



Original Article

Does modified Blumgart pancreatojejunostomy compared with original Blumgart pancreatojejunostomy decrease the rate of clinically relevant postoperative pancreatic fistula? A single-center propensity score-matched analysis

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Backgrounds/Aims: The most common cause of morbidity following pancreatoduodenectomy (PD) is the clinically relevant postoperative pancreatic fistula (CR-POPF). There is currently no universally accepted technique for pancreato-enteric anastomosis. This study aims to compare the Blumgart technique (B-PJ) with the modified Blumgart technique (mB-PJ).

Methods: This is a retrospective study involving patients who underwent PD between January 2011 and December 2021. The primary endpoint was to compare the incidence of CR-POPF. Secondary endpoints included major morbidity, length of postoperative stay, rates of reoperation, hospital readmission, postoperative mortality, and predictors of CR-POPF. Propensity score matching (PSM) was employed to minimize potential selection bias.

Results: The study included 292 patients. After PSM, the incidence of CR-POPF was not significantly different between B-PJ and mB-PJ (18.9% vs. 15.8%, $p = 0.566$). No statistical differences were observed in the secondary endpoints. Independent predictors of CR-POPF included preoperative cholangitis (odds ratio [OR]: 4.906, 95% confidence interval [CI]: 1.440–16.713, $p = 0.011$), soft pancreas (OR: 4.259, 95% CI: 1.043–17.376, $p = 0.043$), and main pancreatic duct size ≤ 3 mm (OR: 5.229, 95% CI: 1.865–14.656, $p = 0.002$).

Conclusions: This study did not demonstrate that mB-PJ is superior to B-PJ in reducing the incidence of CR-POPF. Factors such as soft pancreas, main pancreatic duct size, and preoperative cholangitis are identified as independent risk factors for CR-POPF.

Key Words: Pancreatoduodenectomy; Blumgart pancreato-jejunostomy; Modified Blumgart pancreato-jejunostomy; Clinically relevant postoperative pancreatic fistula

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INTRODUCTION

Pancreatoduodenectomy (PD) is a surgical procedure designed to treat various symptomatic benign, premalignant, and malignant lesions affecting the head of the pancreas and the periampullary region [1]. The centralization and standardization of this procedure in high-volume centers have improved perioperative outcomes, reducing postoperative mortality to less than 3% [1,2]. However, postoperative morbidity remains significant, affecting approximately 40% of patients [1,3]. The most common complication associated with PD is leakage from the pancreato-enteric anastomosis [3], often referred to as the “Achilles heel” of this procedure [4], and is considered the most challenging phase of PD [2]. A failure at this anastomosis can lead to pancreatic leakage into the peritoneal cavity [5], resulting in clinically relevant postoperative pancreatic fistula (CR-POPF), a potentially fatal complication [6], which ranges from 10% to 15% [3,7].

Several techniques for pancreato-enteric anastomosis have been proposed [6], but there is no universally accepted method [2]. The shear forces at the remnant pancreas [8] from the sutures through the pancreatic parenchyma which placed tangentially [9] causes cutting during knot tying [8]. To address this issue, Blumgart developed a technique that combines duct-to-mucosa anastomosis with an invagination approach, wherein the jejunal surface covers the cut surface of the remnant pancreatic stump [6]. A key innovation in Blumgart’s technique is the use of U-shaped transfixing sutures (four to six) to approximate the jejunum to the pancreatic stump, minimizing shear forces and tangential tension [10-13].

The original Blumgart pancreatojejunostomy technique (B-PJ) was later modified and simplified by reducing the number of U-shaped transfixing sutures to three [14,15] and by tying the sutures only after placing the anterior seromuscular suture on the jejunum, rather than first knotting them on the pancreatic anterior surface [13] to avoid lacerations [14]. The modified Blumgart technique (mB-PJ) gained rapid popularity, with some reports suggesting a reduction in CR-POPF and overall morbidity associated with its use [14,15]. However, there are currently no studies comparing the outcomes of the original B-PJ with the mB-PJ technique.

This retrospective study aims to compare the original B-PJ with the mB-PJ technique in terms of CR-POPF rates and major postoperative morbidity and mortality. It will employ a propensity score-matched analysis and identify predictive factors for CR-POPF.

MATERIALS AND METHODS

A retrospective analysis was conducted on patients undergoing PD at our institution (Department of Surgery, Hospital Nacional Guillermo Almenara Irigoyen) from January 1, 2011, to December 31, 2021. B-PJ was performed exclusively from 2011

to 2014, while mB-PJ was utilized from 2014 onward. Patients who underwent PD between 2022 and 2024 were excluded for two reasons: first, our minimally invasive program commenced in 2022, involving combined laparoscopic resection and open reconstruction; second, two new surgeons joined our team and began their learning curve.

This study was approved by the Institutional Ethics Committee of San Martín de Porres University (IRB no. 0517-2024-CIEI-FMH-USMP). Data were collected and analyzed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies [16], and the ethical principles for medical research established in the Helsinki Declaration [17].

Selection criteria and endpoints

Patients who underwent open PD, with B-PJ and mB-PJ, were included in the study. Patients who underwent total pancreatectomy or hepato-PD, and < 18 years-old were excluded (Fig. 1).

The primary endpoint was the comparison of CR-POPF incidence between B-PJ and mB-PJ. Secondary study endpoints included the comparison of major morbidity, postoperative length of stay (LOS), reoperation, hospital readmission, and postoperative mortality rates between B-PJ and mB-PJ techniques.

Definition of outcomes measure

Postoperative pancreatic fistula (POPF) was defined according to the 2016 update from the International Study Group on Pancreatic Surgery (ISGPS) [18]. Grade B and C fistulas were classified as clinically relevant (CR-POPF) [18]. Additionally, post pancreatectomy hemorrhage [19], delayed gastric emptying (DGE) [20], post pancreatectomy acute pancreatitis [21], and chyle leak [22] were also defined and graded based on ISGPS criteria. Surgical site infection was defined according to Center for Disease Control criteria [23]. The Clavien-Dindo (CD) classification [24] was employed to grade postoperative morbidity, with major morbidity considered when the CD

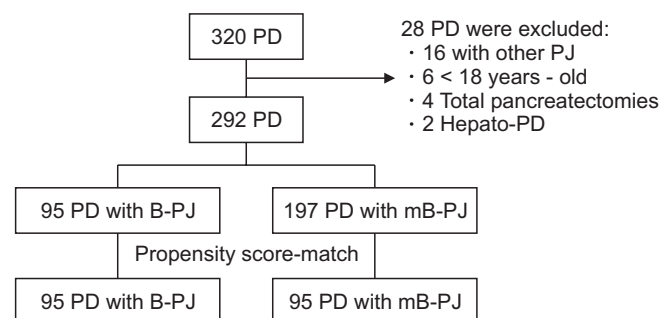


Fig. 1. Flow chart of patients undergoing open PD with B-PJ or mB-PJ. PD, pancreatoduodenectomy; B-PJ, Blumgart pancreatojejunostomy technique; mB-PJ, modified Blumgart technique; PJ, pancreatojejunostomy.

score was $\geq$ III. In cases of multiple morbidities, the highest grade was taken into account.

Postoperative LOS was defined as the number of days from PD to discharge. Postoperative mortality was defined as death occurring within 30 days after PD or during the hospital stay.

Operative technique

All PD were conducted by three experienced pancreatic surgeons. The initial steps involved a partial PD, standard lymphadenectomy, and mobilization of the pancreatic remnant stump edge, approximately 1 cm. Following the resection phase, reconstruction was performed by placing the jejunal loop through the mesocolon, to the right of the middle colic vessels, to create the pancreatojejunostomy (either B-PJ or mB-PJ), as described below. An end-to-side hepaticojejunostomy was performed 10 to 15 cm distal to the pancreatojejunostomy. Lastly, an antecolic end-to-side gastrojejunostomy was created. We routinely performed pylorus ring resection, dividing the stomach 1 cm above the pylorus ring while preserving more than 95% of the stomach [25], except in cases of duodenal cancer, where an antrectomy was performed.

Two continuous-suction silicone drains were routinely placed on the superior and inferior sides of the pancreatojejunostomy.

Octreotide was not regularly utilized.

Blumgart pancreatojejunostomy (B-PJ) technique

Four trans-pancreatic U polyglactin 2/0 sutures were placed through the pancreatic remnant stump, 1 cm distal from the pancreatic edge surface. The needle was straightened to facilitate the placement of the sutures. Each stitch began at the anterior surface of the pancreas, moving straight from front to back, and was followed by a longitudinal seromuscular stitch in the jejunal loop wall, returning through the pancreas from the posterior to the anterior surface (through-and-through) [10]. The distance between each U suture was 5–10 mm. Two U sutures were placed cranially and two caudally to the pancreatic duct. The sutures were left loose with the needle retained until the duct-to-mucosa anastomosis was performed. A small incision was made in the antimesenteric wall of the jejunum, and an interrupted duct-to-mucosa anastomosis was created using 5/0 polydioxanone, with the knots left outside. The polyglactin sutures were then carefully tied on the anterior surface of the pancreas. Finally, the U sutures were completed by placing a seromuscular stitch in the anterior wall of the jejunal loop, then taking a bite of the pancreatic capsule by passing the needle under the previously knotted suture, imbricating the jejunum

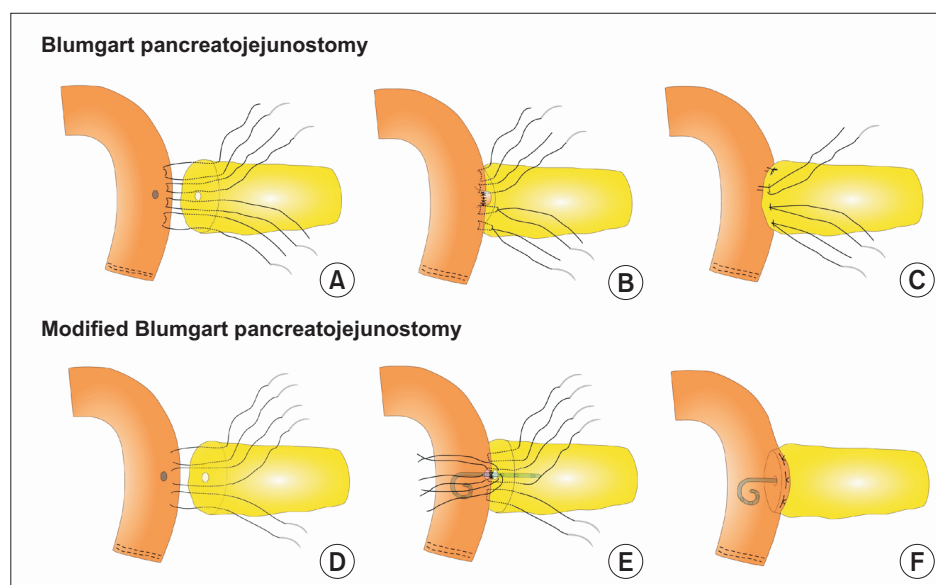


Fig. 2. Blumgart and modified Blumgart pancreatojejunostomy. (A) Placement of full 2/0 polyglactin U sutures, each stitch started in the anterior surface of the pancreas, going from front to back straight, followed by a seromuscular stitch in the jejunal wall coming back through the pancreas from posterior to anterior surface. Four sutures were placed in this fashion. (B) An interrupted duct-to-mucosa anastomosis was performed with 5/0 polydioxanone and the trans pancreatic/jejunal seromuscular sutures are tied. (C) The U sutures were completed by placing a seromuscular stitch in the anterior wall of the jejunal loop and then taking a bite of the pancreatic capsule passing the needle under the previously tied suture and tied again. (D) Placement of three double-armed 3/0 polypropylene trans pancreatic U sutures, each stitch started in the anterior surface of the pancreas, going from front to back straight. This suture was followed by a seromuscular longitudinally stitch in the jejunal loop wall, coming back through the pancreas from posterior to anterior surface. The central suture was placed cranial and caudal to the pancreatic duct. (E) The duct-to-mucosa anastomosis was performed identical as described in the Blumgart pancreatojejunostomy technique. A 6 to 8 Fr polyvinyl catheter was inserted into the pancreatic duct for internal drainage, in patients with non-dilated pancreatic duct. (F) Both needles of the 3/0 polypropylene were stitched longitudinally in the seromuscular anterior wall of the jejunal loop and tied firmly on the anterior serosal surface of the jejunal loop.

over the anterior surface of the pancreatic remnant, and rolling over to the anterior and posterior surfaces of the pancreas. The sutures were then tied (Fig. 2).

Neither internal nor external stent was used performing B-PJ.

Modified Blumgart pancreatojejunostomy (mB-PJ) technique

Three double-armed 3/0 polypropylene trans-pancreatic U sutures were placed straight through the pancreatic remnant stump, 1 cm distal from the pancreatic edge surface. The needles were straightened to facilitate suture placement. Each stitch began on the anterior surface of the pancreas, moving from front to back, followed by a seromuscular longitudinal stitch in the jejunal loop wall, and returning through the

pancreas from the posterior to the anterior surface (through-and-through) [10]. The central suture was placed around the pancreatic duct. The sutures were left loose with both needles retained until the duct-to-mucosa anastomosis was completed. This anastomosis was performed in the same manner as described in the B-PJ. Subsequently, both needles of the 3/0 polypropylene were stitched longitudinally into the seromuscular anterior wall of the jejunal loop, 1 cm away from the pancreatic edge. The anastomosis was finalized by securely tying the three 3/0 polypropylene sutures to the anterior serosal surface of the jejunal loop, without concern for lacerating the pancreatic parenchyma. In patients with a pancreatic duct diameter of ≤ 3 mm, a 6 to 8 Fr catheter was inserted into the pancreatic duct for internal drainage (internal stent) to prevent duct occlusion

Table 1. Baseline characteristics of patients undergoing open PD with B-PJ or mB-PJ technique in the overall and matched population

	Overall				After PSM			
	Total (n = 292)	B-PJ (n = 95)	mB-PJ (n = 197)	p-value	Total (n = 190)	B-PJ (n = 95)	mB-PJ (n = 95)	p-value
Demographic features								
Age (yr)	64.5 (55–71)	64 (54–72)	65 (55–71)	0.951	64 (52–72)	64 (54–72)	65 (57–72)	0.377
Age > 75 (yr)	41 (14)	17 (17.9)	24 (12.2)	0.188	29 (15.3)	17 (17.9)	12 (12.6)	0.313
Sex (male)	143 (49)	49 (51.6)	94 (47.7)	0.536	97 (51.1)	49 (51.6)	48 (50.5)	0.884
Previous abdominal surgery	156 (53.4)	44 (46.3)	112 (56.9)	0.091	91 (47.9)	44 (46.3)	47 (49.5)	0.662
ASA I	113 (38.7)	39 (41.1)	74 (37.6)	0.566	87 (45.8)	39 (41.1)	48 (50.5)	0.190
ASA II	146 (50)	52 (54.7)	94 (47.7)	0.261	93 (48.9)	52 (54.7)	41 (43.2)	0.110
ASA III	33 (11.3)	4 (4.2)	29 (14.7)	0.008*	10 (5.3)	4 (4.2)	6 (6.3)	0.515
Comorbidity	168 (57.5)	49 (51.6)	119 (60.4)	0.228	99 (51.1)	49 (51.6)	50 (52.6)	0.884
Symptoms	284 (97.3)	92 (96.8)	192 (97.5)	0.783	185 (97.4)	92 (96.8)	93 (97.9)	0.205
Cholangitis	32 (11)	12 (12.6)	20 (10.2)	0.525	22 (11.6)	12 (12.6)	10 (10.5)	0.650
Preoperative biliary drainage	115 (39.4)	35 (36.8)	80 (40.6)	0.537	66 (34.7)	35 (36.8)	31 (32.6)	0.542
Albumin (mg/dL)	3.8 (3.3–4.1)	3.6 (3.2–4.1)	3.8 (3.4–4.1)	0.362	3.6 (3.2–3.9)	3.8 (3.3–4.1)	3.5 (3.2–3.9)	0.249
Albumin < 3.5 (mg/dL)	80 (27.4)	33 (34.7)	47 (23.9)	0.051	66 (34.7)	33 (34.7)	33 (34.7)	1.000
Intraoperative outcomes and findings								
Blood loss (mL)	400 (300–500)	400 (250–600)	300 (300–500)	0.220	400 (250–500)	400 (250–600)	300 (250–500)	0.640
Blood loss > 400 mL	147 (50.3)	52 (54.7)	95 (48.2)	0.297	98 (51.6)	52 (54.7)	46 (48.4)	0.384
Blood transfusion	120 (41.4)	44 (46.3)	76 (38.6)	0.208	81 (42.7)	44 (46.3)	37 (38.9)	0.305
Soft pancreas	177 (60.6)	64 (67.4)	113 (57.4)	0.101	130 (68.4)	64 (67.4)	66 (69.5)	0.755
Duct size (mm)	4 (3–5)	4 (2–6)	4 (2–5)	0.071	4 (3–4.5)	4 (2–6)	4 (2–5)	0.544
Duct size ≤ 3 mm	133 (45.5)	38 (40)	95 (48.2)	0.186	79 (41.6)	38 (40)	41 (43.2)	0.659
Vascular resection	20 (6.8)	3 (3.2)	17 (8.6)	0.830	9 (4.7)	3 (3.2)	6 (6.3)	0.306
Histopathologic outcomes								
Ampullary carcinoma	132 (45.2)	51 (53.6)	81 (41.1)	0.042*	93 (48.9)	51 (53.6)	42 (44.2)	0.192
Pancreatic carcinoma	70 (24)	24 (25.3)	46 (23.4)	0.719	47 (24.7)	24 (25.3)	23 (24.2)	0.867
Distal bile duct carcinoma	31 (10.6)	3 (3.2)	28 (14.2)	0.004*	19 (10)	3 (3.2)	16 (16.8)	0.002*
Duodenal carcinoma	12 (4.1)	3 (3.2)	9 (4.6)	0.569	6 (3.2)	3 (3.2)	3 (3.2)	1.000
Other	47 (16.1)	14 (14.7)	33 (16.7)	0.660	25 (13.2)	14 (14.7)	11 (11.6)	0.512
Harvested lymph nodes	14 (9–20)	14 (9–20)	14 (9–20)	0.743	14 (9–20)	14 (9–20)	14 (9–20)	0.834

Values are presented as number (%) or median (interquartile range).

PD, pancreatoduodenectomy; B-PJ, Blumgart pancreatojejunostomy technique; mB-PJ, modified Blumgart technique; PSM, propensity score matching; ASA, American Society of Anesthesiologists score.

*Statistically significant.

or narrowing (Fig. 2).

No external stent was used performing mB-PJ.

Statistical analysis

Patients were stratified in two groups (B-PJ versus mB-PJ). Baseline characteristics were compared before and after propensity score matching (PSM).

PSM was employed to minimize potential selection bias by pairing groups based on demographic factors, intraoperative data, and final histopathologic findings. The variables included in PSM were sex, age, previous abdominal surgery, American Society of Anesthesiologists (ASA) score, comorbidity, cholangitis, preoperative biliary drainage, preoperative albumin levels (< 3.5 mg/dL), pancreatic texture, main pancreatic duct size (≤ 3 mm), and final histopathologic diagnosis. Patients in the B-PJ group were matched to mB-PJ patients using the nearest-neighbor method in a 1:1 ratio.

Continuous variables were reported as medians with interquartile ranges. Normally distributed data, determined by the Kolmogorov-Smirnov normality test, were compared using Student's *t*-test, while non-normally distributed data were analyzed with the Mann-Whitney *U* test. Categorical variables were expressed as absolute frequencies or percentages and analyzed using the chi-square test or Fisher's exact test.

Predictive factors for CR-POPF were identified through multivariate regression analysis. Results were reported as odds ratios (OR) with two-sided 95% confidence intervals (CI). A *p*-value of < 0.05 was considered statistically significant.

Statistical analysis was conducted using IBM SPSS Statistics software, version 29.0 (IBM Corp.) and RStudio, version 4.5.0 (RStudio, Inc.).

RESULTS

Three hundred and twenty PD procedures were performed at our institution during the study period. Twenty-eight patients were excluded, resulting in a total of 292 patients included in this study (Fig. 1). Among these, 149 were females and 143 were males. Ninety-five patients (46 females and 49 males) underwent B-PJ, while 197 patients (78 females and 119 males) underwent mB-PJ. Overall baseline characteristics revealed no significant differences in demographic features, except for the ASA III score, where more ASA III patients were identified in the mB-PJ group ($p = 0.008$) (Table 1).

Patients who underwent mB-PJ experienced prolonged operative times ($p < 0.001$).

Seventy patients (24%) had a histopathologic diagnosis of pancreatic carcinoma, with similar rates in both groups (25.3% for B-PJ and 23.4% for mB-PJ, $p = 0.719$). Of these, only 2 patients (2.8%) received neoadjuvant therapy. There were more patients with distal bile duct carcinoma in the mB-PJ group (14.2% vs. 3.2%, $p = 0.004$). No differences were found regarding the number of harvested lymph nodes (Table 1); for patients with pancreatic carcinoma, the median number of harvested lymph nodes was 16.

After PSM, both groups were balanced, except for the histopathologic diagnosis of distal bile duct carcinoma (3.2% for B-PJ vs. 16.8% for mB-PJ, $p = 0.002$) (Table 1). The operative time remained lower in the B-PJ group (240 minutes vs. 280 minutes, $p < 0.001$).

CR-POPF was identified in 46 patients (15.8%). No differences were observed in CR-POPF (B/C) across the overall population; however, there was a trend favoring mB-PJ in type C POPF patients (7.4% vs. 2.5%, $p = 0.051$). Patients with B-PJ

Table 2. Primary and secondary study endpoints in the overall and matched patients undergoing open PD with B-PJ and mB-PJ

	Overall				After PSM			
	Total (n = 292)	B-PJ (n = 95)	mB-PJ (n = 197)	<i>p</i> -value	Total (n = 190)	B-PJ (n = 95)	mB-PJ (n = 95)	<i>p</i> -value
Primary endpoints								
CR-POPF (B/C)	46 (15.8)	18 (18.9)	28 (14.2)	0.357	33 (17.4)	18 (18.9)	15 (15.8)	0.566
Grade B	34 (12)	11 (11.6)	23 (11.7)	0.882	23 (12)	11 (11.6)	12 (12.7)	0.824
Grade C	12 (4.1)	7 (7.4)	5 (2.5)	0.051	10 (5.3)	7 (7.4)	3 (3.2)	0.194
Secondary endpoints								
Major morbidity (CD $\geq$ III)	78 (26.7)	29 (30.5)	49 (24.9)	0.306	54 (28.4)	29 (30.5)	25 (26.3)	0.520
ICU stay	34 (11.6)	15 (15.8)	19 (9.6)	0.125	24 (12.6)	15 (15.8)	9 (9.5)	0.190
LOS	10 (8–15)	11 (9–16)	9 (8–14)	0.010*	10 (8–14.5)	11 (9–16)	9 (8–14)	0.172
Reoperation	22 (7.5)	11 (11.6)	11 (5.6)	0.069	17 (8.9)	11 (11.6)	6 (6.3)	0.204
Readmission	13 (4.5)	5 (5.3)	8 (3.6)	0.218	8 (4.2)	5 (5.3)	3 (3.2)	0.470
Mortality	12 (4.1)	5 (5.3)	7 (3.6)	0.490	9 (4.7)	5 (5.3)	4 (4.2)	0.733

Values are presented as number (%) or median (interquartile range).

PD, pancreaticoduodenectomy; B-PJ, Blumgart pancreatojejunostomy technique; mB-PJ, modified Blumgart technique; PSM, propensity score matching; CR-POPF, clinically relevant postoperative pancreatic fistula; CD, Clavien-Dindo; ICU, intensive care unit; LOS, length of stay.

*Statistically significant.

experienced a longer LOS (11 days vs. 9 days, $p = 0.010$). There were no differences between groups in terms of major morbidity, intensive care unit (ICU) stay, reoperation, readmission, or mortality (Table 2).

Twenty-two patients (7.5%) underwent reoperation. The reasons for reoperation included: post-pancreatectomy hemorrhage (7 patients: 6 extraluminal and 1 endoluminal), intra-abdominal abscess (5 patients), pancreatojejunostomy dehiscence (4 patients, 2 of whom had post-pancreatectomy acute necrotizing pancreatitis), intestinal ischemia (3 patients: 2 with massive small bowel ischemia and 1 with right colonic ischemia), biliary fistula (1 patient), intestinal obstruction (1 patient), and necrotizing post-pancreatectomy acute pancreatitis (1 patient with peri-pancreatic fat necrosis) (Table 2).

Thirteen patients (4.8%) were readmitted: 4 due to intra-abdominal abscess, 3 due to pancreatitis (1 of whom had necrotizing pancreatitis and underwent reoperation), 3 with DGE (one of whom had obstruction managed medically), 1 with liver abscess, 1 with biloma after removal of a transhepatic biliary catheter, and 1 with abdominal pain.

After PSM, no statistical differences were found between the two groups regarding primary and secondary endpoints (Table

2).

In the overall group, 150 (51.4%) patients did not show any postoperative morbidity, readmissions, or mortality, and had a LOS < 75th percentile: 43 (45.3%) of the B-PJ group and 107 (54.3%) of the mB-PJ group ($p = 0.147$). After PSM, 98 (51.6%) patients did not show any postoperative complications, readmissions, or mortality, and had a LOS < 75th percentile: 43 (45.3%) of the B-PJ group and 55 (57.9%) of the mB-PJ group ($p = 0.082$).

In the multivariate logistic regression analysis of matched patients undergoing open PD with B-PJ and mB-PJ, three factors were found to be independent predictors of CR-POPF: preoperative cholangitis (OR: 4.906, 95% CI 1.440–16.713, $p = 0.011$), soft pancreas (OR: 4.259, 95% CI 1.043–17.376, $p = 0.043$), and main pancreatic duct size ≤ 3 mm (OR: 5.229, 95% CI 1.865–14.656, $p = 0.002$). Main pancreatic duct size ≤ 3 mm was the most powerful predictor (Table 3).

DISCUSSION

CR-POPF remains the most significant source of morbidity and is strongly associated with mortality following PD [14].

Table 3. Univariate and multivariate logistic regression analysis of predictive factors of CR-POPF in matched patients undergoing open PD with B-PJ and mB-PJ

Variables	Univariate analysis			Multivariate analysis		
	OR	95% CI	<i>p</i> -value	OR	95% CI	<i>p</i> -value
Age	1.652	0.639–4.265	0.296			
Sex	1.865	0.859–4.049	0.111			
Previous abdominal surgery	1.191	0.562–2.526	0.647			
ASA I	0.984	0.463–2.090	0.966			
ASA II	1.312	0.618–2.787	0.479			
ASA III	0.479	0.057–3.717	0.455			
Comorbidity	0.839	0.396–1.779	0.647			
Preoperative cholangitis	2.549	0.947–6.858	0.050*	4.906	1.440–16.713	0.011*
Preoperative biliary drainage	1.488	0.692–3.201	0.372			
Albumin ≤ 3.5 mg/dL	0.588	0.248–1.390	0.231			
Blood loss > 400 mL	2.132	0.969–4.699	0.056			
Soft pancreas	5.700	1.665–19.51	0.002*	4.259	1.043–17.376	0.043*
Duct size ≤ 3 mm	4.945	2.149–11.38	<0.001*	5.229	1.865–14.656	0.002*
B-PJ technique	1.247	0.587–2.648	0.566			
Vascular resection	1.382	0.274–6.974	0.694			
Histopathologic diagnosis						
Ampullary carcinoma	0.844	0.397–1.793	0.659			
Pancreatic carcinoma	1.410	0.616–3.230	0.664			
Distal bile duct carcinoma	1.305	0.404–4.212	0.655			
Duodenal carcinoma	0.950	0.107–8.409	0.963			
Other	0.614	0.172–2.184	0.578			

CR-POPF, clinically relevant postoperative pancreatic fistula; PD, pancreatoduodenectomy; B-PJ, Blumgart pancreatojejunostomy technique; mB-PJ, modified Blumgart technique; OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists score.

*Statistically significant.

Pancreato-enteric reconstruction is challenging because the anastomosis connects a solid organ to a hollow abdominal can interfere with the healing and sealing of the anastomosis [12]. Several PJ techniques have been described over the last few decades; however, no surgical technique has yet been able to eliminate CR-POPF [13]. The excellent results reported in the initial series of the B-PJ technique (4.3% and 6.9% CR-POPF rates) [11,12] have led to its widespread adoption in recent years.

In the B-PJ technique, the first U suture is placed between the posterior wall of the jejunum and the anterior surface of the pancreatic parenchyma and then tied. The next step involves placing a suture on the anterior jejunal seromuscular layer, imbricating the jejunum over the anterior surface of the pancreatic stump, and then tying it again [12]. It is important to note that the anterior pancreatic surface remains exposed to shear forces during the first knot-tying [15].

Several years after the initial series of B-PJ, Fujii et al. [14] reported a modification of the original B-PJ (mB-PJ) with a CR-POPF rate of 2.9%. The mB-PJ technique, as described by Fujii et al. [14] and Oda et al. [15], utilizes U sutures with single tying over the jejunal wall. This approach allows the surgeon to tie with significant force without the risk of lacerating the pancreatic parenchyma, thus ensuring a tight adaptation between the pancreatic parenchyma and the jejunum [15].

In this retrospective study conducted at a high-volume center for PD [26], we hypothesized that mB-PJ reconstruction would improve CR-POPF compared with B-PJ. Although there was a trend favoring mB-PJ in type C POPF within the overall population, we were unable to demonstrate a significant reduction in CR-POPF with mB-PJ compared to B-PJ, even after PSM (15.8% vs. 18.9%, $p = 0.566$).

When analyzing secondary endpoints, the postoperative LOS for the overall population was significantly shorter for mB-PJ (9 days vs. 11 days, $p = 0.010$); however, this difference did not reach statistical significance after PSM. Rates of major morbidity, ICU stay, reoperation, readmission, and mortality showed no statistically significant differences between B-PJ and mB-PJ in the overall population or after PSM. No evidence of superiority for mB-PJ over the original B-PJ was found. Although there was a trend favoring mB-PJ across all analyzed variables, statistical significance was not achieved, possibly due to the sample size. A larger study may be required to determine whether these trends reflect real differences. Additionally, studies on robotic-assisted PD demonstrate that mB-PJ is both feasible and effective when compared to open mB-PJ [27,28]. The mB-PJ technique is well-suited to the precision and enhanced dexterity provided by robotic platforms [29].

In this series, we achieved acceptable results, with Ideal Outcomes after PD (absence of in-hospital mortality, severe complications - CD $\geq$ III, CR-POPF, reoperation, LOS > 75th percentile, and readmission) [30] reached in 51.4% of all patients and 51.6% after PSM. Our outcomes are comparable to those reported by the transatlantic study group of 4 registries, which

documented this composite quality measure for major pancreatic surgery in 54% of patients [30]. It is important to note that our results were obtained despite a predominant diagnosis of adenocarcinoma of Vater's ampulla (45.2% of all patients and 48.9% after PSM), which is considered a risk factor for CR-POPF [31].

Although the aim of this study was to compare B-PJ versus mB-PJ in terms of CR-POPF and postoperative outcomes, we also sought to identify the predictive factors for CR-POPF in our matched series. The multivariate logistic regression analysis identified three independent predictors of CR-POPF: preoperative cholangitis (OR: 4.906, 95% CI 1.440–16.713, $p = 0.011$), soft pancreas (OR: 4.259, 95% CI 1.043–17.376, $p = 0.043$), and main pancreatic duct size ≤ 3 mm (OR: 5.229, 95% CI 1.865–14.656, $p = 0.002$). The significant association of soft pancreas and main pancreatic duct size with the development of CR-POPF is well established [31,32]. Soft pancreas is the most widely recognized risk factor for CR-POPF [31]. Several explanations for this association have been proposed. First, soft pancreatic tissue is more vulnerable to tearing during PJ suture placement [31]. Moreover, a soft pancreas is more prone to ischemic or necrotic events due to compression from the suture, which can result in anastomotic failure [32]. Second, the soft pancreas is frequently associated with a smaller pancreatic duct [31,32]. Finally, the soft pancreas has preserved exocrine function with normal exocrine secretion that is rich in proteolytic enzymes. The activation of these enzymes produces the local and systemic effects seen in pancreatic fistula [31]. Similarly, the association between a smaller main pancreatic duct and CR-POPF is multifactorial. First, the PJ is technically more difficult to reconstruct with a smaller duct [31,32]. Second, a small main pancreatic duct is associated with postoperative acute pancreatitis [32], likely due to occlusion during reconstruction. Based on the above, the ISGPS has proposed a classification according to pancreatic texture and main pancreatic duct size (grades A, B, C, and D anastomoses) for better comparability of study outcomes, clinical decision-making, and auditing [32].

The influence of preoperative cholangitis on POPF has also been described [33–36]. Cholangitis is caused by bacterial infection, which can spread to the liver and potentially into the bloodstream. Bacterobilia, rather than perioperative biliary drainage, has been identified as a risk factor for CR-POPF [33,35,36]. The spillage of bile duct bacteria into the abdominal cavity during surgery is associated with infectious complications and may cause an endogenous infection of pancreatic leakage, triggering a CR-POPF [33]. It is necessary to administer broad-spectrum antibiotics based on local microbiological resistance profiles as soon as the diagnosis of preoperative cholangitis is made or suspected, to prevent contamination of the abdominal cavity.

This study has several limitations. First, the retrospective analysis carries an inherent risk of biases, primarily related to patient selection. Although an attempt was made to cor-

rect for this using PSM, distal bile duct carcinoma remained significantly more prevalent in the mB-PJ group compared to the B-PJ group, indicating that appropriate matching was not achieved. Second, the study's single-center design, while conducted at a high-volume center for pancreatic surgery, may limit the generalizability of the findings. Third, the management of CR-POPF and mitigation strategies have improved over time. Since we compared two techniques across different periods, this may introduce time-dependent biases related to evolving postoperative care protocols and surgical learning curves.

In conclusion, this study did not demonstrate the superiority of mB-PJ in reducing CR-POPF. However, mB-PJ is a simple and safe technique for pancreatojejunostomy and has been shown to be noninferior to B-PJ in open pancreaticoduodenectomy.

Soft pancreas, main pancreatic duct size ≤ 3 mm, and preoperative cholangitis are significant independent risk factors for the development of CR-POPF.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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