li, MD[a,d], He Cai, MD[a], Xin Wang, MD[a], Zhong Wu, MD[a], Lingwei Meng, MD[a,b], Man Zhang, BS[a], Zixin Chen, MD[a,b], Jingwen Jiang, MS[e], Ke Cheng, MD[a,f], Jun Li, MD[a,b], Dian Zhang, BS[g], Yu Cai, MD[a], Jiaying You, MD[a], Yunqiang Cai, MD[a,*], Bing Peng, MD[a,*]

Background: Laparoscopic spleen-preserving distal pancreatectomy (LSPDP) is a widely adopted surgical approach for benign and low-grade malignant neoplasms of the distal pancreas. The Kimura and Warshaw techniques represent two principal strategies, yet it still needs to be determined which one is superior. Our investigation aimed to evaluate the clinical outcomes associated with each technique.

Materials and methods: This single-center, parallel-group, patient-blinded randomized controlled trial was conducted at the West China Hospital of Sichuan University. Stratified block randomization was utilized to enroll 114 patients starting in March 2022, with an interim analysis of short-term outcomes scheduled after 45–50% of participant enrollment. Patients were randomized to receive LSPDP via either the Kimura or Warshaw technique. The primary endpoint was intraoperative blood loss, while secondary endpoints included a range of outcomes from composite outcome to quality of life, as quantified by the EQ-5D-5L.

Results: From March 2022 to November 2023, 53 patients were randomly allocated to the Kimura ($n=25$) or Warshaw ($n=28$) groups for LSPDP. Baseline characteristics and postoperative outcomes were similar between the groups, such as pancreatic fistula incidence, EQ-5D-5L index scores, and delayed gastric emptying rates. Per-protocol (PP) analysis revealed that the Kimura group experienced significantly less blood loss (52.5 ± 51.6 ml vs. 91.7 ± 113.5 ml, $P=0.007$) and a reduced rate of composite outcome (23.8 vs. 56.7%, $P=0.019$), but incurred higher costs in the Warshaw group (¥56 227.4 ± ¥7027.0 vs. ¥63 513.8 ± ¥12 944.5, $P=0.013$). Splenic infarction rates were higher in the Warshaw group, though not statistically significant (ITT: 39.3 vs. 12.5%, $P=0.058$; PP: 36.7 vs. 14.3%, $P=0.113$), without necessitating intervention. Neither group experienced postpancreatectomy hemorrhage, 90-day mortality, or ICU admissions, and all postoperative complications were mild (Clavien–Dindo Grade <III).

Conclusions: The 90-day interim analysis postoperatively indicates that both Kimura and Warshaw techniques for LSPDP are safe and viable. The Kimura technique, however, confers superior in terms of reduced intraoperative blood loss and fewer complications, alongside lower costs.

Keywords: Kimura technique, laparoscopic spleen-preserving distal pancreatectomy, Warshaw technique

[a]Division of Pancreatic Surgery, Department of General Surgery, West China Hospital, Sichuan University, [b]West China School of Medicine, West China Hospital, Sichuan University, [c]Department of Pancreatobiliary Surgery, Sun Yat-sen University Cancer Center, Guangzhou, China, [d]Department of Hepatopancreatobiliary Minimal Invasive Surgery, Shangjin Nanfu Hospital, [e]Division of Pancreatic Surgery and West China Biomedical Big Data Center, West China Hospital, Sichuan University, Chengdu, China; and Med-X Center for Informatics, Sichuan University, [f]Division of Liver Surgery, Department of General Surgery, West China Hospital of Sichuan University and [g]Department of Radiology, West China Hospital, Sichuan University, Chengdu, People's Republic of China, Guangzhou, China

Qiangxing Chen, Yangzhi Fu, and Yongbin Li contributed equally to this article.

Bing Peng and Yunqiang Cai contributed equally as co-corresponding authors.

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Department of General Surgery, Division of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, People's Republic of China. Tel.: +861 898 060 148 1. E-mail: z745151058@163.com (B. Peng); Department of General Surgery, Division of Pancreatic Surgery, West China Hospital, Sichuan University, Chengdu 610041, People's Republic of China. Tel.: +861 772 195 022 3. E-mail: yunqiangcaiwch@163.com (Y. Cai).*

International Journal of Surgery (2025) 111:617–627

Received 15 April 2024; Accepted 17 June 2024

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.lww.com/international-journal-of-surgery.

Published online 2 July 2024

http://dx.doi.org/10.1097/JS9.0000000000001874

Introduction

In the management of benign or low-grade malignant neoplasms of the distal pancreas, spleen-preserving distal pancreatectomy is the established surgical treatment supported by substantial evidence[1–4]. There are two principal techniques for this procedure: the Kimura and the Warshaw methods (see Fig. 1)[5]. The Warshaw method, first reported by Warshaw in 1988[6], preserves the short gastric vessels and those of the left gastric omentum while ligating the splenic arteries and veins. Conversely, the Kimura method, introduced by Kimura in 1996[7], maintains both splenic arteries and veins. Given these differences, surgeons have actively compared the clinical outcomes of these methods to identify the superior technique.

Despite numerous comparisons in the literature of the Kimura and Warshaw methods for laparoscopic spleen-preserving distal pancreatectomy (LSPDP), the majority are retrospective, leading to inconsistent outcomes[3,8–11]. A retrospective intention-to-treat (ITT) analysis of 140 who underwent laparoscopic distal pancreatectomy revealed no significant differences between the two techniques in terms of operative duration, blood loss, or conversion rates. However, the Kimura technique demonstrated advantages in terms of spleen preservation and reduced length of hospital stay[8]. Subsequently, a systematic review by Nakata *et al*., incorporating data from 15 retrospective studies and 841 patients, concluded that the Kimura technique was associated with a lower incidence of splenic infarctions, secondary splenectomies, and gastric varices, despite an increase in blood loss during minimal invasive procedures[10]. This review also highlighted the absence of randomized controlled trials in the field. Additionally, a large-scale European study involving 29 centers and 1095 patients reported no significant differences in splenic infarction or major complications (Clavien–Dindo grade 3a or higher) between the techniques. Yet, the Kimura method was linked to longer operative times and less blood loss[9].

The current literature, while extensive, are predominantly limited to retrospective research. Based on current evidence, there is an absence of data from randomized controlled trials that determines which technique is superior. To address this gap, our study aims to directly compare the clinical outcomes of patients undergoing LSPDP by either the Kimura or Warshaw technique. As a result, it will provide high-quality, evidence-based recommendations that will assist pancreatic surgeons in selecting the most appropriate surgical method.

HIGHLIGHTS

- Our study is a randomized controlled trial aimed at comparing the clinical outcomes of the Kimura and Warshaw techniques for laparoscopic spleen-preserving distal pancreatectomy (LSPDP) to identify the superior method.
- The interim analysis of this trial indicates that the Kimura method confers superior in terms of reduced intraoperative blood loss and fewer complications, alongside lower costs compared to the Warshaw method.
- No severe complications (Clavien–Dindo classification ≥ III), mortality, postpancreatectomy hemorrhage (ISGPS grade B/C), grade C postoperative pancreatic fistula (ISGPS classification), or need for reoperation were observed in either group.

Methods

Trial design

This study was a single-center, single-blinded, parallel-group, prospective randomized clinical trial carried out at West China Hospital of Sichuan University. The protocol included an interim analysis of short-term outcomes after enrolling 45–50% of the target sample, with the possibility of early termination if a significant difference in major complications (Clavien–Dindo grade III or higher) was detected. Full trial details are provided in Supplementary Material 1 (Supplemental Digital Content 1, http://links.lww.com/JS9/C985) (Supplemental Digital Content 5, http://links.lww.com/JS9/C989) (Supplemental Digital Content 6, http://links.lww.com/JS9/C990). The study has been reported in line with Consolidated Standards of Reporting Trials (CONSORT) Guidelines[12] (CONSORT-2010-Checklist, Supplemental Digital Content 2, http://links.lww.com/JS9/C986).

Participants

The inclusion and exclusion criteria for this study are as follows. Participants were eligible for the study if they met the following criteria:

(1) Age between 18 and 85 years;
(2) Diagnosis of benign or low-grade malignant distal pancreatic diseases, including pancreatic neuroendocrine tumors, mucinous cystic neoplasms (MCN), serous cystic neoplasms (SCN), intraductal papillary mucinous neoplasms (IPMN), solid pseudopapillary neoplasms, and pancreatic cysts, *et al*.;
(3) Eastern Cooperative Oncology Group performance status (ECOG PS)[13] score is 0 or 1;
(4) American Society of Anesthesiology (ASA) classification grade[14] less than or equal to III;
(5) Voluntary provision of written informed consent.

Participants were excluded from the study if any of the following applied:

(1) Preoperative suspicion of malignancy in the distal pancreas;
(2) Pregnancy or lactation;
(3) Severe mental disorders;
(4) History of abdominal surgery or severe intra-abdominal adhesions that preclude laparoscopic intervention;
(5) Participation in other research protocols with overlapping intervention outcomes;
(6) Unstable angina, myocardial infarction, or cerebrovascular accidents within the last 6 months;
(7) Forced Expiratory Volume in 1 second (FEV1) <50% of predicted;
(8) Preoperative or intraoperative findings of cirrhosis with portal hypertension;
(9) Hyperfunctioning spleen;
(10) Concurrent diseases necessitating splenectomy, such as hereditary spherocytosis, idiopathic thrombocytopenic purpura, or splenic tumors;

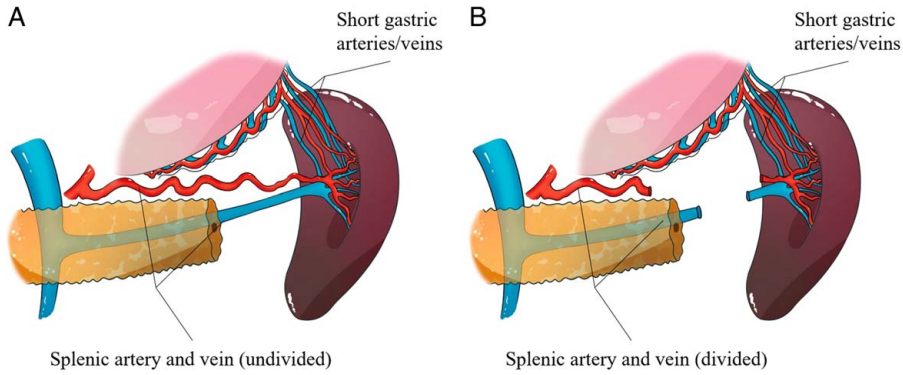

Figure 1. A. Laparoscopic spleen-preserving distal pancreatectomy using the Kimura method, which entails the preservation of the splenic vein and artery. B. Laparoscopic spleen-preserving distal pancreatectomy using the Warshaw method, which preserves the short gastric vessels while transecting the splenic vein and artery.

(11) Evidence of congenital or acquired coagulation disorders (e.g. hemophilia, severe thrombocytopenia, or severe liver disease);
(12) Use of specific medications: clopidogrel within 5 days, ticlopidine within 2 days, or an INR >1.4 if on coumarin therapy;
(13) Concurrent splenic vascular lesions, such as splenic artery aneurysms or thrombosis;
(14) Preoperative imaging (CT or MR) indicating tumor invasion of splenic vessels or intraoperative findings of dense adhesions between the tumor and the spleen;
(15) Preoperative enhanced CT or intraoperative exploration revealing esophageal or peri-gastric varices;
(16) Tumor diameter exceeding 6 cm.

Eligibility of surgeons

The inclusion criteria for the primary surgeons in this study are as follows:
(1) Mandatory possession of requisite qualifications to autonomously execute LSPDP;
(2) A minimum performance record of 20 LSPDP procedures over the preceding 2 years, incorporating no fewer than 10 applications of the Warshaw technique and a further 10 employing the Kimura technique;
(3) Surgeons were required to submit four complete surgical videos (two for each method) for evaluation. These videos were subjected to a blinded review and scoring by a panel of three peer experts. The review process follows the objective structured assessment of technical skills (OSATS) method introduced by J. A. Martin *et al.*[15], with an average score of each surgical video expected to be above 30 points.

Randomization and masking

Eligible patients were randomly assigned in a 1:1 ratio to receive either the Kimura technique or the Warshaw approach in this study. Stratified blocked randomization was employed, with tumor size (categorized as >3 cm or ≤ 3 cm) serving as the stratifying factor, and block sizes of four. Cases without neoplasms were categorized as ≤ 3 cm for randomization purposes. The randomization sequence was created using SPSS version 27.0 and placed in opaque envelopes, which were numbered sequentially and stored in the surgeon's office. The envelopes were opened as patients were enrolled to assign interventions. The primary surgeon, unaware of the randomization process, opened an envelope for each patient to determine the intervention they would receive. This ensured that the surgeon was shielded from selection bias. The randomization list was kept confidential to prevent any anticipation of future allocations. Blinding was strictly maintained for data collectors, analysts, and patients to uphold the methodological rigor.

Intervention

The experimental group received LSPDP via the Kimura technique, while the control group was treated with the Warshaw technique. Detailed descriptions of the procedural steps and technical subtleties for each surgical method are provided in Supplementary Material 1 (Supplemental Digital Content 1, http://links.lww.com/JS9/C985) (Supplemental Digital Content 5, http://links.lww.com/JS9/C989) (Supplemental Digital Content 6, http://links.lww.com/JS9/C990).

Outcomes

This study's short-term follow-up period is 90 days postoperatively, with the primary outcome being intraoperative blood loss. Blood loss is quantified by measuring blood in suction bottles with a graduated cylinder and weighing blood-soaked gauze on an electronic scale, accounting for a 1 g to 1 ml conversion factor[16]. The total blood loss is calculated by adding these two measures and subtracting the volume of saline used for irrigation. Secondary outcomes include postoperative mortality within 90 days, operative duration, intraoperative blood transfusion volume, crystalloid and colloid input during surgery, intraoperative urine output, conversion to open procedure, reoperation, secondary splenectomy, splenic infarction[17], hospital stay duration, ICU admission, spleen preservation rate, complications classified by the Clavien–Dindo system[18], surgical site infection[19], health status as measured by the EQ-5D-5L on the third postoperative day and at discharge[20,21], spleen volume within one week postoperatively[22], and hospital costs. Specific secondary outcomes related to pancreatic surgery included delayed gastric emptying[23], postpancreatectomy hemorrhage (PPH)[24], and postoperative pancreatic fistula[25]. Detailed definitions of these endpoints can be found in Supplementary

Material 1 (Supplemental Digital Content 1, http://links.lww.com/JS9/C985, Supplemental Digital Content 5, http://links.lww.com/JS9/C989, Supplemental Digital Content 6, http://links.lww.com/JS9/C990). A composite endpoint during the short-term follow-up was defined as the occurrence of any one or more of the following complications: 1) in-hospital mortality; 2) severe complications - Clavien–Dindo ≥ 3; 3) reoperation; 4) splenic infarction; 5) delayed gastric emptying (DGE) – ISGPS classification grade B/C; 6) postoperative pancreatic hemorrhage (PPH) – ISGPS classification grade B/C; 7) postoperative pancreatic fistula (POPF) – ISGPS classification grade B/C.

Sample size

The trial's sample size was predicated on the primary endpoint of intraoperative blood loss. After consulting with experts in pancreatic surgery and assessing clinical significance, a noninferiority margin of 30 ml was deemed to represent a clinically meaningful disparity between the experimental and control cohorts. With a significance level (α) of 0.025 and a test power (1-β) of 0.8, a retrospective analysis of 50 cases (35 Kimura, 15 Warshaw) from March 2020 to February 2022 yielded SD of 30.3 and 68.8, respectively, for intraoperative blood loss (Supplementary Material 2, Supplemental Digital Content 3, http://links.lww.com/JS9/C987). According to the noninferiority design, at least 51 patients would be necessary per group. Considering an expected dropout rate of 10%, it was determined that each group needed at least 57 patients. The primary outcome of the long-term follow-up in this study is the incidence of gastric varices. When calculating the sample size based on this long-term follow-up primary outcome, we determined a requirement of 55 participants per group. The calculation details are available in Supplementary Material 1 (Supplemental Digital Content 1, http://links.lww.com/JS9/C985, Supplemental Digital Content 5, http://links.lww.com/JS9/C989, Supplemental Digital Content 6, http://links.lww.com/JS9/C990). To accommodate both short-term and long-term primary outcomes, we resolved to enroll 57 patients per group, totaling 114 participants. Sample size estimations were performed using the PASS 2021 version 21.0.3 software (NCSS).

Statistical analysis

The primary outcome for short-term follow-up will be evaluated via noninferiority tests. Should noninferiority be confirmed, a subsequent test for superiority will be implemented[26]. Continuous secondary outcomes with a normal distribution will be examined using independent samples *t*-tests, with results presented as means ± SD. Non-normally distributed continuous variables will be assessed using the median (interquartile range) and the Mann–Whitney *U* test. Categorical variables will be evaluated using either Fisher's exact test or the Pearson χ^2 test, as appropriate. Potential associations between variables and the postoperative composite outcome will be explored using logistic regression. The analysis will adhere to both ITT and per-protocol (PP) principles for comprehensive evaluation. Statistical significance is defined by a two-tailed *P*-value of less than 0.05. All analyses were conducted using SPSS version 27.0 (IBM Corp).

Results

Study population and lead surgeon allocation across study groups

From March 2022 to November 2023, 62 patients were evaluated for eligibility, with 53 subsequently randomized into the Kimura ($n=25$) and Warshaw ($n=28$) groups (Supplementary Material 3, Supplemental Digital Content 4, http://links.lww.com/JS9/C988), as depicted in Figure 2. This interim analysis accounts for 46.5% of the target enrollment. In the Kimura group, 21 patients adhered to the assigned intervention, while 4 initially assigned to this cohort received alternative treatments (three transitioned to the Warshaw method, and one underwent Radical Antegrade Modular Pancreatosplenectomy [RAMPS]). The Warshaw group consisted of 27 patients who received the Warshaw treatment and one who underwent laparoscopic enucleation. No patients were lost to follow-up. The ITT analysis included all 25 patients from the Kimura group and 28 from the Warshaw group, whereas the per-protocol (PP) analysis encompassed 21 and 30 patients, respectively. Baseline characteristics were comparable between the two cohorts, showing no significant differences in age (ITT: 39 [31–61] vs. 51 [40–60], $P=0.193$; PP: 38 [30–58] vs. 54 [41–60], $P=0.073$), BMI (ITT: 23.02 ± 3.02 vs. 24.01 ± 3.35, $P=0.264$; PP: 23.44 ± 3.03 vs. 23.53 ± 3.26, $P=0.240$), tumor size (ITT: 2.7 [2.0–3.6] vs. 2.5 [1.5–3.2], $P=0.309$; PP: 2.6 [1.9–3.6] vs. 2.5 [1.5–3.3], $P=0.534$), and ECOG PS, which was 0 in both groups. Other characteristics, including Malnutrition Universal Screening Tool (MUST) score[27,28], histopathological diagnosis, tumor markers CA199 and CEA, preoperative fasting plasma glucose, diabetes status, and previous abdominal surgery are detailed in Table 1, showing no significant intergroup differences. In this study, a total of three lead surgeons were included. We conducted a χ^2 test to evaluate the distribution of lead surgeons between the two study groups. The findings revealed no statistically significant difference in the distribution of lead surgeons (ITT, $P=0.297$; PP, $P=0.312$) (Table 1).

Intraoperative outcomes

According to the ITT analysis, within a predefined noninferiority margin, the intraoperative blood loss associated with the Kimura procedure was not significantly different from that of the Warshaw procedure (ITT: 70.1 ± 73.8 ml vs. 78.8 ± 108.8 ml, $P=0.141$). PP analysis further confirmed the noninferiority of the Kimura group regarding blood loss compared to the Warshaw group. Subsequent superiority testing demonstrated significantly less blood loss in the Kimura group (PP: 52.5 ± 51.6 ml vs 91.7 ± 113.5 ml, $P=0.007$). No significant differences were found in operative time (ITT: 170.8 ± 47.7 min vs. 165.4 ± 55.0 min, $P=0.703$; PP: 167.1 ± 50.1 min vs. 171.2 ± 51.2 min, $P=0.774$), colloid input (ITT: 500 ml [100–600 ml] vs 500 ml [0–500 ml], $P=0.500$; PP: 500 ml [100–750 ml] vs 500 ml [0–500 ml], $P=0.650$), or urine output (ITT: 200 ml [0–1000 ml] vs 200 ml [0–800 ml], $P=0.512$; PP: 200 ml [0–1000 ml] vs 200 ml [0–800 ml], $P=1.000$) between the two groups. While the ITT analysis showed no significant differences in crystalloid input, the PP analysis revealed that the Warshaw group had a higher intraoperative crystalloid input (PP: 1211.9 ± 356.7 ml vs. 1458.3 ± 498.0 ml, $P=0.045$). There were no conversions to open surgery, and neither group required transfusions of packed red

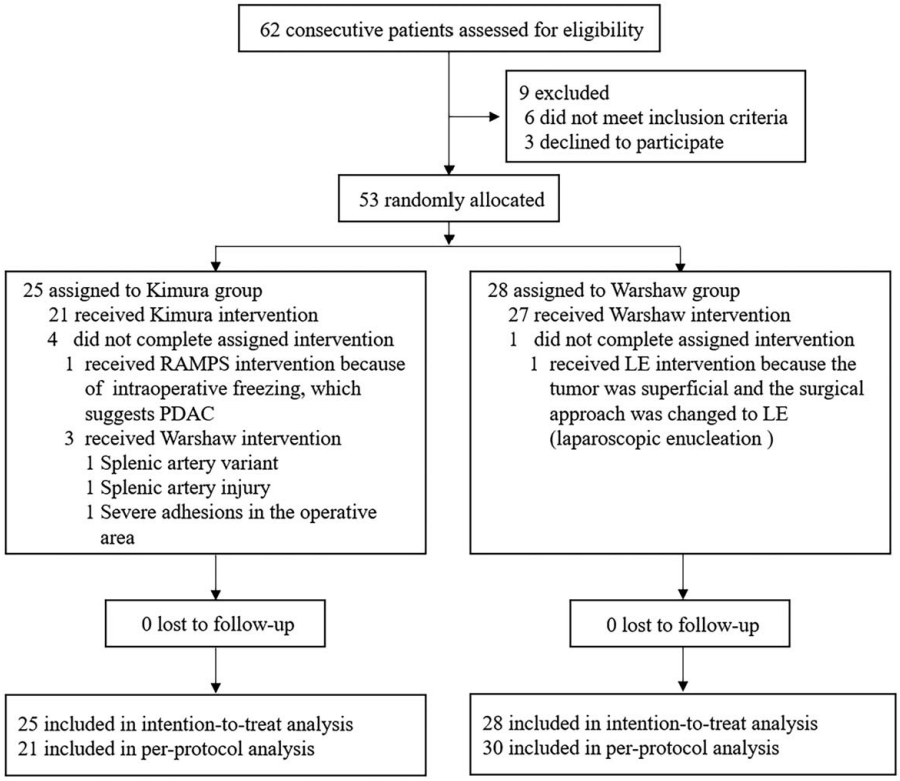

Figure 2. Flowchart of participant enrollment, allocation, follow-up, and analysis. PDAC, pancreatic ductal adenocarcinoma; RAMPS, radical antegrade modular pancreatosplenectomy.

blood cells or plasma. Among the 53 patients, only one required RAMPS due to a malignant tumor identified during intraoperative frozen section examination; the remaining 52 patients successfully retained their spleens, as detailed in Table 2.

Postoperative clinical outcomes within 90 days

In the ITT analysis, the Warshaw group exhibited a significantly higher composite outcome rate compared to the Kimura group (57.1 vs. 24%, $P = 0.025$). The PP analysis also reflected similar results (56.7 vs. 23.8%, $P = 0.025$). Additionally, the PP analysis indicated that the Warshaw group incurred higher hospitalization costs (¥56 227.4 ± 7,027.0 vs. ¥63 513.8 ± 12 944.5, $P = 0.013$). Although differences in rates of splenic infarction did not reach statistical significance in either the ITT (39.3 vs. 12.5%, $P = 0.058$) or PP (36.7 vs. 14.3%, $P = 0.113$) analyses, a higher incidence was noted in the Warshaw group. There were no cases of secondary splenectomy or surgical site infections in either group. Additionally, no significant differences were observed in pancreas-specific complications, including delayed gastric emptying (ITT: $P = 0.742$; PP: $P = 0.756$) or postoperative pancreatic fistula (ITT: $P = 0.171$; PP: $P = 0.301$). As seen in Table 2, nine cases of Grade B pancreatic fistula were reported, resulting in an overall incidence rate of 17.0% (ITT analysis) or 17.6% (PP analysis). None of the 53 patients in the study developed a Grade C fistula. Detailed information regarding the nine patients with Grade B pancreatic fistula can be found in Supplementary Material 6 (Supplemental Digital Content 7, http://links.lww.com/JS9/C991). In this study, we observed a total of 5 readmission cases postdischarge. Specifically, two patients were readmitted due to Grade C gastric emptying delay, two were readmitted with abdominal pain accompanied by fever, and one case was attributed to encapsulated fluid collection following pancreatic surgery. For comprehensive details, refer to Supplementary Material 7 (Supplemental Digital Content 8, http://links.lww.com/JS9/C992). There were no statistically significant differences in readmission rates between the two patient groups. Postpancreatectomy hemorrhage was not reported, and there were no mortalities within the 90-day postoperative period. Both groups had a median hospital stay of 9 days, as detailed in Table 2.

The risk of composite outcome following the Warshaw method is higher than that of the Kimura method

The risk of a composite outcome was significantly higher with the Warshaw method than the Kimura method. A binary logistic regression analysis was conducted to evaluate the influence of various preoperative and intraoperative factors on this combined outcome. The variables considered included BMI, tumor size, intraoperative blood loss, operative duration, and surgical approach. The linearity of continuous predictors was assessed using the Box-Tidwell procedure, with a Bonferroni-adjusted alpha of 0.005, confirming a linear relationship in the final model. Ultimately, the Logistic model obtained was statistically significant [ITT: $\chi^2 = 22.127$, $P < 0.001$; PP: $\chi^2 = 18.616$, $P = 0.002$]. Based on the model derived from ITT analysis data, the model correctly classified

Table 1

Baseline characteristics of enrolled patients and lead surgeon allocation across study groups.

		Intention-to-treat analysis				Per-protocol analysis		
Variable	**Overall (*n* = 53)**	**Kimura LDP group (*n* = 25)**	**Warshaw LDP group (*n* = 28)**	***P***	**Overall (*n* = 51)**	**Kimura LDP group (*n* = 21)**	**Warshaw LDP group (*n* = 30)**	***P***
Age, years, median (IQR)	48 (34–60)	39 (31–61)	51 (40–60)	0.193	48 (33–59)	38 (30–58)	54 (41–60)	0.073
Sex, *n* (%)				0.075				0.070
Male, *n* (%)	17 (32.1%)	5 (20.0%)	12 (42.9%)		17 (33.3%)	4 (19.0%)	13 (43.3%)	
Female, *n* (%)	36 (67.9%)	20 (80.0%)	16 (57.1%)		34 (66.7%)	17(81.0%)	17 (56.7%)	
BMI, kg/m^2, mean ± SD	23.54 ± 3.21	23.02 ± 3.02	24.01 ± 3.35	0.264	23.53 ± 3.18	23.44 ± 3.03	23.53 ± 3.26	0.240
ASA score, *n* (%)				0.262				0.064
I	2 (3.8%)	2 (8.0%)	0 (0.0%)		2 (3.9%)	2 (9.5%)	0 (0.0%)	
II	44 (83.0%)	21 (84.0%)	23 (82.1%)		42 (82.4%)	18 (85.7%)	24 (80.0%)	
III	7 (13.2%)	2 (8.0%)	5 (17.9%)		7 (13.7%)	1 (4.8%)	6 (20.0%)	
MUST score, *n* (%)				0.825				0.787
0	46 (86.8%)	21 (84.0%)	25 (89.3%)		45 (88.2%)	18 (85.7%)	27 (90.0%)	
1	6 (11.3%)	3 (12.0%)	3 (10.7%)		5 (9.8%)	2 (9.5%)	3 (10.0%)	
2	1 (1.9%)	1 (4.0%)	0 (0.0%)		1 (2.0%)	1 (4.8%)	0 (0.0%)	
ECOG PS, *n* (%)								
0	53 (100%)	25 (100%)	28 (100%)		51 (100%)	21 (100%)	30 (100%)	
Prior abdominal surgery, *n* (%)	13 (24.5%)	7 (28.0%)	6 (21.4%)	0.579	12 (23.5%)	6 (28.6%)	6 (20.0%)	0.518
Hepatitis viral infection	2 (3.8%)	0 (0.0%)	2 (7.1%)	0.492	2 (3.9%)	0 (0.0%)	2 (6.7%)	0.506
Child-Pugh score, *n* (%)								
A	53 (100%)	25 (100%)	28 (100%)		51 (100%)	21 (100%)	30 (100%)	
Normal or prediabetes or diabetes, *n* (%)				0.708				0.345
Normal	44 (83.0%)	22 (88.0%)	22 (78.6%)		42 (82.4%)	19 (90.5%)	23 (76.7%)	
Prediabetes	7 (13.2%)	2 (8.0%)	5 (17.9%)		7 (13.7%)	1 (4.8%)	6 (20.0%)	
Diabetes	2 (3.8%)	1 (4.0%)	1 (3.6%)		2 (3.9%)	1 (4.8%)	1 (3.3%)	
Fasting plasma glucose, mmol, median (IQR)	4.72 (4.49–5.20)	4.72 (4.44–5.15)	4.76 (4.49–5.23)	0.504	4.72 (4.49–5.13)	4.72 (4.38–4.96)	4.72 (4.48–5.42)	0.438
PLT before surgery, mean ± SD	189.7 ± 48.9	197.6 ± 50.3	182.6 ± 47.4	0.270	190.8 ± 49.2	207.4 ± 45.8	179.2 ± 48.9	**0.043**
PT before surgery, S, mean ± SD	11.0 ± 0.7	11.1 ± 0.8	11.0 ± 0.7	0.529	11.1 ± 0.7	11.1 ± 0.8	11.1 ± 0.6	0.892
APTT before surgery, S, mean ± SD	27.9 ± 2.3	27.9 ± 2.7	27.8 ± 1.9	0.880	27.9 ± 2.3	28.1 ± 2.6	27.9 ± 2.0	0.741
INR before surgery, median (IQR)	0.97 (0.94–1.01)	0.98 (0.94–1.01)	0.97 (0.92–1.01)	0.734	0.98 (0.94–1.01)	0.97 (0.94–1.01)	0.98 (0.92–1.01)	0.931
CA199 before surgery, U/ml, median (IQR)	9.17 (5.71–13.87)	8.13 (5.23–14.21)	9.72 (5.87–13.54)	0.708	9.17 (5.68–13.64)	7.35 (4.54–13.05)	10.18 (5.94–13.75)	0.410
CEA before surgery, ng/ml, median (IQR)	1.29 (0.75–2.07)	1.25 (0.67–1.73)	1.49 (0.87–2.24)	0.167	1.35 (0.84–2.07)	1.29 (0.57–1.80)	1.41(0.93–2.15)	0.221
Splenic volumes before surgery, ml, median (IQR)	172.1 (138.2–240.2)	167.5 (140.3–225.9)	186.9 (115.2–243.8)	0.880	172.4 (137.1–241.4)	166.1 (142.4–214.8)	188.5(118.1–248.4)	0.722
Tumor size, cm, median (IQR)	2.6 (1.7 – 3.4)	2.7 (2.0 – 3.6)	2.5 (1.5 – 3.2)	0.309	2.6 (1.8–3.5)	2.6 (1.9–3.6)	2.5 (1.5–3.3)	0.534
Tumor size, n (%)				1.000				1.000
≦3 cm	36 (67.9%)	17 (68.0%)	19 (67.9%)		34 (66.7%)	14 (66.7%)	20 (66.7%)	
> 3 cm	17 (32.1%)	8 (32.0%)	9 (32.1%)		17 (33.3%)	7 (33.3%)	10 (33.3%)	
Lead surgeons, *n* (%)				0.297				0.312
Surgeon A	16 (30.2%)	10 (40.0%)	6 (21.4%)		16 (31.4%)	9 (42.9%)	7 (23.3%)	
Surgeon B	18(34.0%)	8 (32.0%)	10 (35.7%)		18 (35.3%)	7 (33.3%)	11 (36.7%)	
Surgeon C	19(35.8%)	7 (28.0%)	12 (42.9%)		17 (17.0%)	5 (23.8%)	12 (40.0%)	
Histopathological diagnosis, *n* (%)				0.260				0.102
SCN	23 (43.4%)	14 (56.0%)	9 (32.1%)		22 (43.1%)	14 (66.7%)	8 (26.7%)	
MCN	6 (11.3%)	2 (8.0%)	4 (14.3%)		6 (11.8%)	1 (4.8%)	5 (16.7%)	
SPT	8 (15.1%)	5 (20.0%)	3 (10.7%)		8 (15.7%)	4 (19.0%)	4 (13.3%)	
Neuroendocrine tumor	6 (11.3%)	1 (4.0%)	5 (17.9%)		6 (11.8%)	1 (4.8%)	5 (16.7%)	
IPMN	5 (9.4%)	1 (4.0%)	4 (14.3%)		5 (9.8%)	1 (4.8%)	4 (13.3%)	
Accessory Spleen	2 (3.8%)	1 (4.0%)	1 (3.6%)		2 (3.9%)	0 (0.0%)	2 (6.7%)	
Pancreatic duct stones	1 (1.9%)	0 (0.0%)	1 (3.6%)		1 (2.0%)	0 (0.0%)	1 (3.3%)	
Pancreatic benign cyst	1 (1.9%)	0 (0.0%)	1 (3.6%)		1 (2.0%)	0 (0.0%)	1 (3.3%)	
IPMN-IC	1 (1.9%)	1 (4.0%)	0 (0.0%)					

Bold indicate statistical significance $P < 0.05$.

APTT, activated partial thromboplastin-time; ASA, American Society of Anesthesiologists; CA199, carbohydrate antigen (CA)19-9; CEA, carcinoembryonic antigen; INR, international normalized ratio; IPMN, intraductal papillary mucinous neoplasm; IPMN-IC, IPMN-associated invasive pancreatic carcinoma; IQR, interquartile range; LDP, laparoscopic distal pancreatectomy; MCN, mucinous cystic neoplasms, PLT, platelet; PT, prothrombin time; SCN, serous cystadenomas serous cystic neoplasms; SPT, solid pseudopapillary tumor

Table 2

Clinical outcomes of the Kimura group and Warshaw group.

		Intention-to-treat analysis				Per-protocol analysis		
Outcome	**Overall ($n=53$)**	**Kimura LDP group ($n=25$)**	**Warshaw LDP group ($n=28$)**	***P***	**Overall ($n=51$)**	**Kimura LDP group ($n=21$)**	**Warshaw LDP group ($n=30$)**	***P***
Intraoperative outcomes								
Blood loss, ml, mean ± SD	74.7 ± 93.2	70.1 ± 73.8	78.8 ± 108.8	**0.141**	75.5 ± 94.4	52.5 ± 51.6	91.7 ± 113.5	**0.007**
Success of spleen preservation, *n* (%)	52 (98.1%)	24 (96.0%)	28 (100%)	0.472	51 (100%)	21 (100%)	30 (100%)	
Operative time, minutes, mean ± SD	167.9 ± 51.3	170.8 ± 47.7	165.4 ± 55.0	0.703	169.5 ± 50.3	167.1 ± 50.1	171.2 ± 51.2	0.774
Conversion to open procedure, *n* (%)	0	0	0		0	0	0	
Urine output, ml, median (IQR)	200 (0–1000)	200 (0–1000)	200 (0–800)	0.512	200 (0–1000)	200 (0–1000)	200 (0–800)	1.000
Crystalloid, ml, mean ± SD	1358.5 ± 470.2	1274.0 ± 381.4	1433.9 ± 533.0	0.212	1356.9 ± 458.6	1211.9 ± 356.7	1458.3 ± 498.0	**0.045**
Colloid, ml, median (IQR)	500 (0–500)	500 (100–600)	500 (0–500)	0.500	500 (0–500)	500 (100–750)	500 (0–500)	0.650
Packed red blood cells, ml, median (IQR)	0	0	0		0	0	0	
Fresh frozen plasma, ml, median (IQR)	0	0	0		0	0	0	
Postoperative clinical outcomes								
Composite outcome, n (%)	22 (41.5%)	6 (24.0%)	16 (57.1%)	**0.025**	22 (43.1%)	5 (23.8%)	17 (56.7%)	**0.019**
Complication (CD classification), II, *n* (%)	53 (100.0%)	25 (100.0%)	28 (100.0%)		51 (100.0%)	21 (100.0%)	30 (100.0%)	
Splenic infarction, *n* (%)	14 (26.9%)	3 (12.5%)	11 (39.3%)	0.058	14 (27.5%)	3 (14.3%)	11 (36.7%)	0.113
Secondary splenectomy, *n* (%)	0	0	0		0	0	0	
POPF, *n* (%)				0.171				0.301
Normal*	4 (7.5%)	0 (0.0%)	4 (14.3%)		3 (5.9%)	0 (0.0%)	3 (10.0%)	
BL	40 (75.5%)	21 (84.0%)	19 (67.9%)		39 (76.5%)	18 (85.7%)	21 (70.0%)	
Grade B	9 (17.0%)	4 (16.0%)	5 (17.9%)		9 (17.6%)	3 (14.3%)	6 (20.0%)	
DGE, *n* (%)				0.742				0.756
Normal#	49 (92.5%)	24 (96.0%)	25 (89.3%)		47 (92.2%)	20 (95.2%)	27 (90.0%)	
Grade A	2 (3.8%)	0 (0.0%)	2 (7.1%)		2 (3.9%)	0 (0.0%)	2 (6.7%)	
Grade C	2 (3.8%)	1 (4.0%)	1 (3.6%)		2 (3.9%)	1 (4.8%)	1 (3.3%)	
PPH grade A/B/C, n (%)	0	0	0		0	0	0	
SSI, n (%)	0	0	0		0	0	0	
Spleen volume ratio	1.27 ± 0.35	1.28 ± 0.37	1.26 ± 0.34	0.818	1.27 ± 0.35	1.30 ± 0.35	1.24 ± 0.35	0.566
ICU admission, *n* (%)	0	0	0		0	0	0	
Readmission within 90 days, *n* (%)	5 (9.4%)	2 (8.0%)	3 (10.7%)	1.000	5 (9.8%)	2 (9.5%)	3 (10.0%)	1.000
Mortality within 90 days, *n* (%)	0	0	0		0	0	0	
Length of hospital stay, days, median (IQR)	9 (7–11)	9 (7–11)	9 (6–11)	0.816	9 (7–11)	9 (7–11)	9 (7–11)	0.758
Hospital costs, ¥, mean ± SD	59998.9 ± 11623.2	56873.5 ± 6779.4	62789.4 ± 14220.3	0.056	60513.5 ± 11404.0	56227.4 ± 7027.0	63513.8 ± 12944.5	**0.013**

* Drainage fluid amylase three times less than plasma amylase; # No need for gastric tube, no DGE; Composite outcome: defined as the occurrence of any one or more of the following complications among patient outcomes: 1) in-hospital mortality; 2) severe complications – Clavien–Dindo ≥ 3; 3) reoperation; 4) splenic infarction; 5) delayed gastric emptying (DGE) – ISGPS classification grade B/C; 6) Postpancreatectomy hemorrhage (PPH) - ISGPS classification grade B/C; 7) postoperative pancreatic fistula (POPF) – ISGPS classification grade B/C. CD, Clavien–Dindo classification; DGE, Delayed gastric emptying; IQR, Interquartile range; POPF, Postoperative pancreatic fistula; PPH, Postpancreatectomy hemorrhage; Spleen volume ratio: ratio of spleen volume at 1 week postoperatively to preoperative spleen volume; SSI, Surgical Site Infection.

77.4% of the study subjects, with a sensitivity of 72.7%, specificity of 80.6%, positive predictive value of 72.7%, and negative predictive value of 80.6%. The PP model's corresponding metrics were 76.5, 72.7, 79.3, 72.7, and 79.3%, respectively. Among the variables, the surgical approach was significant (ITT: $P = 0.016$; PP: $P = 0.047$), with the Warshaw method associated with a higher risk of composite outcomes (ITT: odds ratio [OR], 6.190; 95% CI: 1.406–27.241; PP: OR, 4.537; 95% CI: 1.022–20.138) as detailed in Table 3.

Participant health status assessment

The EQ-5D-5L, a standardized instrument developed by the European Quality of Life Society[29], was employed to assess health-related quality of life in this study. This widely applicable questionnaire evaluates five dimensions—mobility, self-care, usual activities, pain/discomfort, and anxiety/depression—each with five response levels ranging from 'no problems' to 'unable to/extreme problems'. EQ-5D index values, derived from a Chinese value set[30], were used for analysis. Preoperative, postoperative day 3, and discharge day EQ-5D-5L index values showed no significant differences between the two groups in both ITT and PP analyses (Table 4).

Discussion

In this prospective randomized controlled clinical trial, we performed an interim analysis to evaluate the 90-day postoperative outcomes of 52 patients who underwent LSPDP using either the Kimura or Warshaw methods. We included two cases where preoperative imaging tests indicated pancreatic neuroendocrine tumors, but postoperative pathology revealed them to be intrapancreatic accessory spleen. It is common for pancreatic accessory spleen to be misdiagnosed as intrapancreatic neuroendocrine tumors before surgery[5,31]. Our study results show that the Kimura technique confers superior in terms of reduced intraoperative blood loss and fewer complications, alongside lower costs.

Contrary to some retrospective studies[10,32,33] suggesting higher intraoperative blood loss with the Kimura method, our prospective findings revealed no significant difference in blood loss between the two methods within the noninferiority margin, as confirmed by both ITT and PP analyses. A post-hoc superiority test within the PP analysis indicated a significant reduction in blood loss with the Kimura method, aligning with a large European retrospective study that also reported less blood loss for the Kimura method (100 ml vs. 150 ml, $P < 0.001$)[9]. Regarding operative time, a critical concern for surgeons, our study aligned with a recent meta-analysis[11], finding no significant differences between the Kimura and Warshaw methods in ITT and PP analyses, thereby supporting the notion of equivalent operative durations for both techniques.

Limited research has examined health status and spleen volume outcomes following LSPDP. In our study, we employed the EQ-5D-5L scale, a validated instrument for health status assessment[20,30], to evaluate patients at baseline and two postoperative intervals. Additionally, considering the prognostic relevance of spleen volume for hemodynamic alterations[34], we quantified spleen volume preoperatively and postoperatively. We observed no significant differences in spleen volume between the groups before or after surgery. However, an increase in spleen volume was noted 1 week after surgery in both cohorts, suggesting a transient impact on hemodynamics attributable to both surgical techniques. Andrew L. Warshaw and colleagues[35] followed patients who underwent spleen-preserving distal pancreatectomy using the Warshaw method for 21 years. In their cohort of 65 with imaging data, 16 (25%) developed gastric varices without associated gastrointestinal bleeding or hypersplenism. Notably, the study did not track spleen volume changes, underscoring the need for long-term follow-up to assess the spleen volume. Regarding the EQ-5D-5L health status measure, our findings indicated no significant differences in index scores between the surgical methods. Both groups approached a score of 1 by the time of discharge, suggesting that neither surgical approach exerts a lasting effect on patient functionality or quality of life.

Concurrently, we observed a higher occurrence of splenic infarctions in the Warshaw group compared with the Kimura group, although this difference did not reach statistical significance. The splenic infarctions detected in our cohort were all asymptomatic and did not necessitate surgical intervention. These findings are consistent with previous retrospective studies[36,37] and a recent meta-analysis[11], which reported an increased incidence of splenic infarction with the Warshaw method. The meta-analysis, which synthesized data from 18 studies involving 1987 patients, noted a significantly lower incidence of splenic infarction in the group undergoing spleen-vascular preservation during distal pancreatectomy (SVP-DP).

Table 3

Regression analysis of the incidence of composite outcome

	Intention-to-treat analysis 95% CI for OR				Per-protocol analysis 95% CI for OR			
Independent variables	**OR**	**Lower**	**Upper**	***P***	**OR**	**Lower**	**Upper**	***P***
BMI of before surgery	1.258	0.985	1.607	0.066	1.251	0.988	1.585	0.063
Tumor size	1.373	0.807	2.334	0.242	1.331	0.796	2.225	0.275
Blood loss	1.004	0.993	1.015	0.527	1.001	0.990	1.012	0.869
Operative time	1.014	0.996	1.033	0.127	1.014	0.996	1.032	0.120
Intervention (W vs K)	6.190	1.406	27.241	**0.016**	4.537	1.022	20.138	**0.047**

OR, odds ratio.

Table 4

Impact of treatment on EQ-5D-5L index score.

	Intention-to-treat analysis				Per-protocol analysis			
Follow time	Overall ($n=53$)	Kimura LDP group ($n=25$)	Warshaw LDP group ($n=28$)	*P*	Overall ($n=51$)	Kimura LDP group ($n=21$)	Warshaw LDP group ($n=30$)	*P*
Preoperative, median (IQR)	0.89 (0.88–0.95)	0.89 (0.88–0.95)	0.95 (0.88–0.95)	0.674	0.89 (0.88–0.95)	0.89 (0.88–0.95)	0.92 (0.88–0.95)	1.00
3 days after surgery, median (IQR)	0.64 (0.53–0.69)	0.64 (0.53–0.69)	0.64 (0.52–0.70)	0.733	0.64 (0.56–0.69)	0.64 (0.53–0.71)	0.64 (0.55–0.69)	0.714
Time of discharge, median (IQR)	0.93 (0.88–1.00)	0.93 (0.89–1.00)	0.93 (0.84–0.95)	0.389	0.93 (0.88–1.00)	0.93 (0.88–1.00)	0.93 (0.84–0.97)	0.369

While the Warshaw method is associated with a heightened risk of splenic infarction, the clinical consequences seem to be minimal, indicating that careful monitoring without the need for surgical intervention may be sufficient.

In the initial design of our study, we instituted a composite outcome measure, a strategy that reduces the required sample size while maintaining the desired statistical power. This approach, which has gained traction in clinical research, including within the realm of pancreatic disease studies, enhances the viability and cost-effectiveness of clinical trials[38]. The Textbook Outcome[39] and Optimal Pancreatic Surgery[40] are examples of composite outcome in pancreatic surgery. Our composite outcome, tailored to the nuances of spleen-preserving distal pancreatectomy, encompasses seven complications, including splenic infarction and gastric varices. Our analysis, conducted both ITT and PP, revealed a more frequent occurrence of composite outcome in the Warshaw group, correlated with an elevated risk coefficient. Moreover, the PP analysis indicated increased hospitalization costs for the Warshaw group, suggesting a potential correlation between the heightened incidence of composite outcomes and augmented expenditures.

It is important to note that we did not decide to terminate our study due to the following reasons: 1) The proportion of splenic infarctions, the most prevalent component of the composite outcome, did not require surgical intervention; 2) Patients in both groups have not experienced severe complications (Clavien–Dindo classification $\geq$ III), mortality, postpancreatectomy hemorrhage (ISGPS grade B/C), postoperative pancreatic fistula (ISGPS classification grade C), or required reoperation; 3) Further data collection is required to fully evaluate long-term outcomes, including postpancreatectomy new-onset diabetes[41–43], the development of gastric varices[35,37], instances of delayed splenectomy, and occurrences of gastrointestinal bleeding, among others.

Our study is conducted at a single-center. Compared to multicenter research, implementing single-center studies may be more straightforward, with easier control over data quality. However, it is undeniable that single-center studies are prone to center effects. High-quality multicenter studies have superior external validity to single-center studies. Furthermore, our current study involves an interim analysis of short-term follow-up outcomes within 90 days postoperatively. It lacks the analysis results of long-term follow-up outcomes. Despite retrospective studies indicating a higher proportion of gastric varices with the Warshaw method compared to the Kimura method[11], further validation is required through prospective randomized controlled clinical trials with unbiased baseline data.

Conclusions

The 90-day interim analysis postoperatively indicates that both Kimura and Warshaw techniques for LSPDP are safe and viable. The Kimura technique, however, confers superior in terms of reduced intraoperative blood loss and fewer complications, alongside lower costs.

Ethical approval

This study was approved by the Biomedical Research Ethics Committee of West China Hospital of Sichuan University, Chengdu, China. (No. 2022-IRB-093) on 1 March 2022.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Source of funding

This work was supported by grant from 1.3.5 project for disciplines of excellence, West China Hospital, Sichuan University (2018HXFH015).

Author contribution

B.P., Y.Q.C., and Q.X.C.: concept and design; Q.X.C., Y.Z.F., and Y.B.L.: drafting of the manuscript; Q.X.C., J.W.J., and J.J.Y.: statistical analysis; All authors: acquisition, analysis, and interpretation of data; B.P. and Y.Q.C.: critical revision of the article; B.P. and Y.Q.C.: Project administration; Z.W., L.W.M., and J.W.J.: Supervision. All authors contributed in final approval of the article.

Conflicts of interest disclosure

The authors declare that they have no competing interests.

Research registration unique identifying number (UIN)

(1) Name of the registry: Chinese Clinical Trial Registry chictr.org.cn.
(2) Unique identifying number or registration ID: ChiCTR 2200057763.
(3) Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.chictr.org.cn/showproj.html?proj=162589

Guarantor

Bing Peng and Yunqiang Cai.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author on reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Acknowledgement
The authors thank all patients who participated in this study.

References

[1] Govil S, Imrie CW. Value of splenic preservation during distal pancreatectomy for chronic pancreatitis. Br J Surg 1999;86:895–8.
[2] Shoup M, Brennan MF, McWhite K, *et al*. The value of splenic preservation with distal pancreatectomy. Arch Surg 2002;137:164–8.
[3] Shi N, Liu SL, Li YT, *et al*. Splenic preservation versus splenectomy during distal pancreatectomy: a systematic review and meta-analysis. Ann Surg Oncol 2016;23:365–74.
[4] Dai MH, Shi N, Xing C, *et al*. Splenic preservation in laparoscopic distal pancreatectomy. Br J Surg 2017;104:452–62.
[5] Zhang Y, Shi G, Meng L, *et al*. Laparoscopic treatment for an intrapancreatic accessory spleen: A case report. Front Oncol 2022;12:972883.
[6] Warshaw AL. Conservation of the spleen with distal pancreatectomy. Arch Surg 1988;123:550–3.
[7] Kimura W, Inoue T, Futakawa N, *et al*. Spleen-preserving distal pancreatectomy with conservation of the splenic artery and vein. Surgery 1996;120:885–90.
[8] Jean-Philippe A, Alexandre J, Christophe L, *et al*. Laparoscopic spleen-preserving distal pancreatectomy: splenic vessel preservation compared with the Warshaw technique. JAMA Surg 2013;148:246–52.
[9] Korrel M, Lof S, Al Sarireh B, *et al*. Short-term outcomes after spleen-preserving minimally invasive distal pancreatectomy with or without preservation of splenic vessels: a pan-european retrospective study in high-volume centers. Ann Surg 2023;277:e119–25.
[10] Nakata K, Shikata S, Ohtsuka T, *et al*. Minimally invasive preservation versus splenectomy during distal pancreatectomy: a systematic review and meta-analysis. J Hepatobiliary Pancreat Sci 2018;25:476–88.
[11] Hang K, Zhou L, Liu H, *et al*. Splenic vessels preserving versus Warshaw technique in spleen preserving distal pancreatectomy: a systematic review and meta-analysis. Int J Surg 2022;103:106686.
[12] Schulz KF, Altman DG, Moher D, *et al*. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ 2010;340:c332.
[13] Park CM, Koh Y, Jeon K, *et al*. Impact of Eastern Cooperative Oncology Group Performance Status on hospital mortality in critically ill patients. J Crit Care 2014;29:409–13.
[14] Horvath B, Kloesel B, Todd MM, *et al*. The evolution, current value, and future of the American Society of Anesthesiologists physical status classification system. Anesthesiology 2021;135:904–19.
[15] Martin JA, Regehr G, Reznick R, *et al*. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg 1997;84:273–8.
[16] Petrowsky H, McCormack L, Trujillo M, *et al*. A prospective, randomized, controlled trial comparing intermittent portal triad clamping versus ischemic preconditioning with continuous clamping for major liver resection. Ann Surg 2006;244:921–8.
[17] Antopolsky M, Hiller N, Salameh S, *et al*. Splenic infarction: 10 years of experience. Am J Emerg Med 2009;27:262–5.
[18] Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205–13.
[19] Mangram AJ, Horan TC, Pearson MC, *et al*. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Am J Infect Control 1999;27:97–132.
[20] Herdman M, Gudex C, Lloyd A, *et al*. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L. Qual Life Res 2011;20:1727–36.
[21] In: Devlin N, Roudijk B, Ludwig K, eds. *Value Sets for EQ-5D-5L: A Compendium, Comparative Review & User Guide*. 2022.
[22] Xu Z, Gertz AL, Burke RP, *et al*. Improving spleen volume estimation via computer-assisted segmentation on clinically acquired CT scans. Acad Radiol 2016;23:1214–20.
[23] Wente MN, Bassi C, Dervenis C, *et al*. Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS. Surgery 2007;142:761–8.
[24] Wente MN, Veit JA, Bassi C, *et al*. Postpancreatectomy hemorrhage (PPH): an International Study Group of Pancreatic. Surgery (ISGPS) definition Surgery 2007;142:20–5.
[25] Bassi C, Marchegiani G, Dervenis C, *et al*. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 2017;161:584–91.
[26] Marso SP, Daniels GH, Barown-Frandsen K, *et al*. Liraglutide and cardiovascular outcomes in type 2 diabetes. N Engl J Med 2016;375:311–22.
[27] Stratton RJ, Hackston A, Longmore D, *et al*. Malnutrition in hospital outpatients and inpatients: prevalence, concurrent validity and ease of use of the 'malnutrition universal screening tool' ('MUST') for adults. Br J Nutr 2004;92:799–808.
[28] Henderson S, Moore N, Lee E, *et al*. Do the malnutrition universal screening tool (MUST) and Birmingham nutrition risk (BNR) score predict mortality in older hospitalised patients. BMC Geriatr 2008;8:26.
[29] EuroQol G. EuroQol--a new facility for the measurement of health-related quality of life. Health Policy 1990;16:199–208.
[30] Luo N, Liu G, Li M, *et al*. Estimating an EQ-5D-5L Value Set for China. Value Health 2017;20:662–9.
[31] Kwon YJ, Park HK, Lee KG. Misdiagnosis of intrapancreatic accessory spleen as an endocrine tumor of the pancreatic tail. Clin Gastroenterol Hepatol 2012;10:A27–8.
[32] Fernandez-Cruz L, Martinez I, Gilabert R, *et al*. Laparoscopic distal pancreatectomy combined with preservation of the spleen for cystic neoplasms of the pancreas. J Gastrointest Surg 2004;8:493–501.
[33] Yongfei H, Javed AA, Burkhart R, *et al*. Geographical variation and trends in outcomes of laparoscopic spleen-preserving distal pancreatectomy with or without splenic vessel preservation: a meta-analysis. Int J Surg 2017;45:47–55.
[34] Romero-Cristobal M, Clemente-Sanchez A, Ramon E, *et al*. CT-derived liver and spleen volume accurately diagnose clinically significant portal hypertension in patients with hepatocellular carcinoma. JHEP Rep 2023;5:100645.
[35] Ferrone CR, Konstantinidis IT, Sahani DV, *et al*. Twenty-three years of the Warshaw operation for distal pancreatectomy with preservation of the spleen. Ann Surg 2011;253:1136–9.
[36] Zhou ZQ, Kim SC, Song KB, *et al*. Laparoscopic spleen-preserving distal pancreatectomy: comparative study of spleen preservation with splenic vessel resection and splenic vessel preservation. World J Surg 2014;38:2973–9.
[37] Yohanathan L, Loveday BPT, Brar N, *et al*. Effect of vessel preservation on splenic volume and function in patients with spleen preserving distal pancreatectomies. HPB (Oxford) 2020;22:1563–8.
[38] Irony TZ. The "Utility" in composite outcome measures: measuring what is important to patients. JAMA 2017;318:1820–1.
[39] van Roessel S, Mackay TM, van Dieren S, *et al*. Textbook outcome: nationwide analysis of a novel quality measure in pancreatic surgery. Ann Surg 2020;271:155–62.

[40] Beane JD, Borrebach JD, Zureikat AH, *et al*. Optimal pancreatic surgery: are we making progress in North America? Ann Surg 2021; 274:e355–63.
[41] Yang J, Zhang J, Wang R, *et al*. Prevalence of dysglycemia and associated risk factors in patients with pancreatic benign and low-grade malignant tumors before pancreatic surgery: a prospective observational study. Front Endocrinol (Lausanne) 2022;13:960843.
[42] Ko SW, Seo DW, So H, *et al*. Effects of pancreatic resection for benign pancreatic neoplasms on pancreatic volume and endocrine function: a long-term computed tomography-based study. Pancreatology 2020;20: 1732–8.
[43] Maxwell DW, Jajja MR, Galindo RJ, *et al*. Post-Pancreatectomy Diabetes Index: a validated score predicting diabetes development after major pancreatectomy. J Am Coll Surg 2020;230:393–402 e3.