Original Article

A modified single-needle continuous suture of duct-to-mucosa pancreaticojejunostomy in pancreaticoduodenectomy

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Background: The pancreatic reconstruction technique decides the incidence of postoperative pancreatic fistulas (POPF) in pancreaticoduodenectomy (PD). This study aims to evaluate the safety of modified single-needle continuous suture (SNCS) of duct-to-mucosa and compare the efficacy with double-layer continuous suture (DLCS) of duct-mucosa pancreaticojejunostomy (PJ) in open PD (OPD).

Methods: A total of 266 patients that received PD between January 2019 and May 2023 were retrospectively analyzed. Among them, 130 patients underwent DLCS, and 136 patients underwent SNCS [73 OPD and 63 laparoscopic PD (LPD)]. The primary outcome was clinically relevant POPF (CR-POPF) according to the definition of the revised 2016 International Study Group of Pancreatic Fistula (ISGPF). Propensity score matching (PSM) was conducted to reduce confounding bias.

Results: A total of 66 pairs were successfully matched using PSM in OPD. No significant difference was observed in the occurrence of CR-POPF between the two groups (9.1% *vs.* 21.2%, P=0.052). However, the median duration of operation and PJ was shorter in the SNCS group. The incidence of CR-POPF in LPD was 9.5%. Furthermore, regarding the alternative fistula risk score (a-FRS), the CR-POPF rate were 2.1%, 10.5%, and 15.6% in low-, intermediate-, and high-risk groups (P=0.067).

Conclusions: The SNCS is a facile, safe, and effective PJ technique and does not increase the incidence of POPF, regardless of a-FRS stratification, pancreatic texture, and main pancreatic duct (MPD) size.

Keywords: Laparoscopic; pancreaticoduodenectomy (PD); pancreatic fistula; duct-to-mucosa; pancreaticojejunostomy (PJ)

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Introduction

Pancreaticoduodenectomy (PD) is a complex abdominal operation that remains the only curative treatment for periampullary neoplasms (1). Although postoperative mortality has significantly fallen with improved surgical techniques and postoperative management, the incidence of postoperative complications remains high, ranging from 32% to 52%. Postoperative pancreatic fistula (POPF) is the most common and lethal complication (2). Currently, laparoscopic PD (LPD) has been widely used and it has less intraoperative bleeding and shorter hospital stays. However, no difference was noted in POPF rate and other postoperative complications (3).

Multiple factors have been linked to POPF, including individual characteristic, operation approaches, and skills (4). The pre- and post-managements, including amelioration of patients nutritional status, improvement of anastomosis technique, postoperative drainage, and somatostatin usage, have been shown to prevent the incidence of POPF (5). Several modified anastomotic methods have been proposed to obtain stable anastomosis, including end-to-side duct-to-mucosa pancreaticojejunostomy (PJ), invagination PJ, binding PJ, and pancreatogastrostomy (PG). The duct-to-mucosa PJ is the most widely used one in LPD (6), which simultaneously guarantees mucosal continuity and anastomotic patency, favoring anastomoses healing. Since the laparoscopic surgery greatly increases the difficulty of anastomosis, especially for delicated pancreatic ducts, the advanced technique is still demanding.

In this study, a modified single-needle continuous suture (SNCS) of duct-mucosa PJ was developed, which aimed to simplify anastomotic process and improve the anastomotic quality. We described a SNCS method, also compared the outcomes of patients who have received SNCS and double-layer continuous suture (DLCS) of duct-mucosa PJ in open PD (OPD). Our data demonstrated that SNCS is reliable, safe, fast, and effective anastomotic technology. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-340/rc).

Highlight box

Key findings

- A modified single-needle continuous suture (SNCS) of duct-to-mucosa pancreaticojejunostomy (PJ) is a facile, safe, and effective PJ technique, and worthy of wide use.

What is known and what is new?

- Pancreatoenteric anastomotic failure is the main cause of pancreatic fistula after pancreaticoduodenectomy (PD). Currently, controversy persists concerning which anastomosis is best.
- This study describes in detail the modified SNCS of duct-to-mucosa PJ. It simplifies the procedure and does not increase the rate of pancreatic fistula.

What is the implication, and what should change now?

- We believe that this modified SNCS of duct-to-mucosa PJ can be used as an optional anastomotic method for PD and merits promotion and application.

Methods

Patients

Two hundred and sixty-six patients who underwent PD at Department of Pancreatic and Biliary Surgery, The First Affiliated Hospital of Harbin Medical University were involved in this study. Among them, 130 patients underwent DLCS between January 2019 and December 2020, while 136 patients underwent SNCS (73 and 63 who had OPD and LPD respectively) between January 2021 and May 2023. All the surgeries were performed by the same surgical team and the PJ were performed by the same surgeon. The inclusion criteria included a resectable benign and malignant disorders of the pancreatic head and periampullary mass. The better condition which could tolerate anesthesia and surgery. The exclusion criteria included those described by NCCN guideline.

All preoperative, perioperative, and postoperative data were collected from hospital records. Preoperative data included gender, age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, comorbidities, and operation method. Perioperative data included operative time, duration of PJ, estimated blood loss (EBL), intraoperative blood transfusion, diameter of MPD, and pancreatic texture. The alternative fistula risk score (a-FRS) was calculated by following formula: P = exp[−3.136 + 0.947 (texture) + 0.0679 (BMI) − 0.385 (PD size)]/{1 + exp[−3.136 + 0.947 (texture) + 0.0679 (BMI) − 0.385 (PD size)]}, (P = probability; texture 1 = soft, 0 if not soft; PD size = pancreatic duct size in mm) according to pancreatic texture, pancreatic duct size, and BMI. Postoperative data included histopathologic diagnosis, postoperative hospital stay, postoperative complications, 90-day readmission, reoperation, and 90-day mortality. Postoperative complications included biliary leak, abdominal fluid collection, delayed gastric emptying (DGE), post-pancreatectomy hemorrhage (PPH), infection (pulmonary or urinary tract infections, wound infection), and pancreatic fistula.

POPF definition was based on the 2016 guidelines by the International Study Group of Pancreatic Fistula (ISGPF) (7). Grade A was indicated by biochemical leaks without clinical impact, while grade B and C were considered clinically relevant POPF (CR-POPF). Amylase content in the drainage fluid was measured daily for the first 3 postoperative days and afterwards where necessary. PPH and DGE were defined according to ISGPS definitions (8,9).

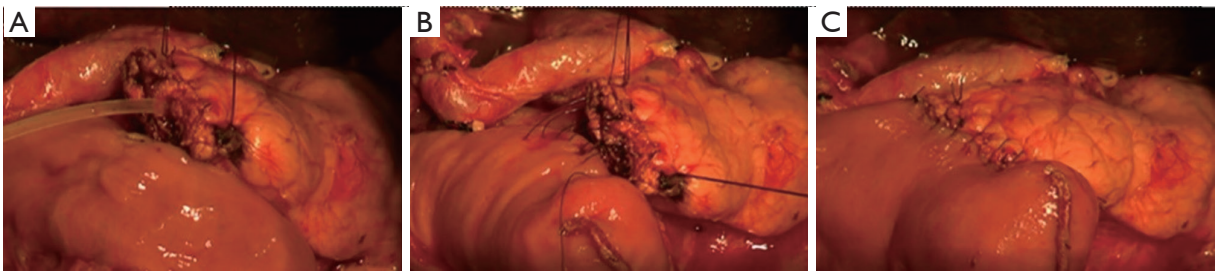

Figure 1 Intraoperative images of SNCS. (A) An incision corresponding to the pancreatic duct was made in the jejunum; (B) posterior layer suture with continuous suture; (C) anterior layer suture with continuous sutures. SNCS, single-needle continuous suture.

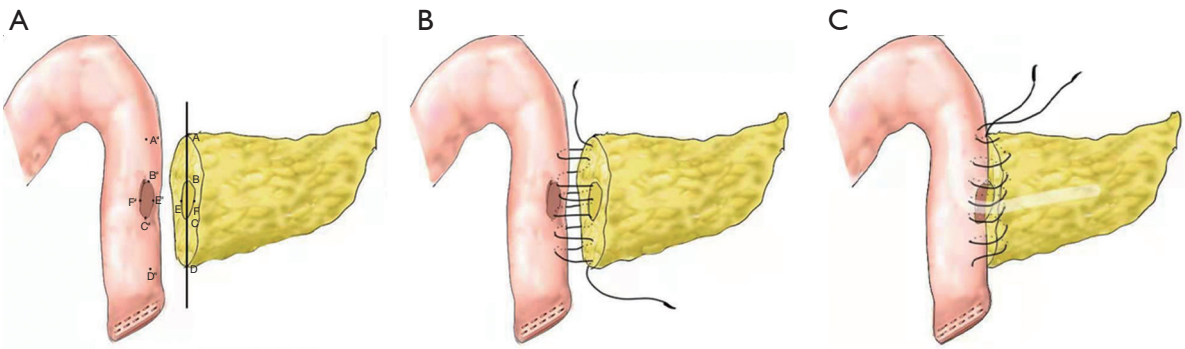

Figure 2 Schematic diagram of SNCS. (A) The point of entry of the needle; (B) posterior layer suture with continuous sutures: the posterior layer of pancreatic duct-to-jejunal mucosa was stitched with three were located at 12, 9, 6 o'clock positions on the pancreatic side (point B, E, C) and 12, 3, 6 o'clock positions on the corresponding jejunum side (point B', E', C'); (C) anterior layer suture with continuous sutures: the anterior layer of pancreatic duct-to-jejunal mucosa was stitched with three stitches which were located at 12, 3, and 6 o'clock position on the pancreatic side (point B, F, C) and corresponding sites on the jejunum were 12, 9, and 6 o'clock positions (point B', F', C'). SNCS, single-needle continuous suture.

Patients were stratified by low-risk (P<5%) intermediate-risk (P=5% to 20%) and high-risk (P>20%) by a-FRS. Timing of drainage removal was at the discretion of the surgeon. Our retrospective study was approved by the institutional Ethics Committees of the First Affiliated Hospital of Harbin Medical University (approval number: IRB-AF/SC-04/02.0) and conducted in accordance with the ethical guidelines of the Declaration of Helsinki (as revised in 2013) and individual consent for this retrospective analysis was waived.

Surgical techniques

The standard PD removed pancreatic head, duodenum, proximal jejunum, common bile duct, gall bladder, and a segment of the stomach. The child method was used for reconstructing PJ, cholangioenterostomy, and gastrojejunostomy sequentially.

SNCS-PJ procedure

After removal of the PD specimen, SNCS-PJ was performed (*Figures 1*,*2*). First, a small incision (size of the pancreatic duct) was made in the contralateral jejunal wall using electrocautery (*Figure 1A*). The posterior suturing layer was then sutured using a continuous-suture technique, with double needles with a 4-0 prolene suture. The needle entry site was in the midline of the pancreatic section, 1–2 mm from the superior edge of the pancreas (point A) (*Figure 2A*). The exit points of the needles were approximately 0.5–1 cm from the edge of the pancreatic incision in the posterior wall of the pancreas. The main pancreatic duct (MPD)

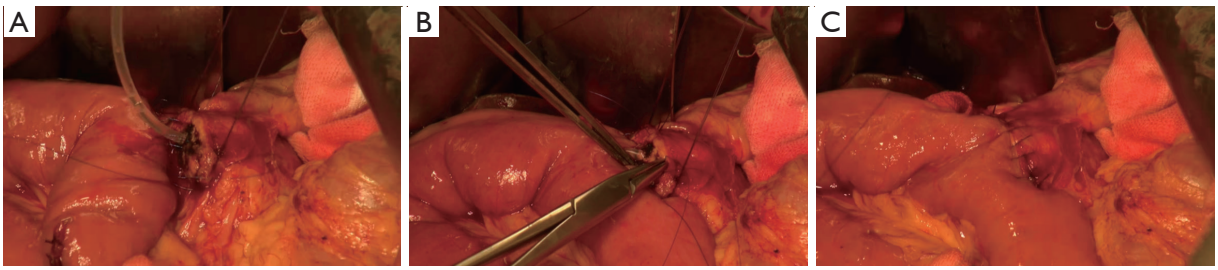

Figure 3 Intraoperative images of DLCS. (A) Posterior layer suture with continuous suture; (B) MPD and the jejunum mucous membrane was stitched with continuous suture; (C) anterior layer suture with continuous sutures. DLCS, double-layer continuous suture; MPD, main pancreatic duct.

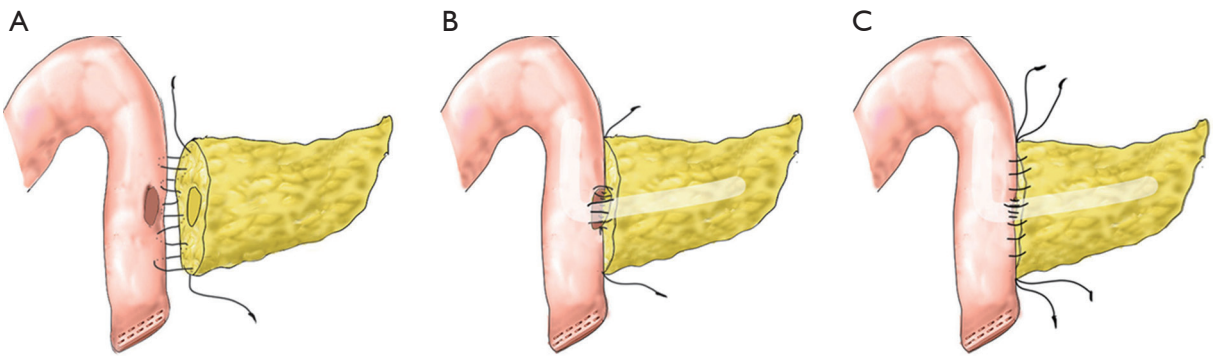

Figure 4 Schematic diagram of DLCS. (A) Posterior layer suture with continuous suture; (B) MPD and the jejunum mucous membrane was stitched with continuous suture; (C) anterior layer suture with continuous sutures. DLCS, double-layer continuous suture; MPD, main pancreatic duct.

and the jejunum mucous membrane were sutured when reaching pancreatic duct. Generally, three stitches were needed for the anterior and posterior half of pancreatic duct and the small hole of the jejunum. The pancreatic duct stitch included enough pancreatic parenchyma and duct and the jejunal wall stitch included the whole layer of the jejunal wall (*Figures 1B*,*2B*). A stent tube matching the size of pancreatic duct without fixation was placed in the MPD and jejunum. The stent tube was cut 2–4 side holes at the insertion end. The length of stent in the pancreatic duct was 4–5 cm, and the length in the jejunum was approximately 8–10 cm, beyond the bilioenteric anastomotic site. The same 4-0 prolene suture was used to suture the anterior suturing layer by the same protocol. The exit points of the needles were in the midline of the pancreatic section to avoid dead space (*Figures 1C*,*2C*). After the posterior and anterior wall were sutured, the suture is gently pulled taut and tied. During suturing, care should be taken to ensure that the suture does not become tangled. When tightening the sutures, slow and continuous force should be used to maintain proper tension. The needle number between point B and C should be added when the MPD is obviously delated.

DLCS-PJ procedure

After removal of the PD specimen, DLCS-PJ was performed (*Figures 3*,*4*). First, a small incision (size of the pancreatic duct) was made in the contralateral jejunal wall. Then, the posterior suturing layer was sutured using a continuous-suture technique with a 4-0 prolene suture (*Figures 3A*,*4A*). A stent tube was placed in the MPD and jejunum. The pancreatic duct-to-jejunal mucosa was continuously sutured by absorbable 5-0 suture material (*Figures 3B*,*4B*). Finally, another 4-0 prolene suture was used to suture the anterior suturing layer by the same protocol of posterior suturing layer (*Figure 3C*,*4C*).

A continuous suture was taken for cholangiojejunostomy

and a stapler was used for the gastrojejunostomy in both groups. After anastomosis, two prophylactic drains were placed under the pancreaticoenteric and bilioenteric anastomosis.

Statistical analysis

Propensity score matching (PSM) was performed in a 1:1 ratio to reduce bias between the SNCS-PJ and DLCS-PJ groups in OPD. Nearest neighbor matching with a calliper width of 0.02 standard deviations of the logit of the propensity score was used. Covariates were gender, age, BMI, ASA, pancreatic texture, MPD, and pathological diagnosis. Continuous data were plotted as the mean ± standard deviation (SD) or median (range), based on data distribution. Categorical variables were presented as counts and proportions. The chi-square test (or Fisher exact test) was used to compare the statistical difference and P value <0.05 was considered as statistically significant. Statistical analyses were performed by SPSS 26.0 (SPSS Inc., Chicago, IL, USA).

Results

A total of 266 patients were included for analysis. SCNS PJ was performed in 136 patients (n=73 in the OPD group and n=63 in the LPD group) and DLCS PJ in 130 patients. After PSM, 66 patients from each group were successfully matched in OPD. The pre- and post-PSM characteristics of patients are shown on *Table 1*. There was no difference between the two groups after PSM.

The operative and postoperative details after PSM in OPD are shown in *Table 2*. The median operation times were shorter in the SNCS group (median 220 *vs.* 225 minutes, P=0.045). And the median PJ duration was significantly shorter in the SNCS group (median 9 *vs.* 13 minutes, P<0.001). There was no difference in CR-POPF (9.1% *vs.* 21.2%, P=0.052). The incidences of DGE, bile leakage, abdominal fluid collection, PPH, and infection were 13.6%, 10.6%, 10.6%, 6.1%, 19.7%, respectively. The results were similar between the two groups. The re-operation was taken for 1 patient (1.5%) in the SNCS group and 2 patients (3.0%) in DLCS group due to intra-abdominal hemorrhages related to POPF. Two patients died in the SNCS group because of intra-abdominal hemorrhage and organ failure, one patient died in DLCS group because of intra-abdominal hemorrhage. No significant difference was observed in 90-day readmission, 90-day mortality, postoperative hospital stay, and reoperation.

A feasibility of SNCS-PJ in LPD was assessed. Patient characteristics and perioperative data are summarized in *Table 3*. A total of 33 males and 30 females were included, with a median age of 60 (range, 18–73) years. Thirty-five patients with soft pancreas and the MPD of 36 patients was less than 3 mm. Median operative time was 290 (range, 240–470) minutes. The median duration of PJ was 17 (range, 8–30) minutes and the median EBL was 100 (range, 50–800) mL. The CR-POPF rate was 9.5%. The incidence of grade B POPF was 7.9% and grade C was 1.6%. Eight (12.7%) patients who had isolated DGE and 4 patients (6.3%) with bile leak were treated conservatively. The abdominal fluid collection occurred in 4 patients (6.3%) and infection in 4 patients (6.3%). The PPH occurred in three patients and one of them received re-operation. The median length of postoperative hospital stay was 18 (range, 9–45) days and there was no readmission and postoperative mortalities in the 90-day follow-up period.

Patients with SNCS in OPD and LPD were stratified according to the a-FRS in three groups: low-risk (47 patients, P<5%), intermediate-risk (57 patients, P=5% to 20%), and high-risk (32 patients, P>20%). There was no difference between the low-, intermediate-, and high-risk groups with respect to CR-POPF (P>0.05) (*Table 4*). Likewise, no significant differences in pancreatic texture, MPD size, and operation method (P>0.05) (*Table 5*).

Discussion

The technical maturity of PD is increasing, but the incidence of POPF is still high (2). Numerous risk factors are associated with pancreatic fistula, including pancreatic factors, patient factors, and operative factors, particularly pancreatoenteric anastomotic techniques, which has been termed the "Achilles' heel" of PD (4). Although there are various advanced PJ techniques for reducing POPF, none of them seems to be the best.

Two types of anastomoses (PG and PJ) are widely used for pancreatic-digestive tract anastomosis, PJ remains the best choice for pancreatic remnant reconstruction (7). Generally, PJ includes duct-to-mucosa anastomosis, binding anastomosis, and invagination anastomosis, none of them has clear advantage over the others. Bassi *et al.* (10) compared POPF incidence in patients receiving duct-to-mucosa anastomosis or invagination anastomosis and no difference was found. However, a recent meta-analysis suggested that invagination anastomosis is superior to duct-

Table 1 Comparison of clinical characteristics between the SNCS and DLCS groups in OPD before and after PSM

Variables	Before matching			After matching		
	SNCS (n=73)	DLCS (n=130)	P	SNCS (n=66)	DLCS (n=66)	P
Gender			0.036*			0.862
Male	35 (47.9)	82 (63.1)		35 (53.0)	34 (52.5)	
Female	38 (52.1)	48 (36.9)		31 (47.0)	32 (48.5)	
Age (years)	61 [29–76]	61 [25–80]	0.408	61 [29–76]	61 [26–79]	0.848
BMI (kg/m^2)	23.5 [17.4–40.3]	22.4 [16.3–33.3]	0.129	23.1 [17.4–40.3]	23.2 [17.9–29.3]	0.911
ASA score			0.185			0.600
II	30 (41.1)	66 (50.8)		29 (43.9)	32 (48.5)	
III	43 (58.9)	64 (49.2)		37 (56.1)	34 (51.5)	
Pancreatic texture			0.046*			0.481
Soft	27 (37.0)	67 (51.5)		36 (54.5)	40 (60.6)	
Hard	46 (63.0)	63 (48.5)		30 (45.5)	26 (39.4)	
MPD size			0.503			0.615
<3 mm	38 (52.1)	74 (56.9)		37 (52.1)	34 (47.9)	
≥3 mm	35 (47.9)	56 (43.1)		34 (47.9)	37 (52.1)	
Diagnosis			0.747			0.930
Pancreatic ductal adenocarcinoma	31 (42.5)	49 (37.7)		29 (43.9)	30 (45.5)	
Ampullary adenocarcinoma	5 (6.8)	11 (8.5)		5 (7.6)	7 (10.6)	
Distal cholangiocarcinoma	21 (28.8)	36 (27.7)		17 (25.8)	14 (21.2)	
Duodenal adenoma	9 (12.3)	25 (19.2)		9 (13.6)	11 (16.7)	
Pancreatic neuroendocrine tumor	1 (1.4)	1 (0.8)		1 (1.5)	1 (1.5)	
Pancreatic cystic tumors	4 (5.5)	3 (2.3)		3 (4.5)	1 (1.5)	
Others	2 (2.7)	5 (3.8)		2 (3.0)	2 (3.0)	
Comorbidity			0.980			0.600
None	40 (54.8)	71 (54.6)		34 (51.5)	37 (56.1)	
One or more	33 (45.2)	59 (45.4)		32 (48.5)	29 (43.9)	

Data are presented as n (%) or median [range]. *, P<0.05. SNCS, single-needle continuous suture; DLCS, double-layer continuous suture; OPD, open pancreaticoduodenectomy; PSM, propensity score matching; BMI, body mass index; ASA, American Society of Anesthesiologists; MPD, main pancreatic duct.

to-mucosa anastomosis with respect to POPF (11). Senda *et al.* (12) reached the same conclusion but in patients with soft pancreatic texture, they found that invagination anastomosis is superior to duct-to-mucosa anastomosis when dealing with a soft pancreas. Bai *et al.* have suggested that the incidence of CR-POPF with invagination anastomosis is significantly higher than that in duct-to-mucosa anastomosis (17.6% *vs.* 3.1%), with more severe complications (13). All of the differences above may be due to different definitions of POPF, surgeon experience, and variations in surgical technique. Theoretically, duct-to-mucosa anastomosis retains mucosal continuity and anastomotic patency. The pancreatic surface section is covered by jejunal serosal, which protects the pancreatic remnant from corrosion by pancreatic juice. The duct-to-mucosa has been widely used in both OPD and LPD. The

Table 2 Comparison of the outcomes after PJ between the SNCS and DLCS groups after PSM

Variables	SNCS (n=66)	DLCS (n=66)	P value
Operation time (min)	220 [170–320]	225 [180–330]	0.045*
PJ time (min)	9 [7–15]	13 [9–20]	<0.001*
EBL (mL)	200 [50–1,000]	200 [50–800]	0.784
Required transfusion	8 (12.1)	7 (10.6)	0.573
Postoperative complications			
DGE	9 (13.6)	8 (12.1)	0.795
Grade A	2 (3.0)	1 (1.5)	>0.99
Grade B	3 (4.5)	3 (4.5)	>0.99
Grade C	4 (6.1)	4 (6.1)	>0.99
Biliary fistula	7 (10.6)	10 (15.2)	0.436
Abdominal fluid collection	7 (10.6)	7 (10.6)	>0.99
PPH	4 (6.1)	7 (10.6)	0.345
Grade A	1 (1.5)	3 (4.5)	0.612
Grade B	3 (4.5)	3 (4.5)	>0.99
Grade C	0 (0)	1 (1.5)	>0.99
Infection	13 (19.7)	9 (13.6)	0.350
CR-POPF	6 (9.1)	14 (21.2)	0.052
Grade B	4 (6.1)	10 (15.2)	0.090
Grade C	2 (3.0)	4 (6.0)	0.676
Postoperative hospital stay (days)	18 [10–48]	19 [10–61]	0.199
90-day readmission	0 (0.0)	0 (0.0)	>0.99
90-day mortality	2 (3.0)	1 (1.5)	>0.99
Reoperation	1 (1.5)	2 (3.0)	>0.99

Data are presented as n (%) or median [range]. *, P<0.05. PJ, pancreaticojejunostomy; SNCS, single-needle continuous suture; DLCS, double-layer continuous suture; PSM, propensity score matching; EBL, estimated blood loss; DGE, delayed gastric emptying; PPH, post-pancreatectomy hemorrhage; CR-POPF, clinically relevant postoperative pancreatic fistulas.

SNCS follows the duct-to-mucosa anastomosis protocol. Furthermore, the number of layers in anastomosis also affect POPF incidence. Kwon *et al.* (14) described a single-layer anastomosis, which was considered as convenient and feasible. Several studies indicated that the single-layer technique is superior with regards to anastomotic

Table 3 The demographic characteristics and perioperative data of patients undergoing LPD with SNCS

Variables	Data
Gender	
Male	33 (52.4)
Female	30 (47.6)
Age (years)	60 [18–73]
BMI (kg/m^2)	23.2±3.1
ASA score	
II	31 (49.2)
III	32 (50.8)
Pancreatic texture	
Soft	35 (55.6)
Hard	28 (44.4)
MPD size	
<3 mm	36 (57.1)
≥3 mm	27 (42.9)
Diagnosis	
Pancreatic ductal adenocarcinoma	21 (33.3)
Ampullary adenocarcinoma	6 (9.5)
Distal cholangiocarcinoma	16 (25.4)
Duodenal adenoma	8 (12.7)
Pancreatic neuroendocrine tumor	2 (3.2)
Pancreatic cystic tumors	6 (9.5)
Others	4 (6.3)
Comorbidity	
None	43 (68.3)
One or more	20 (31.7)
Operation time (min)	290 [240–470]
PJ time (min)	17 [8–30]
EBL (mL)	100 [50–800]
Required transfusion	2 (3.2)
Postoperative complications	
DGE	8 (12.7)
Grade A	1 (1.6)
Grade B	4 (6.3)
Grade C	3 (4.8)

Table 3 (*continued*)

Table 3 (*continued*)

Variables	Data
Biliary fistula	4 (6.3)
Abdominal fluid collection	4 (6.3)
PPH	3 (4.8)
Grade A	0 (0.0)
Grade B	1 (1.6)
Grade C	2 (3.2)
Infection	4 (6.3)
CR-POPF	6 (9.5)
Grade B	5 (7.9)
Grade C	1 (1.6)
Postoperative hospital stay (days)	18 [9–45]
90-day readmission	0 (0.0)
90-day mortality	0 (0.0)
Reoperation	1 (1.6)

Data are presented as n (%), median [range], or mean ± SD. LPD, laparoscopic pancreaticoduodenectomy; SNCS, single-needle continuous suture; BMI body mass index; ASA, American Society of Anesthesiologists; MPD, main pancreatic duct; PJ, pancreaticojejunostomy; EBL, estimated blood loss; DGE, delayed gastric emptying; PPH, post-pancreatectomy hemorrhage; CR-POPF, clinically relevant postoperative pancreatic fistulas; SD, standard deviation.

Table 4 Comparison of CR-POPF between patients with SNCS in low, intermediate and high-risk a-FRS groups

Variables	Low (<5%) (n=47)	Intermediate (5–20%) (n=57)	High (>20%) (n=32)	P value
CR-POPF	1 (2.1)	6 (10.5)	5 (15.6)	0.067
Grade B	1 (2.1)	5 (8.8)	3 (9.4)	0.247
Grade C	0 (0.0)	1 (1.8)	2 (6.3)	0.151

Data are presented as n (%). CR-POPF, clinically relevant postoperative pancreatic fistulas; SNCS, single-needle continuous suture; a-FRS, alternative fistula risk score.

blood supply, thereby reducing pancreatic fistula (15,16). Additionally, Lee *et al.* (17) showed that duct-to-mucosa anastomosis with continuous suture was safe and with low morbidity, which was favored by surgeons in LPD (18). Previous studies have suggested that even a small pinhole may cause pancreatic fistula, thus, higher number of sutures for anastomosis should be avoided. Regarding suture material, a study found that DLCS of duct-mucosa PJ, using only one polypropylene monofilament suture, did not increase the incidence of POPF (19). In comparison to absorbable suture material absorbable suture material, polypropylene monofilament suture is difficult to degrade, has controllable tension, and is easy to knot tying. Therefore, it is more applicable for single-layer continuous suture.

In recent years, novel and modified PJ techniques constantly being proposed and either of them has its own characteristics. In this study, a modified duct-mucosa anastomosis method was described and clinical outcomes was evaluated. Our approach simplified the anastomosis procedure by one continuous stitch throughout. After PSM, the rate of CR-POPF rate in the SNCS group was lower and the PJ time was shorter. Our data showed that the incidence of complications is within an acceptable range in LPD, which suggests that SNCS-PJ is equally feasible in LPD. Compared with recent reports of PJ techniques with the updated ISGPS definition (18,20-31) (*Table 6*), the duct-to-mucosa anastomosis is the main anastomosis method, especially in LPD. The incidence of CR-POPF is relatively low (1.2–3.2% in OPD, 0–9.1% in LPD) after duct-mucosa anastomosis, which is comparable with our results. Meanwhile, the PJ time is shorter in our study. Liu *et al.* (32) have described a one-layer suture PJ technique which is a little similar to ours. In their study, the SNCS was used to suture pancreatic duct to the jejunal mucosa to prevent anastomotic misplacement and serve a protective function for stent tube. They sutured the anterior suturing layer without replacing the stitches, which obtained a coherently and smoothly anastomosis process and lower incidence of POPF (6.1%). However, they were not classified by the updated ISGPS definition.

The impact of pancreatic texture, MPD size, operation method, and a-FRS to POPF were analyzed. Our results indicated that the incidence of CR-POPF was slightly higher in patients with soft pancreas (12.9% *vs.* 5.4%), small MPD size (12.2% *vs.* 4.8%) and OPD (8.2% *vs.* 9.5%) without any difference (P>0.05) (*Table 5*). Furthermore, no difference was found among the low, intermediate and high-risk groups (P>0.05). The POPF rate in patients with soft and small MPD pancreas was favorably with those from other reports by the updated ISGPS definition. A meta-analysis (33) showed the CR-POPF rate in patients with soft pancreas is 26.2%, which is higher than our study (14.3%).

Table 5 Comparison of CR-POPF between patients with SNCS in small and large MPD groups, soft pancreas and hard pancreas groups, OPD and LPD groups

Variables	MPD size			Pancreatic texture			Operation methods		
	Small MPD (<3 mm) (n=75)	Large MPD (≥3 mm) (n=61)	P value	Soft pancreas (n=63)	Hard pancreas (n=73)	P value	OPD (n=73)	LPD (n=63)	P value
CR-POPF	9 (12.2)	3 (4.8)	0.134	8 (12.9)	4 (5.4)	0.125	6 (8.2)	6 (9.5)	0.789
Grade B	7 (9.5)	2 (3.2)	0.267	6 (9.7)	3 (4.1)	0.333	4 (5.5)	5 (7.9)	0.819
Grade C	2 (2.7)	1 (1.6)	>0.99	2 (3.2)	1 (1.4)	0.877	2 (2.7)	1 (1.6)	>0.99

Data are presented as n (%). CR-POPF, clinically relevant postoperative pancreatic fistulas; SNCS, single-needle continuous suture; MPD, main pancreatic duct; OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy.

Table 6 Comparison between our study and other methods

Source	Case No.	Methods	Time (min)	CR-POPF (%)	90-day mortality (%)
OPD					
Zeng *et al.* (23), 2020	63	DTM (one-layer: interrupted)	NA	3.2	3.2
Wang *et al.* (24), 2020	199	IG (end-to-side: running)	NA	14.1	NA
Wu *et al.* (26), 2019	82	DTM-PJ (out layer: running; DTM layer: interrupted)	9.3	1.2	0
Jung *et al.* (22), 2021	125	IG-PJ (end-to-side: interrupted)	NA	20.5	1.64
Ferencz *et al.* (25), 2020	130	IG-PJ (end-to-side: purse string suture)	NA	6.9	0.7
Zhang *et al.* (31), 2023	193	IG (end-to-side: interrupted)	12	4.7	0
Wu *et al.* (28), 2023	529	Non-DTM-PJ (one-layer: running)	NA	7.9	NA
Ours	66	DTM-PJ (one-layer: running)	9	9.1	3.0
LPD					
Du *et al.* (27), 2019	31	DTM-PJ (out layer: running; DTM layer: purse string suture)	30.9	6.5	0
Cai *et al.* (18), 2019	238	DTM-PJ (out layer: running; DTM layer: running)	23	3.8	0.4
Sun *et al.* (21), 2021	120	DTM-PJ (out layer: transpancreatic; DTM layer: interrupted)	35	9.1	0.83
Tang *et al.* (20), 2021	35	DTM-PJ (out layer: running; DTM layer: running)	34	0	0
Zhao *et al.* (30), 2023	98	DTM-PJ (one-layer: interrupted)	17	4.1	1.0
Barberio *et al.* (29), 2023	67	IG-PJ (end-to-end: interrupted)	21.57	19.3	4.4
Ours	63	DTM-PJ (one-layer: running)	17	9.5	0

CR-POPF, clinically relevant postoperative pancreatic fistulas; OPD, open pancreaticoduodenectomy; DTM, duct-to-mucosa; NA, not available; IG, invagination; PJ, pancreaticojejunostomy; LPD, laparoscopic pancreaticoduodenectomy.

Jin *et al.* (34) analyzed the CR-POPF rate in two-layer duct-to-mucosa anastomosis and the rates in soft pancreas and small MPD group were 27.8% and 19.2%. Several studies (35,36) have validated the a-FRS model which is useful and reliable. The CR-POPF rates in low, intermediate and high risks were relatively lower than previous reports (2.1% *vs.* 8.5%, 5.88%, 10.5% *vs.* 20.8%, 24.38% and 15.6% *vs.* 27.5%, 57.69%). These results indicate that the new technology is feasible, reliable, and safe, regardless of pancreatic texture, MPD size, operation method, and a-FRS stratification.

This technique has the following strengths. First, anastomosis of the pancreatic duct to the jejunal mucosa aids anastomotic healing, and avoids pancreatic stump

immersion into the intestinal lumen, which may cause infection, hemorrhage, and necrosis. Second, single-layered suture anastomosis prevents POPF caused by very dense suture and suture line tearing of pancreatic tissue. Third, anterior and posterior layer sutures intersect at the midline of the pancreas, which prevents dead space and avoids high tension on the anastomosis, due to digestate accumulation in the gap. Fourth, continuous-suture anastomosis with same suture distributes tension evenly and reduces the duration of operation. Finally, this technique decreases the number of suturing and knot tying to facilitate performed under laparoscopy. In summary, the SNCS is easy to learn and launch, making it convenient for laparoscopy and reducing anastomosis time.

This study has some limitations. First, this is a retrospective study and selection bias may be unavoidable. Second, the sample size in this study is small. Third, it is a single-center study and all the operations were completed by the same surgical group. Fourth, it is evaluated short-term postoperative outcomes with a lack of long-term follow-up. Thus, a multicenter prospective randomized controlled trial is required to evaluate its technical feasibility, safety, efficacy, and long-term outcomes.

Conclusions

We introduce a modified anastomosis technique for PJ. The present study shows that the SNCS is reliable, safe and fast, and it does not increase POPF incidence regardless of pancreatic texture, MPD size, operation method, and a-FRS stratification.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-340/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-340/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki (as revised in 2013). Our retrospective study was approved by the institutional Ethics Committees of the First Affiliated Hospital of Harbin Medical University (approval number: IRB-AF/SC-04/02.0) and individual consent for this retrospective analysis was waived.

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