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Prospective Evaluation of a Ligature-Free Modified Peng Pancreatojejunostomy Reinforced with Blumgart Sutures in Patients with a Narrow Main Pancreatic Duct after Pancreaticoduodenectomy

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Abstract

Background or Purpose:

Clinically relevant postoperative pancreatic fistula (CR-POPF) remains a major complication after pancreaticoduodenectomy, particularly with a narrow main pancreatic duct (MPD ≤ 3 mm). We evaluated a ligature-free modification of Peng pancreatojejunostomy reinforced with Blumgart sutures.

Methods

This prospective single-center cohort included 160 consecutive patients undergoing pancreaticoduodenectomy at the National Cancer Institute, Cairo University, from December 2021 to December 2025. Eligibility required an MPD ≤ 3 mm on both magnetic resonance cholangiopancreatography and endoscopic ultrasound. The primary endpoint was CR-POPF (ISGPS Grade B/C, 2016 criteria).

Results

CR-POPF occurred in 10 patients (6.2%; exact 95% CI, 3.0–11.2%), all Grade B; no Grade C fistulae occurred. Overall morbidity was 23.1%, surgical-site infection 21.2%, and biliary leakage 1.2%. Median postoperative hospital stay was 7 days (range, 7–30). In exploratory analysis, CR-POPF occurred more frequently in patients with diabetes mellitus (15.8% vs 1.0%; Fisher's exact P = 0.0004).

Discussion or Conclusion:

The modified technique was feasible and was associated with a 6.2% CR-POPF rate in this narrow-duct cohort. Because the study was single-arm and non-comparative, the findings do not establish efficacy, superiority, or non-inferiority. Comparative multicenter studies are warranted.

INTRODUCTION

Pancreaticoduodenectomy (PD) remains the standard curative-intent surgical procedure for malignant and selected benign neoplasms of the pancreatic head and periampullary region. Outcomes have improved with centralization, multidisciplinary perioperative care, and enhanced recovery pathways, although PD remains associated with substantial postoperative morbidity. Clinically relevant postoperative pancreatic fistula (CR-POPF), defined by the 2016 International Study Group for Pancreatic Surgery (ISGPS) criteria as Grade B or C fistula, remains one of the most important complications after PD [1–3].

Among the established predictors of CR-POPF, a narrow MPD and soft pancreatic texture are particularly important. The Fistula Risk Score (FRS), alternative Fistula Risk Score, and the ISGPS duct-size/texture classification all incorporate pancreatic duct diameter and gland texture as major determinants of fistula risk [4–7]. In the ISGPS classification, an MPD ≤ 3 mm is associated with substantially higher CR-POPF risk, particularly when combined with soft pancreatic texture. These findings support focused evaluation of anastomotic strategies in patients with a narrow duct [6,7].

Numerous pancreatoenteric reconstruction techniques have been developed, including duct-to-mucosa pancreatojejunostomy, invagination pancreatojejunostomy, Blumgart-style anastomosis, pancreaticogastrostomy, and binding pancreatojejunostomy [8,9]. Comparative trials and meta-analyses have not established a universally superior reconstruction. The RECOPANC randomized trial found no significant difference in Grade B/C POPF between pancreatogastrostomy and pancreatojejunostomy [10], while systematic reviews have suggested potential advantages of Blumgart-style reinforcement and invagination in selected settings [8,11,12].

Binding pancreatojejunostomy, first described by Peng and colleagues, uses an intussuscepted jejunal cuff secured around the pancreatic remnant [13,14]. Although favorable results were reported in the original randomized experience, subsequent independent studies have reported variable outcomes [15,16]. One proposed explanation is that circumferential compression may compromise perfusion of the inverted jejunal cuff. Imaging studies of anastomotic perfusion provide biological support for the possibility that excessive circumferential compression may reduce local blood flow, although this mechanism has not been demonstrated specifically for the present technique [17].

Blumgart-style transpancreatic mattress sutures distribute tension through the pancreatic parenchyma and have been associated with lower CR-POPF rates in comparative studies of pancreaticojejunostomy [18,19]. In the present modification, these sutures are used to reinforce the intussuscepted anastomosis after deliberate omission of the circumferential binding ligature. This is a technical hypothesis rather than a proven physiological mechanism.

No prospective study identified by the authors has evaluated this specific combination of ligature-free Peng invagination with transpancreatic Blumgart reinforcement in a cohort restricted to patients with MPD ≤ 3 mm confirmed by both MRCP and EUS. The present study therefore aimed to prospectively describe the feasibility, reproducibility, and short-term clinical outcomes of this defined technical modification. The study was designed as a single-arm cohort and was not intended to establish superiority or non-inferiority over alternative reconstruction techniques.

METHODS

Study Design and Setting

This prospective single-center cohort included consecutive patients referred to the National Cancer Institute, Cairo University, between December 2021 and December 2025 for surgical management of

pancreatic head or periampullary neoplasms. Four consultant hepato-biliary surgeons performed the procedures. The technique was standardized through joint operative planning and intraoperative supervision. The study was reported according to the STROBE recommendations for observational cohort studies.

Participant Selection and Flow

Inclusion criteria were pancreatic head or second-part duodenal neoplasms requiring PD and a narrow or non-dilated MPD (≤ 3 mm) confirmed on both preoperative MRCP and EUS. Patients with an MPD > 3 mm on either modality were excluded. All 160 enrolled patients fulfilled the predefined duct-calibre criterion on dual assessment. No formal a priori sample-size calculation was performed; the cohort comprised all consecutive eligible patients during the prespecified study period.

Surgical Technique

All patients underwent open Whipple PD through a right subcostal incision. Reconstruction was performed in a Roux-en-Y configuration. Pancreatojejunostomy was performed using the Peng binding concept as modified by our group. The pancreatic remnant was mobilized for at least 3 cm from the splenic vessels until a free, flag-like configuration was obtained. The efferent jejunal limb was everted over approximately 3 cm using silk sutures to create an everted cuff. The everted mucosa was ablated with electrocautery and irrigated with swabs soaked in alcohol and saline.

The pancreatojejunostomy was completed by end-to-end intussusception. Posterior anastomotic sutures were placed circumferentially with 3 – 0 Vicryl, incorporating the MPD in the posterior layer while engaging only the mucosa. The everted jejunal cuff was then inverted over the pancreatic remnant. Interrupted transpancreatic seromuscular sutures were placed in an anterior–posterior alternating pattern using 3 – 0 PDS (Blumgart-type reinforcement). The circumferential binding ligature used in the original Peng technique was deliberately omitted to avoid potential compression of the distal inverted jejunal cuff. No transanastomotic pancreatic duct stent was used. A methylene-blue watertight test was performed before abdominal closure.

Pancreatojejunostomy was completed in an end-to-end intussusception fashion. Posterior raw anastomotic sutures were placed circumferentially using 3 – 0 Vicryl, incorporating the MPD in the posterior layer, engaging only the mucosa. The everted jejunal cuff was then inverted over the pancreatic body, and the anastomosis was reinforced with interrupted transpancreatic-sero-muscular sutures placed in an anterior–posterior alternating pattern (Blumgart sutures) using 3 – 0 PDS. This constituted the first modification. The circumferential binding ligature described in the original Peng technique was deliberately omitted to avoid potential ischaemia of the distal inverted jejunal cuff — the second modification (Fig. 2). No trans-anastomotic pancreatic duct stent was used. A methylene blue watertight test was performed in all cases prior to abdominal closure.

Pre-operative Ductal Assessment

All patients underwent preoperative assessment of the MPD using MRCP and EUS as complementary modalities. Eligibility required an MPD calibre ≤ 3 mm on both examinations. Patients with an MPD > 3 mm on either modality were excluded. No formal interobserver or intraobserver reliability assessment was performed, and no method-comparison analysis was undertaken.

Postoperative Management

Following surgery, patients were transferred to the general surgical ward unless ICU admission was clinically indicated. Clear oral fluids were introduced on postoperative day (POD) 1, semi-solid feeding on POD 5, and a regular diet thereafter as tolerated. Drain output was monitored; drain fluid amylase > 3 times the upper limit of normal serum amylase was considered diagnostic of a biochemical pancreatic leak/POPF in accordance with ISGPS definitions. Drains were removed when output was < 10 mL/24 hours and CT showed no intra-abdominal collection. Somatostatin analogues were not administered prophylactically. In confirmed POPF, somatostatin analogues were administered at 300–600 µg/day for 7–14 days. Patients were followed for 90 postoperative days.

Outcome Definitions and Statistical Analysis

The primary endpoint was CR-POPF, defined as ISGPS Grade B or C according to the 2016 classification [3]. Postoperative morbidity was graded using the Clavien–Dindo classification. Exact two-sided 95% confidence intervals (CIs) were calculated for key binary outcomes using the Clopper–Pearson method.

Because this was a single-arm study with only 10 CR-POPF events, the primary analysis was descriptive. Exploratory comparisons of CR-POPF across available baseline subgroups were performed using Fisher’s exact test. No multivariable regression model was considered sufficiently reliable for the primary analysis given the limited number of outcome events; therefore, adjusted odds ratios were not reported. Continuous variables were summarized using mean ± standard deviation or median (range), as appropriate. A two-sided $P < 0.05$ was considered statistically significant for exploratory analyses.

Given the single-arm design and the limited number of CR-POPF events (10/160 patients), the primary analysis was descriptive and focused on the observed CR-POPF proportion and its exact 95% CI. Comparisons of CR-POPF across available baseline subgroups were considered exploratory and were performed using Fisher's exact test because of the small number of outcome events.

Ethical Considerations

The study was approved by the Institutional Review Board of the National Cancer Institute, Cairo University (Reference: SO2406-210-102). Written informed consent was obtained from all participants

before enrolment. The manuscript was prepared in accordance with STROBE recommendations; the completed STROBE checklist should be submitted as supplementary material.

RESULTS

Patient Characteristics

Between December 2021 and December 2025, 160 consecutive patients underwent PD with the modified Peng pancreatojejunostomy. No patients were lost during the planned 90-day follow-up. The cohort was predominantly male (118/160, 73.8%) and aged > 60 years (119/160, 74.4%); 57 patients (35.6%) had diabetes mellitus. All 160 patients fulfilled the predefined MPD ≤ 3 mm criterion on both MRCP and EUS. Baseline characteristics are summarized in Table 1.

Table 1
Baseline Demographic and Clinical Characteristics (n = 160)

Variable	Modified Peng (n = 160)
Age > 60 years, n (%)	119 (74.4%)
Age ≤ 60 years, n (%)	41 (25.6%)
Male, n (%)	118 (73.8%)
Female, n (%)	42 (26.2%)
BMI < 23 kg/m², n (%)	110 (68.8%)
BMI 23–26 kg/m², n (%)	50 (31.2%)
No comorbidity, n (%)	69 (43.1%)
Hypertension only, n (%)	35 (21.9%)
Diabetes mellitus only, n (%)	44 (27.5%)
DM + Hypertension, n (%)	12 (7.5%)
Pancreatic head, n (%)	72 (45.0%)
Uncinate process, n (%)	71 (44.4%)
Duodenal mass, n (%)	17 (10.6%)
Duct calibre ≤ 3 mm (MRCP + EUS), n (%)	160 (100%)
Child–Pugh class A, n (%)	160 (100%)

BMI = body mass index; **DM** = diabetes mellitus; **EUS** = endoscopic ultrasound; MRCP = magnetic resonance cholangiopancreatography. Diabetes mellitus was present in 57/160 patients (35.6%), including 44 with diabetes alone, 12 with diabetes plus hypertension, and 1 patient with diabetic ketoacidosis.

Table 2
Postoperative outcomes (n = 160)

Outcome	Present Cohort (n = 160)	95% CI
CR-POPF Grade B, n (%)	10 (6.2%)	3.0–11.2%
CR-POPF Grade C, n (%)	0 (0%)	0–2.3%
Overall CR-POPF, n (%)	10 (6.2%)	3.0–11.2%
Wound infection, n (%)	34 (21.2%)	15.2–28.4%
Biliary leakage, n (%)	2 (1.2%)	0.2–4.4%
Lymphorrhoea, n (%)	10 (6.2%)	3.0–11.2%
Overall morbidity, n (%)	37 (23.1%)	16.8–30.4%
Median hospital stay (days, range)	7 (7–30)	—

Table 3
Exploratory subgroup analysis of CR-POPF according to baseline variables (n = 160)

Variable	Group 1	CR-POPF n/N (%) [95% CI]	Group 2	CR-POPF n/N (%) [95% CI]	P value
Sex	Female	5/42 (11.9%; 4.0–25.6%)	Male	5/118 (4.2%; 1.4–9.6%)	0.130
Age	≤ 60 years	3/41 (7.3%; 1.5–19.9%)	> 60 years	7/119 (5.9%; 2.4–11.7%)	0.717
BMI	< 23 kg/m²	3/110 (2.7%; 0.6–7.8%)	23–26 kg/m²	7/50 (14.0%; 5.8–26.7%)	0.011
Diabetes	No DM	1/103 (1.0%; 0.0–5.3%)	Yes DM	9/57 (15.8%; 7.5–27.9%)	0.0004

CR-POPF = clinically relevant postoperative pancreatic fistula. Exact 95% CIs are Clopper–Pearson intervals; P values are Fisher's exact tests. These analyses are exploratory, based on 10 events only, and are not powered for subgroup comparisons

Operative Parameters

All 160 procedures were completed without intraoperative conversion. Mean operative time was 272.1 ± 23.2 minutes. The pancreatojejunostomy was completed within 20 minutes in 110 patients (68.8%). An R0 resection margin was achieved in all patients. The intraoperative methylene-blue watertight leak test was negative in all cases.

Postoperative Complications and Outcomes

Postoperative complications were classified according to Clavien–Dindo. Of the 37 patients (23.1%) who experienced at least one postoperative complication, 5 (3.1%) had Grade I, 30 (18.8%) Grade II, and 2 (1.2%) Grade IIIa complications; no Grade IIIb–V complications were recorded. CR-POPF (ISGPS Grade

B) occurred in 10 patients (6.2%; exact 95% CI, 3.0–11.2%); no Grade C fistulae occurred. All Grade B fistulae were managed non-operatively with image-guided percutaneous drainage, somatostatin analogue therapy, and dietary modification. Surgical-site infection occurred in 34 patients (21.2%), biliary leakage in 2 (1.2%), and lymphorrhoea in 10 (6.2%). Median postoperative hospital stay was 7 days (range, 7–30), compared with 14 days among patients with CR-POPF and 7 days among those without CR-POPF (Mann–Whitney U, P < 0.001).

CR-POPF (ISGPS Grade B) was recorded in 10 patients (6.2%; exact 95% CI, 3.0–11.2%); no Grade C fistulae were recorded. All Grade B fistulae were managed conservatively with radiologically guided percutaneous drain insertion, somatostatin analogue infusion, and dietary modification. Surgical-site infection occurred in 34 patients (21.2%; 95% CI, 15.2–28.4%). Diabetes mellitus was associated with CR-POPF in exploratory analysis (Fisher's exact p = 0.0004). Biliary leakage occurred in 2 patients (1.2%; 95% CI, 0.2–4.4%). The median postoperative hospital stay was 7 days (range 7–30); patients with CR-POPF had a median stay of 14 days versus 7 days for those without (Mann–Whitney U, p < 0.001).

Histopathological Findings

Histopathological review identified pancreatic ductal adenocarcinoma in 151 patients (94.4%), gastrointestinal stromal tumor in 5 (3.1%), and neuroendocrine tumor in 4 (2.5%). R0 resection was achieved in all 160 patients. Among patients with adenocarcinoma, 142 (94.0%) had moderately differentiated tumors and 9 (6.0%) had poorly differentiated tumors. Pathological staging comprised T1N0M0 in 27 patients (16.9%), T2N0M0 in 124 (77.5%), T2N1M0 in 6 (3.8%), and T3N0M0 in 3 (1.9%). Lymphovascular invasion and perineural invasion were each identified in 12 patients (7.5%).

Exploratory Subgroup and Multivariable Analysis

CR-POPF occurred in 10 of 160 patients (6.2%; exact 95% CI, 3.0–11.2%). In exploratory subgroup analyses, CR-POPF was more frequent among patients with diabetes mellitus than among those without diabetes (15.8% vs 1.0%; Fisher’s exact P = 0.0004). No statistically significant association was observed for sex or age. These comparisons were exploratory and were not interpreted as definitive risk estimates.

DISCUSSION

The principal finding of this prospective single-center cohort is that the modified Peng pancreatojejunostomy was technically feasible and was associated with a CR-POPF rate of 6.2% (10/160; exact 95% CI, 3.0–11.2%) in a cohort restricted to patients with an MPD ≤ 3 mm. All fistulae were Grade B and no Grade C fistula occurred. Because the study had no contemporaneous comparator, these findings should be interpreted as prospective descriptive outcome data rather than evidence of superiority or non-inferiority over conventional Peng, Blumgart, duct-to-mucosa, or other reconstruction techniques.

The observed CR-POPF rate should be interpreted in the context of heterogeneous evidence on pancreatic reconstruction. A 2021 systematic review and meta-analysis reported lower CR-POPF with Blumgart anastomosis than with non-Blumgart duct-to-mucosa reconstruction, whereas a 2024 meta-analysis of randomized trials reported lower Grade B/C POPF with invagination than with duct-to-mucosa reconstruction [11, 12]. These studies support continued interest in both transpancreatic reinforcement and invagination-based reconstruction but do not directly evaluate the present technical combination.

All included patients had an MPD diameter ≤ 3 mm, a recognized high-risk feature for CR-POPF. The ISGPS classification study found that an MPD ≤ 3 mm was associated with increased CR-POPF risk and that the combination of a narrow duct and soft pancreatic texture identifies the highest-risk category [6, 20]. Because pancreatic texture was not systematically recorded in the present dataset, the cohort cannot be further stratified according to the complete ISGPS risk classification. The 6.2% CR-POPF rate is therefore a descriptive outcome in a narrowly defined anatomical subgroup and should not be interpreted as evidence that the modification eliminates intrinsic fistula risk.

The rationale for the modification was to combine the invagination and binding principles of the Peng reconstruction with the tension-distributing concept of transpancreatic mattress sutures while omitting the circumferential binding ligature. The proposed benefit is mechanical and remains unproven in this clinical cohort. Tissue perfusion, intrapancreatic pressure, tissue strain, and shear forces were not measured; therefore, any reduction in compression or ischaemic risk remains a hypothesis [17].

The modification should be viewed as a targeted technical refinement rather than a fundamentally new pancreatojejunostomy. Importantly, the present study cannot isolate the effect of removing the circumferential ligature from the effect of adding Blumgart reinforcement. A factorial or comparative design would be required to determine whether either component provides an independent clinical benefit.

Diabetes mellitus was associated with CR-POPF in the exploratory subgroup analysis: CR-POPF occurred in 15.8% of patients with diabetes compared with 1.0% of those without diabetes (Fisher’s exact P = 0.0004). This association should be considered hypothesis-generating because only 10 CR-POPF events occurred and multiple subgroup comparisons were performed. No adjusted association estimate is presented because the event count was insufficient for a reliable multivariable model. Biliary leakage occurred in 2 patients (1.2%), overall morbidity in 37 (23.1%), and median hospital stay was 7 days.

Published estimates are presented for clinical context only. Differences in patient selection, risk profile, operative technique, and perioperative care preclude formal statistical comparison with the present cohort. RD = risk difference; OR = odds ratio; RR = relative risk; PJ = pancreatojejunostomy.

Strengths

Several strengths should be acknowledged. First, the study prospectively evaluated a clearly defined anatomical population with an MPD ≤ 3 mm confirmed by two preoperative modalities. Second, patients were recruited consecutively according to predefined eligibility criteria. Third, the operative technique was standardized across four surgeons. Fourth, postoperative outcomes were recorded prospectively using contemporary ISGPS and Clavien–Dindo definitions. Finally, the analysis was deliberately limited to descriptive and exploratory methods appropriate to the small number of CR-POPF events.

Limitations

This study has several important limitations. First, it was a single-center prospective cohort without a contemporaneous control group; causal attribution of the observed outcomes to the technical modification is therefore not possible. Second, no formal a priori sample-size calculation was performed because the cohort was based on consecutive eligible patients during the study period. Third, only 10 CR-POPF events occurred, limiting the precision of subgroup analyses and precluding a reliable multivariable model. Fourth, pancreatic texture, exact MPD diameter below the 3-mm threshold, intraoperative blood loss, and other complete FRS components were not available in the analytic dataset, preventing valid FRS-based risk stratification. Fifth, the present dataset did not contain complete patient-level information for reoperation and 90-day mortality; these outcomes should be verified from the clinical records before submission if they are to be reported. Finally, the study assessed short-term postoperative outcomes and did not evaluate long-term pancreatic function, quality of life, or oncological outcomes. These limitations are consistent with the exploratory feasibility design and underscore the need for comparative multicenter studies.

Future Research Directions

The present findings should be regarded as hypothesis-generating. The next step should be a prospective comparative study including a contemporaneous conventional Peng or Blumgart control group, with standardized recording of pancreatic texture, exact MPD diameter, intraoperative blood loss, FRS components, and ISGPS-defined CR-POPF. A multicenter propensity-score-matched cohort could strengthen comparative inference where randomization is not feasible, while a randomized trial would provide the most robust evaluation of efficacy. Physiological studies using intraoperative perfusion assessment could also test the proposed rationale for omitting circumferential ligation.

CONCLUSION

In this prospective single-center cohort of 160 consecutive patients with a narrow MPD (≤ 3 mm), the ligature-free modified Peng pancreatojejunostomy with transpancreatic Blumgart reinforcement was technically feasible and was associated with a CR-POPF rate of 6.2%. These data provide prospective short-term outcome information in a defined high-risk anatomical population but do not establish efficacy, risk reduction, superiority, or non-inferiority compared with established reconstruction techniques. Comparative multicenter studies are required to determine whether this technical modification provides a clinically meaningful advantage.

Abbreviations

CR-POPF
Clinically relevant postoperative pancreatic fistula
EUS
Endoscopic ultrasound
FRS
Fistula Risk Score
HPB
Hepato-biliary
ISGPS
International Study Group for Pancreatic Surgery
LVI
Lymphovascular invasion
MPD
Main pancreatic duct
MRCP
Magnetic resonance cholangiopancreatography
PD
Pancreaticoduodenectomy
PJ
Pancreatojejunostomy
PNI
Perineural invasion
POPF
Postoperative pancreatic fistula
pTNM
Pathological tumour–node–metastasis
R0
Microscopically negative resection margin

Declarations

Ethics approval and consent to participate:

This study received Institutional Review Board approval from the National Cancer Institute, Cairo University (Reference: SO2406-210-102). All study procedures involving human participants were conducted in accordance with the ethical standards of the Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all participants before enrolment.

Consent for publication

Not Applicable. No identifying images or other personal or clinical details that could compromise participant anonymity are presented in this manuscript.

Competing Interests:

The authors declare that they have no competing interests.

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Author Contribution

Abdalwahab R. Abdalwahab (ARA) and Alaadin Hussien (AH) conceived the study and collected data. Samir Samir (SS), Fouad Abdelshahid (FA), Shady Mohammed Elsebai (SME) designed the methodology. Ahmed Ramadan (AR), and Sayed Shaker Shaeir (SSS) performed data analysis and manuscript drafting. Abdalwahab R. Abdalwahab (ARA) and Sayed Shaker Shaeir (SSS) supervised the study and critically revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The patient-level dataset underlying the analyses is not publicly available because of institutional and participant confidentiality restrictions. De-identified data may be made available from the corresponding author on reasonable request and subject to institutional approval, where applicable.

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Figures

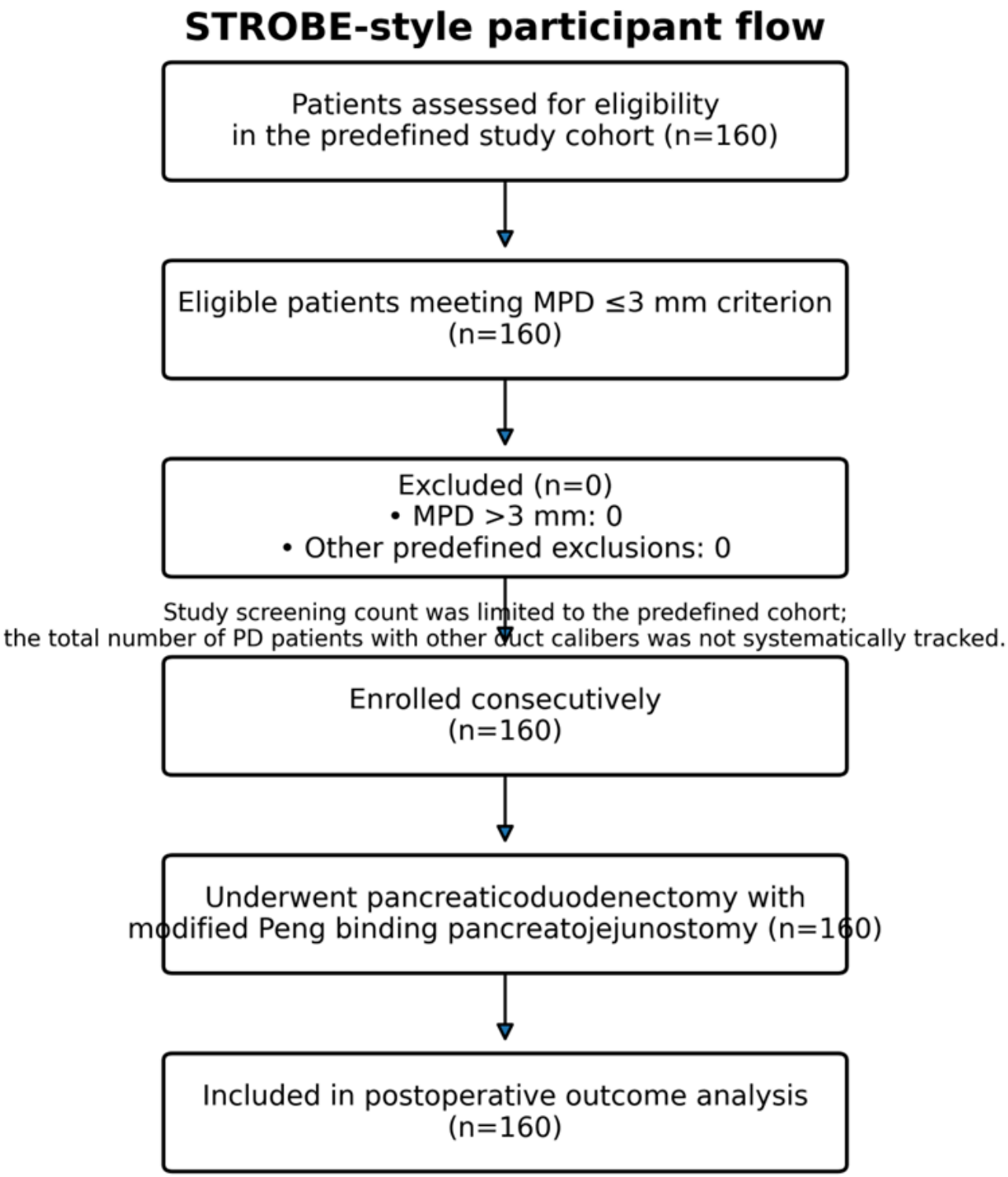


Figure 1

STROBE-style participant flow diagram. The study cohort comprised 160 consecutively eligible patients; the total number of PD patients with other duct calibers during the study period was not systematically tracked.

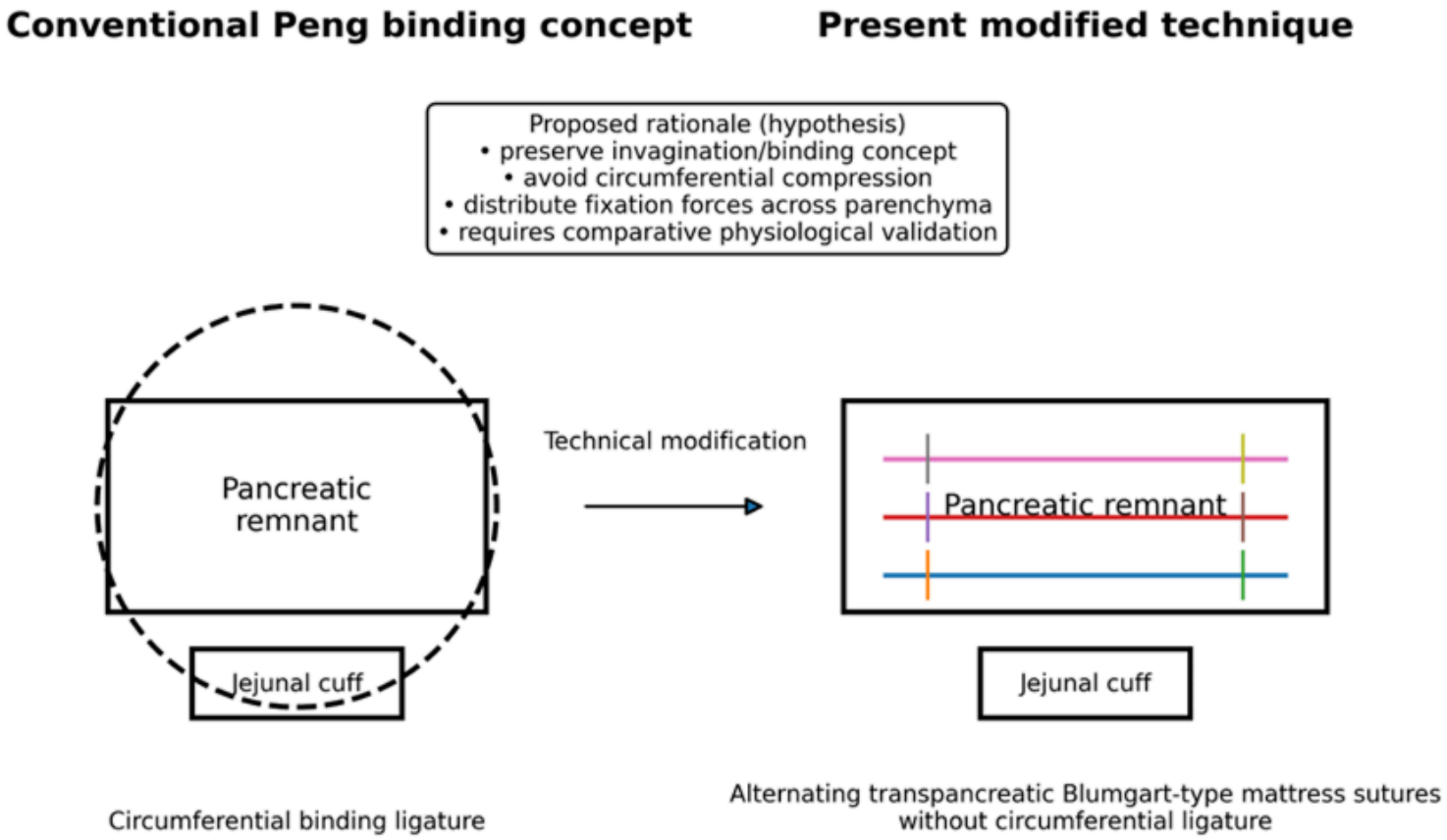


Figure 2

Schematic representation of the conventional binding concept (left) and the present ligature-free modification with transpancreatic Blumgart-type reinforcement (right). The proposed perfusion and mechanical benefits remain hypotheses to be tested in future comparative studies.