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Original Article

Single-loop versus double-loop reconstruction after pancreatoduodenectomy: Does it impact on the risk of postoperative pancreatic fistula?

Giovanni Domenico Tebala[1], Fanny Massimi[2], Francesca Duro[1], Ahmed Abdelsamad[3], Stefano Avenia[4], Gian Luca Baiocchi[5], Andrea Barberis[6], Chafik Bouzid[7], Antoine Castel[8], Graziano Ceccarelli[9], Andrea Celotti[5], Nicola Cillara[10], Nicola Cinardi[11], Roberto Cirocchi[1], Maria Conticchio[12], Giuseppe Currò[13], Antonella Delvecchio[12], Raffaele Vincenzo De Rosa[8], Jacopo Desiderio[1], Antonio Di Cintio[1], Fabio Francesco Di Mola[14], Domenico Di Nardo[1], Alessia Fassari[15], Alessandro Gemini[1], Carlos Augusto Gomes[16], Gian Luca Grazi[17], Giuseppe Margani[18], Alessandro Mazzotta[19], Luca Morelli[20], Andrea Muratore[21], Fabrice Muscari[22], Edoardo Maria Muttillo[2], Alberto Patriti[23], Gaetano Piccolo[24], Luca Properzi[1], Alessandro Puzziello[25], Lucia Romano[26], Edoardo Rosso[27], Sara Saeidi[28], Andrea Sagnotta[29], Edoardo Saladino[30], Marcello Giuseppe Spampinato[31], Laurent Sulpice[8], Nádia Tenreiro[32], Paolo Ubiali[33], Riccardo Memeo[11], DoS-RAP Collaborative

[1]Digestive and Emergency Surgery Unit, Azienda Ospedaliera S.Maria, Terni, Italy,
[2]Department of Medical Surgical Science and Translational Medicine, S.Andrea Hospital, Sapienza University of Rome, Rome, Italy,
[3]Department of Surgery II, Witten/Herdecke University, Witten, Germany,
[4]Hepatobiliopancreatic and Liver Transplant Unit, AORN "Cardarelli", Naples, Italy,
[5]General Surgery Unit, ASST Cremona, Cremona, Italy,
[6]General and HPB Surgery Unit, Ente Ospedaliero Ospedali Galliera, Genoa, Italy,
[7]Department of Surgical Oncology, DBK Anticancer Centre, Mouloud Mammeri University, Tizi Ouzou, Algeria,
[8]Hepatobiliary and Digestive Surgery Department, Hopital Pontchaillou, CHU Rennes, Rennes, France,
[9]General Surgery Unit, Ospedale "S.Giovanni Battista", Foligno, Italy,
[10]General Surgery Unit, P.O. Santissima Trinità, Cagliari, Italy,
[11]HPB Surgery Unit, ARNAS "G. Garibaldi", Catania, Italy,
[12]HPB Surgery Unit, Ospedale Regionale "Miulli", Acquaviva delle Fonti, Italy,
[13]Department of Health Science, University Hospital Dulbecco, Magna Graecia University of Catanzaro, Catanzaro, Italy,
[14]General and Surgical Oncology Unit, Department of Innovative Technologies in Clinical Medicine and Dentistry, Clinica Pierangeli, Università "Gabriele D'Annunzio", Pescara, Italy,
[15]General Surgery Unit, Centre Hospitalier de Luxembourg, Luxembourg City, Luxembourg,
[16]General Surgery Unit, Faculdade De Ciências Médicas e da Saúde, Universidade Federal de Juiz De Fora, Juiz de Fora, Brazil,
[17]Hepato-Biliary and Pancreatic Surgery Unit, Department of Clinical and Experimental Medicine, AOU Careggi Hospital, University of Florence, Florence, Italy,
[18]General Surgery Unit, Ospedale SS Giovanni e Paolo, Venice, Italy,
[19]General Surgery and Transplant Unit, Policlinico "Umberto I", Sapienza University of Rome, Rome, Italy,
[20]Academic General Surgery Unit, Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy,
[21]General Surgery Unit, Ospedale "E. Agnelli", Pinerolo, Italy,
[22]Department of Hepatobiliopancreatic Surgery and Hepatic and Pancreatic Transplantation, CHU Toulouse, Toulouse, France,
[23]General and Oncologic Surgery Unit, AST Pesaro-Urbino, Pesaro, Italy,
[24]General Surgery Unit, ASST Santi Paolo e Carlo, Milan, Italy,
[25]General Surgery Unit, Department of Surgery and Transplant, AOU "S.Giovanni Di Dio e Ruggi d'Aragona", Università di Salerno, Salerno, Italy,
[26]General and Transplant Surgery Unit, Università "Gabriele d'Annunzio", L'Aquila, Italy,
[27]Centre de Chirurgie Digestive, Institut de Chirurgie Foie et Pancréas, Pôle Santé Sud, Le Mans, France,
[28]Department of Surgery, Mashhad University of Medical Sciences, Mashhad, Iran,
[29]General and Oncologic Surgery, Ospedale "S. Filippo Neri", Rome, Italy,
[30]Oncologic Surgery Unit, Azienda Ospedaliera "Papardo", Messina, Italy,
[31]Department of General Surgery, Ospedale "Vito Fazzi", ASL Lecce, Lecce, Italy,
[32]General Surgery Unit, Unidade Local de Saúde de Trás-os-Montes e Alto Douro, Vila Real, Portugal,
[33]General Surgery Unit, Ospedale S.Maria degli ngeli, Pordenone, Italy

Backgrounds/Aims: Postoperative pancreatic fistula (POPF) remains a significant complication following pancreatoduodenectomy (PD). It has been hypothesized that single loop (SL) reconstruction may increase the risk of POPF, leading to the proposal of double-loop (DL) reconstruction. In this approach, the pancreatic duct is connected to an isolated loop of bowel in a Roux-en-Y configuration.

Methods: We conducted a retrospective multicenter study to compare various types of reconstruction after PD, analyzing data from 1,502 patients who underwent open, laparoscopic, or robotic PD across 28 centers worldwide. Propensity score matching (PSM) was applied to enhance comparability.

Results: The overall rate of POPF was 34.89%, with a grade C POPF rate of 4.26%. The type of reconstruction (SL vs. DL) did not significantly impact the rates of POPF or grade C POPF, both before and after PSM. The rate of delayed gastric emptying (DGE) was 20.71%, and patients with DL reconstruction had a lower incidence of DGE both before and after PSM.

Conclusions: Our study found no significant differences in the risk of POPF between SL and DL reconstruction. However, DL reconstruction is associated with a reduced risk of DGE, suggesting it may be a preferable option following open PD.

Key Words: Pancreaticoduodenectomy; Pancreatic fistula; Pancreaticojejunostomy

INTRODUCTION

The first reported case of pancreatoduodenectomy (PD) was performed by Alessandro Codivilla at the Hospital of Imola, Italy, in 1898 [1]. This procedure has often been mistakenly attributed to Allen Whipple from New York [2]. Since then, PD has undergone several modifications due to advancements in anatomical and pathophysiological knowledge and technology. Today, the traditional technique of PD, which remains widely used, includes a reconstructive phase following resection that involves pancreatojejunostomy (PJ), hepaticojejunostomy (HJ), and gastrojejunostomy (GJ) on a single jejunal loop (SL), starting from the stapled end of the small bowel.

To prevent biliary reflux into the stomach and to facilitate the drainage of pancreatobiliary fluid into the low-pressure distal jejunum, a modification of the SL reconstruction technique was proposed. This modification adds a jejuno-jejunal side-to-side anastomosis between the afferent (biliopancreatic) and efferent (alimentary) limbs of the GJ (single loop reconstruction with jejuno-jejunal anastomosis, SLJJ). However, the primary concern with PD continues to be the risk of postoperative pancreatic fistula (POPF) and its complications. The International Study Group on Pancreatic Fistula classifies POPFs into three grades: grade 1 (diagnosed by high levels of amylase in the drain), grade 2 (requiring changes in standard postoperative management), and grade 3 (necessitating invasive procedures or associated with sepsis or death). Recently, grade 1 POPFs have been redefined as biochemical leaks (BL), as they have no clinical impact [3].

Bile-activated pancreatic secretion can disrupt the PJ and lead to both local and systemic complications in the event of a POPF. To distinguish biliogastric efflux from pancreatic fluid and ensure that a POPF is a "pure" pancreatic fistula (rather than an "activated" one), it has been suggested to construct the PJ on an isolated Roux-en-Y (RnY) jejunal loop (double loop reconstruction, DL). Another option, favored by some surgeons either routinely or in cases of soft pancreatic texture or very small pancreatic ducts, is pancreatogastric anastomosis (PG), which connects the distal pancreatic stump to the posterior wall of the stomach. Other variations have been proposed but have not gained widespread acceptance.

Several comparative studies have assessed different reconstruction types but have not demonstrated a clear superiority of one over the others [4-7]. A meta-analysis comparing SL, DL, and SLJJ found that SLJJ is associated with the lowest risk of POPF [8]. However, a recent umbrella review highlighted the lack of high-level evidence in analyzing the various factors contributing to POPF [9].

Our study aims to address this gap in the existing literature by analyzing a large multicenter database with specific entry criteria and comparing homogeneous groups.

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Corresponding author: Giovanni Domenico Tebala, MD, FACS, FRCS
Digestive and Emergency Surgery Unit, Azienda Ospedaliera S.Maria, Viale Tristano di Joannuccio, Terni 05100, Italy
Tel: +3907442051, E-mail: gtebala@gmail.com, ORCID: https://orcid.org/0000-0001-7152-4096

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MATERIALS AND METHODS

The international multicenter observational retrospective study titled "Double Or Single Loop Reconstruction After Pancreatoduodenectomy" (DoS-RAP) was endorsed by the Italian Society of Endoscopic Surgery and New Technologies (Società Italiana di Chirurgia Endoscopica e Nuove Tecnologie) and received approval from by the Regional Ethic Committee of Umbria (Comitato Etico Regionale dell'Umbria), protocol number n. 4737/24. No funding was provided for this study.

Data was collected from 1,502 patients across 28 centers worldwide who met the inclusion criteria: patients aged 18 years or older who underwent elective open, laparoscopic, or robotic PD with pancreatodigestive anastomosis between 2018 and 2024 for any diagnosis, with at least three months of follow-up.

Anonymized demographic data (sex, age, body mass index) and clinical information (ASA score, diagnosis, any neoadjuvant treatment, surgical approach, type of reconstruction, general morbidity, POPF, degree of POPF, delayed gastric emptying (DGE), intraperitoneal postoperative bleeding, and 90-day mortality) were entered into a password-protected electronic database (Microsoft Excel for Mac v.16.66.1) and reviewed for consistency and homogeneity. Statistical analyses were conducted using the same database with an add-on (StatPlus for Mac v.7.8.11, AnalystSoft). Categorical dependent variables were compared using the chi-square test or Fisher's exact test, as appropriate. Missing data were excluded listwise.

The following groups have been compared: SL, 1,288 cases (85.75%) (Fig. 1A); SLJJ, 54 cases (3.60%); DL, 113 cases (7.52%) (Fig. 1B); PG, 47 cases (3.13%).

After excluding PG and SLJJ patients, propensity score matching (PSM) was applied, taking into account sex, age, smoking status, alcohol consumption, neoadjuvant therapy, pancreatic texture, and pancreatic duct size. Two matching groups were created, each comprising 101 patients, and they were compared (SL vs. DL).

Endpoints of the study were: rate of grade C POPF, rate of all-grade POPF (including BL), rate of postoperative intra-abdominal bleeding, rate of DGE, rate of Clavien-Dindo > 2 complications [10], 90-day mortality.

Demographics and clinical data before and after PSM are reported in Table 1 and 2.

The present paper was written in accordance to the STROBE guidelines (https://www.equator-network.org/reporting-guidelines/strobe/).

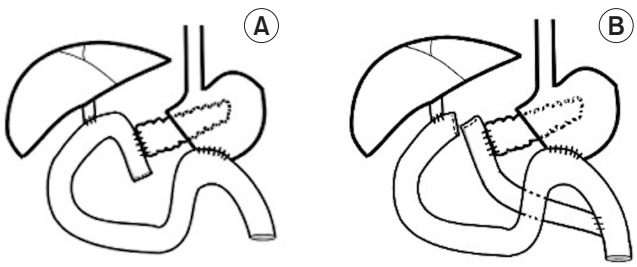

Fig. 1. (A) Single-loop reconstruction after pancreatoduodenectomy. (B) Double-loop reconstruction after pancreatoduodenectomy.

Table 1. Demographics and clinical data

	Before PSM	After PSM (and excluding PG and SLJJ)
Total	1,502	202
Sex		
Male	845 (56.26)	128 (63.37)
Female	657 (43.74)	74 (36.63)
Age (yr)	67.53 ± 10.81	71.26 ± 9.66
BMI (kg/m^2)	24.51 ± 4.14	25.04 ± 3.87
ASA		
1	137 (9.12)	4 (1.98)
2	703 (46.80)	63 (31.19)
3	625 (41.61)	126 (62.38)
4	37 (2.46)	9 (4.46)
Missing	0	0
Diagnosis		
Malignant	1,376 (91.61)	182 (90.10)
Benign	126 (8.39)	20 (9.90)
Neoadjuvant treatment		
No	1,301 (86.62)	176 (87.13)
Chemotherapy	176 (11.72)	26 (12.87)
Radiochemotherapy	25 (1.66)	0
Missing	0	0
Operation		
Whipple's	1,103 (73.44)	143 (70.79)
Pylorus preserving	399 (26.56)	59 (29.21)
Approach		
Open	1,261 (83.95)	188 (93.07)
Minimally invasive	241 (16.05)	14 (6.93)
Conversion	34/241 (14.11)	3/14 (21.43)
Reconstruction		
SL	1,288 (85.75)	101 (50.00)
SLJJ	54 (3.60)	0
DL	113 (7.52)	101 (50.00)
PG	47 (3.13)	0

Values are presented as number only, number (%), or mean ± standard deviation.
PSM, propensity score matching; SL, single loop reconstruction; SLJJ, single loop reconstruction with jejuno-jejunal anastomosis; DL, double loop reconstruction; PG, pancreatogastric anastomosis; BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 2. Distribution of preoperative variables in SL vs. DL reconstruction, before and after PSM

	Pre PSM		After PSM	
	SL	DL	SL	DL
Sex				
Male	55.51	66.37	64.36	62.38
Female	44.49	33.63	35.64	37.62
	$p = 0.026$		$p = 0.770$	
Age (yr)	67.43 ± 10.82	70.62 ± 10.64	71.24 ± 8.66	71.28 ± 10.66
	$p = 0.003$		$p = 0.981$	
BMI (kg/m^2)	24.49 ± 4.26	25.13 ± 3.26	24.96 ± 4.40	25.13 ± 3.28
	$p = 0.147$		$p = 0.767$	
ASA				
1	10.25	1.77	1.98	1.98
2	49.07	29.20	32.67	29.70
3	38.35	63.72	61.39	63.37
4	2.33	5.31	3.96	4.95
	$p < 0.001$		$p = 0.963$	
Diagnosis				
Malignant	91.23	92.92	88.11	92.07
Benign	8.77	7.08	11.88	7.93
	$p = 0.539$		$p = 0.346$	
Neoadjuvant treatment				
No	86.88	87.61	87.13	87.13
Yes	13.12	12.39	12.87	12.87
	$p = 0.825$		$p > 0.999$	
Operation				
Whipple's	73.14	65.49	80.20	61.39
Pylorus preserving	26.86	34.51	19.80	38.61
	$p = 0.081$		$p = 0.003$	
Approach				
Open	82.69	92.03	94.06	92.08
Minimally invasive	17.31	7.96	5.94	7.92
	$p = 0.010$		$p = 0.579$	
Pancreatic texture				
Hard	29.50	37.17	40.59	39.60
Soft	70.50	62.83	59.41	60.40
	$p = 0.088$		$p = 0.886$	
Pancr.Duct				
≤ 3 mm	43.40	51.33	57.43	53.46
> 3 mm	56.60	48.67	42.57	46.53
	$p = 0.104$		$p = 0.571$	

Values are presented as percentage or mean ± standard deviation.
SL, single loop reconstruction; DL, double loop reconstruction; PSM, propensity score matching; BMI, body mass index; ASA, American Society of Anesthesiologists; Pancr.Duct, pancreatic duct.

RESULTS

Results of the statistical analysis are reported in Table 3.

About one-third of the patients in the entire series experienced a POPF (524 out of the whole series had a POPF (524/1,502, or 34.89%), but only 4.26% had a complicated POPF. Slightly less than one in ten patients (9.32%) experienced significant intra-abdominal bleeding, and one in five reported DGE (20.71%). Two-thirds of the patients in the series had some form of complication following PD, resulting in a total morbidity rate of 67.38%. Three hundred twenty-five patients (21.64%) developed one or more complications classified as

Table 3. Pre- and post-PSM analysis

	POPF-all	POPF-C	Intraperitoneal bleeding	DGE	Morbidity (CD > 2)	90-day mortality
Pre-PSM						
SL (n = 1,288)	450 (34.94)	50 (3.88)	114 (8.85)	287 (22.28)	272 (21.12)	78 (6.06)
SLJJ (n = 54)	23 (42.59)	6 (11.11)	9 (16.67)	5 (9.26)	21 (38.89)	6 (11.11)
DL (n = 113)	42 (37.17)	4 (3.54)	12 (10.62)	12 (10.62)	22 (19.47)	11 (9.73)
PG (n = 47)	9 (19.15)	4 (8.51)	5 (10.64)	7 (14.89)	10 (21.28)	2 (4.25)
p	NS	0.031	NS	0.003	0.018	NS
PJ vs. PG						
p	0.021	NS	NS	NS	NS	NS
SL vs. DL						
p	NS	NS	NS	0.003	NS	NS
Post-PSM						
Total (n = 202)	77 (38.12)	5 (2.47)	30 (14.85)	38 (18.81)	47 (23.27)	21 (10.40)
SL (n = 101)	43 (42.57)	3 (2.97)	19 (18.81)	26 (25.74)	29 (28.71)	10 (9.90)
DL (n = 101)	34 (33.66)	2 (1.98)	11 (10.89)	12 (11.88)	18 (17.82)	11 (10.89)
p	NS	NS	NS	0.011	0.067	NS

Values are presented as number (%).
PSM, propensity score matching; POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying; CD, Clavien-Dindo classification; SL, single loop reconstruction; SLJJ, single loop reconstruction with jejuno-jejunal anastomosis; DL, double loop reconstruction; PG, pancreatogastric anastomosis; NS, not significant.

Clavien-Dindo > 2, indicating that they required some form of invasive treatment or experienced life-threatening conditions. No patients were lost to follow-up in the first 90 days after surgery. The overall 90-day mortality rate was 6.46%, with most cases attributed to multiple causes. The causes of mortality are detailed in Table 4.

The type of reconstruction did not influence the rates of all-grade POPF or grade C POPF, both in the overall cohort and within the propensity score-matched groups. However, patients who underwent PG exhibited the lowest risk of POPF compared to any type of PJ ($p = 0.021$). The relatively small number of patients who received PG (47) compared to those with PJ (1,455) suggests that this comparison lacks clinical significance. Additionally, our data indicate that the SLJJ and PG have the highest risk of grade C POPF, but the comparison with the more traditional SL and DL reconstructions is too imbalanced to be clinically meaningful.

Table 4. Causes of mortality in 97 cases

Causes	Number
Bleeding	32
POPF C with sepsis	20
Disease progression (after discharge)	12
Sepsis	7
Cardiopulmonary complications	4
Small bowel ischaemia	4
Biliary fistula with peritonitis	3
Liver failure	2
Multiple organ failure	1
Stump pancreatitis	1
Missing	17

In some cases, mortality was a multifactorial event where multiple causes contributed to the exitus. For this reason, the total number of potential causes does not correspond to the number of unfavorable events.
POPF, postoperative pancreatic fistula.

Patients who underwent a "Braun" jejuno-jejunal anastomosis following SL had the lowest risk of DGE; however, this group is too small for further analysis. In contrast, DL reconstruction was associated with a 50% reduction in the risk of DGE compared to SL, both in the overall cohort ($p = 0.003$) and in direct comparisons after PSM ($p = 0.011$).

SLJJ was linked to higher morbidity rates of Clavien-Dindo > 2 in the overall series, and this finding was statistically significant ($p = 0.018$). After PSM, DL showed a lower risk of significant morbidity compared to SL, but this difference was not statistically significant ($p = 0.067$).

Subgroup analysis (Table 5) confirmed that DL is associated with the lowest risk of DGE compared to SL. Patients who underwent neoadjuvant treatment (either chemotherapy or chemoradiotherapy) exhibited a borderline significant increase in the risk of POPF with DL reconstruction. Similarly, patients who had a minimally invasive PD with DL reconstruction faced a higher risk of postoperative intraperitoneal bleeding and 90-day mortality compared to those who received PD with SL. In the subgroup of patients who underwent PD for a non-malignant disorder, mortality was significantly higher among those who had DL reconstruction.

Table 5. Subgroup analysis of SL vs. DL in the whole series

	POPF		POPF C		Intraperitoneal bleeding		DGE		Morbidity (CD > 2)		Mortality	
	SL	DL	SL	DL	SL	DL	SL	DL	SL	DL	SL	DL
Texture												
Hard	17.63%	19.05%	1.31%	0	6.58%	4.76%	20.00%	7.14%	13.68%	7.14%	4.47%	7.14%
p	NS		NS		NS		0.043		NS		NS	
Soft	42.18%	47.89%	4.96%	5.63%	9.80%	14.08%	23.24%	12.68%	24.23%	26.76%	6.72%	11.27%
p	NS		NS		NS		0.040		NS		NS	
Pancr.Duct												
≤ 3 mm	49.73%	51.72%	5.72%	1.72%	11.27%	15.52%	23.26%	10.34%	22.72%	24.14%	5.90%	10.34%
p	NS		NS		NS		0.024		NS		NS	
> 3 mm	23.59%	21.82%	2.47%	5.45%	6.99%	5.45%	21.54%	10.91%	19.89%	14.54%	6.17%	9.09%
p	NS		NS		NS		0.061		NS		NS	
Malignant												
Yes	35.40%	38.09%	3.91%	3.81%	8.68%	9.52%	21.79%	10.48%	21.53%	19.05%	6.55%	8.57%
p	NS		NS		NS		0.006		NS		NS	
No	30.09%	25.00%	3.54%	0	10.62%	25.00%	27.43%	12.50%	16.81%	25.00%	0.88%	25.00%
p	NS		NS		NS		NS		NS		< 0.001	
MI												
Yes	43.50%	44.44%	4.03%	0	9.86%	33.33%	22.87%	0	17.04%	33.33%	3.59%	22.22%
p	NS		NS		0.026		NS		NS		0.006	
No	33.14%	36.54%	3.85%	3.85%	8.63%	8.65%	22.16%	11.53%	21.97%	18.27%	6.57%	8.65%
p	NS		NS		NS		0.011		NS		NS	
Neoadjuvant treatment												
Yes	26.04%	50.00%	1.77%	0	7.69%	0	28.40%	21.43%	13.61%	0	3.55%	0
p	0.054		NS		NS		NS		NS		NS	
No	36.28%	35.35%	4.20%	4.04%	9.03%	12.12%	21.36%	9.09%	22.25%	22.22%	6.43%	11.11%
p	NS		NS		NS		0.004		NS		NS	

SL, single-loop reconstruction; DL, double-loop reconstruction; POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying; CD, Clavien-Dindo classification; Pancr.Duct, pancreatic duct; NS, not significant.

DISCUSSION

PD is a complex surgical procedure with a high risk of complications. A critical step in the reconstructive phase is the management of the pancreatic stump, which includes the severed distal pancreatic duct. The typical approach is to connect the pancreatic duct to the bowel to facilitate physiological digestion. However, this anastomosis carries a significant risk of pancreatic fluid leakage, leading to POPF. POPF can result in severe intraperitoneal complications, such as collections, abscesses, perforations, and vascular erosion, potentially leading to life-threatening sepsis and bleeding. To mitigate the risk of POPF, some surgeons choose total pancreatectomy, either routinely or in selected cases. While this strategy effectively prevents POPF, it can lead to poorly controlled diabetes and malnutrition, and, when accompanied by splenectomy, may increase the risk of sepsis.

In 1987, Funovics et al. [11] recommended against routine total duodenopancreatectomy for lesions of the pancreatic head due to its association with excessively high mortality rates. However, some indications for total duodenopancreatectomy still exist, including chronic small duct pancreatitis resistant to medical therapy and main duct intraductal pancreatic mucinous neoplasms accompanied by dilatation and dysplasia of the entire pancreatic duct [12]. It is still a debatable topic whether total duodenopancreatectomy is indicated to prevent a POPF that could compromise the integrity of the vascular anastomosis in patients with arterial reconstruction [12].

An alternative approach is to perform a PG, which reduces the risk of POPF but increases the risk of bleeding and requires extensive mobilization of the pancreatic remnant. In our series, PG was significantly associated with a lower risk of POPF (p = 0.021) compared to any PJ. However, we found no significant differences in the risks of grade C POPF, bleeding, DGE, severe morbidity, or mortality. This comparison is limited in clinical relevance due to the vastly different sample sizes (47 for PG vs. 1,288 for PJ). Consequently, PG has not gained widespread acceptance, being used primarily in select cases at a few special-

ized centers, while PJ remains the preferred method.

The traditional and most common form of reconstruction involves performing the PJ, HJ, and GJ sequentially on the same loop of small bowel (SL reconstruction). To mitigate issues related to bile and pancreatic fluid reflux into the stomach, one option is to create an additional "Braun" jejuno-jejunal anastomosis between the biliopancreatic afferent loop and the digestive efferent loop (SLJJ). Another option involves constructing an additional jejunojejunostomy (JJ) between the afferent pancreatic loop to the HJ and the efferent biliary loop from the HJ, thereby diverting pancreatic juice away from the bilioenteric anastomosis (modified single-loop, mSL) [13]. Additionally, the sequence of anastomoses can be rearranged to GJ, PJ, HJ [14]. However, the last two options have not gained widespread acceptance and, to our knowledge, have not been replicated by other authors. The SLJJ reconstruction has seen limited use, with only 3.6% of patients in our database undergoing this procedure.

In 1976, Machado et al. [15] proposed a method of reconstruction in which the PJ was fashioned on an isolated loop of small bowel, while HJ and GJ were sequentially created on the main loop. The rationale behind this approach was that, in the event of a POPF, it would result in a "pure" pancreatic fistula. This would mean that non-bile-activated pancreatic fluid would lead to fewer local and systemic complications, as later confirmed by Jester et al. in 2017 [16].

Pancreatic phospholipase A2 (PPA2) is activated by bile and has a strong lipolytic effect. Activated PPA2 converts biliary lecithin to lysolecithin, which possesses significant cytotoxic activity. Additionally, pancreatic trypsinogen is activated into trypsin, which functions optimally at the alkaline pH provided by bile [13,17]. Based on these findings, it is logical to conclude that a DL reconstruction would cause less tissue disruption and, consequently, fewer complications in the event of a POPF.

Eleven years after Machado's paper, Funovics et al. [11] published the results of their prospective non-randomized study, comparing 64 SL and 48 DL andreconstructions. They concluded that "the use of separate intestinal loops for anastomoses of the pancreas and biliary tract offers the best solution, since no fatal complications of the PJ were observed." In 2008, Grobmyer et al. [18] published the results of their retrospective study, which analyzed a 700-case series spanning 15 years. They compared SL, DL, and a modified reconstruction with a biliopancreatic limb connected in a RnY fashion to an alimentary limb with GJ (biliopancreatic double loop, BPDL), claiming that there was no difference in the rates of POPF or clinically significant POPF. The group sizes in the studies are significantly imbalanced, with 588, 12, and 100 patients, respectively, making direct comparisons difficult. In 2018, Aghalarov et al. [13] compared SL, DL, and mSL techniques in three groups of 50, 25, and 50 patients, respectively. They found that the rate of grade C POPF was significantly higher in the SL group compared to the DL and mSL groups. In 2021, Morandi et al. [19] published results from a 12-year retrospective series involving 64 patients who underwent PD with either SL or DL reconstruction (28 and 36 patients, respectively). They did not find any significant differences in outcomes between the two groups. In 2022, Clemente et al. [20] conducted a retrospective study of patients with a small pancreatic duct and soft pancreatic texture who underwent PD over a 16-year period, using either SL or DL reconstruction (112 vs. 109 patients before PSM and 96 patients in each group after PSM). The authors reported that DL was associated with a reduced risk of clinically relevant POPF, with other significant independent prognostic factors including sex, pancreatic duct size, and intraoperative blood loss. In 2015, Klaiber et al. [4] published a meta-analysis comparing DL and SL techniques across a pooled cohort of 802 patients from three randomized controlled trials and four non-randomized controlled trials. They found no differences in rates of POPF, DGE, mortality, or morbidity, but did note a longer duration of surgery in the DL group. In 2021, a meta-analysis by Mobarak et al. [6] included a pooled series of 2,031 patients from 14 studies, encompassing both randomized controlled trials and observational studies, and found no differences in the rate of POPF among SL, DL, and BPDL groups.

Our large multicenter study confirmed the findings of the previously reported systematic reviews on POPF, demonstrating that the choice between SL and DL reconstruction does not significantly impact the overall risk of POPF or the risk of POPF of clinical significance (POPF-C). We observed a marginally significant reduction in the risk of POPF among patients who underwent SL reconstruction after neoadjuvant treatment. This finding is challenging to explain, as the number of patients who had PD following neoadjuvant treatment is relatively low, suggesting it may be a random effect.

When interpreting our results in light of existing literature regarding the impact of reconstruction type after PD on POPF, we conclude that any benefits of DL reconstruction are situational rather than universal. Other factors, such as pancreatic texture and pancreatic duct size, play a much more substantial role than the type of reconstruction. While the experience and case volume of the surgical team certainly contribute to outcomes, we believe these factors may sometimes be overestimated compared to others, such as the ability to manage postoperative complications. However, these considerations are beyond the scope of the present study.

As a side finding, we demonstrated that DL nearly halves the risk of DGE, suggesting that routine DL reconstruction after PD is warranted. A meta-analysis by Schorn et al. [8], which included 19 studies, found that DL did not affect mortality, morbidity, POPF, or DGE following PD; however, adding a Braun JJ (SLJJ) to a SL reconstruction reduced the risk of DGE. In contrast, a large meta-analysis by Dai et al. [21] did not show any significant impact of reconstruction technique on DGE. This analysis considered only four studies, all from Asia, and compared SL and SLJJ, making the results less applicable to

DL. Similarly, a recent retrospective cohort study by Li et al. [22] compared SL and SLJJ and found no differences between the two methods regarding DGE. Conversely, a previous meta-analysis by Zhou et al. [23] involving 1,672 pooled patients indicated that SLJJ can reduce the risk of both DGE and clinically significant DGE. Additionally, a recent meta-analysis by Xiao et al. [24] showed that RnY reconstruction decreases the risk of DGE. The RnY reconstruction after PD (BPDL) was first proposed by Grobmyer et al. in 2008 [18], who acknowledged that it does not reduce the risk of POPF. Clearly, the theoretical advantage of BPDL is related not to preventing POPF, as bile and pancreatic juice inevitably mix, but rather to reducing DGE. We assume that the definition of RnY after PD is homogenous across the studies in the meta-analysis, referring to the same anatomical RnY reconstruction used in total or subtotal gastrectomy, which features an isolated alimentary limb connecting to a common biliopancreatic limb. It's important to note that DL is also a form of Y-type reconstruction, which may cause confusion in the literature. Nevertheless, it is reasonable to assume that reducing pancreatic reflux (with or without bile) into the stomach could help prevent DGE. However, the exact mechanism of DGE after PD remains unclear, so any theoretical explanations should be approached with caution.

Explaining why minimally invasive PD is associated with a higher risk of postoperative bleeding and morbidity in DL compared to SL reconstruction is challenging. This may be partly due to the substantial differences in sample sizes between the two groups (minimally invasive vs. open PD). In our entire series, only 9 patients underwent minimally invasive DL reconstruction, compared to 223 patients who had minimally invasive SL reconstruction, resulting in a mortality rate of 22.22% (2 patients). However, it is more likely that the increased risk stems from the inherent complexities of minimally invasive PD, which is less standardized than open PD, thereby escalating the already high surgical risks. A detailed comparison between minimally invasive and open PD is beyond the scope of this paper and is mentioned only for scientific integrity.

Additionally, our data indicate that postoperative mortality was significantly higher in patients with non-malignant disease who underwent DL reconstruction. This finding is difficult to explain with the available data and may be biased due to a significantly imbalanced sample size. In fact, only 8 patients had DL reconstruction for non-malignant conditions, compared to 113 who had SL reconstruction, with a mortality rate of 25% (2 patients). We believe that these discrepancies could diminish in a more balanced series with a higher number of minimally invasive cases, allowing for a more consistent comparison between minimally invasive and open techniques.

The strength of our study lies in its large sample size, which includes cases from high, medium, and low-volume centers. This diversity allows it to better reflect real-life scenarios and what the average patient undergoing PD may expect. Most clinical studies published in the literature originate from high-volume centers, and their results may not be applicable to lower-volume institutions.

A weakness of the study is its retrospective nature and the wide variation in preoperative and postoperative protocols among the different centers. Additionally, the reconstruction technique can exhibit team-specific variations, such as the length of the isolated loop in the DL group, the distance between the pancreatic and biliary anastomosis in the SL group, and the length of the alimentary limb in the SLJJ group. An adequately powered randomized controlled trial with precise inclusion criteria and a strict protocol may help clarify the advantages of SL versus DL and potentially facilitate the standardization of the PD technique, whether performed open or minimally invasively. Our study did not fully evaluate the impact of PG on the risk of POPF. Although our figures seem to favor PG over PJ regarding the risk of POPF—except for grade C POPF—the number of PG cases in our database is too low to draw clinically significant conclusions.

In patients undergoing PD with PJ, the type of reconstruction—does not affect the risk of POPF. However, the significant reduction in the risk of DGE associated with double-loop reconstruction is linked to lower overall morbidity and potentially shorter hospital stays. Therefore, it would be reasonable to choose a double-loop reconstruction after open PD for malignant disease whenever possible, based on the surgeon's experience and preference.

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CONFLICT OF INTEREST

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ORCID

Giovanni Domenico Tebala,
https://orcid.org/0000-0001-7152-4096
Fanny Massimi, https://orcid.org/0009-0003-3560-7064
Francesca Duro, https://orcid.org/0009-0003-7535-142X
Ahmed Abdelsamad, https://orcid.org/0000-0002-6257-2077
Stefano Avenia, https://orcid.org/0000-0002-5818-6405
Gian Luca Baiocchi, https://orcid.org/0000-0003-2402-2178
Andrea Barberis, https://orcid.org/0000-0003-0472-0120
Chafik Bouzid, https://orcid.org/0000-0003-1467-8050
Antoine Castel, https://orcid.org/0009-0003-9810-8887
Graziano Ceccarelli, https://orcid.org/0000-0002-7859-6815
Andrea Celotti, https://orcid.org/0000-0003-2246-0684
Nicola Cillara, https://orcid.org/0000-0001-6877-2267

Nicola Cinardi, https://orcid.org/0009-0006-0856-9658
Roberto Cirocchi, https://orcid.org/0000-0002-2457-0636
Maria Conticchio, https://orcid.org/0000-0003-3177-5274
Giuseppe Currò, https://orcid.org/0000-0001-9566-1378
Antonella Delvecchio, https://orcid.org/0000-0002-7759-4340
Raffaele Vincenzo De Rosa, https://orcid.org/0000-0002-9430-5002
Jacopo Desiderio, https://orcid.org/0000-0003-2883-4560
Antonio Di Cintio, https://orcid.org/0000-0002-4660-9327
Fabio Di Mola, https://orcid.org/0000-0001-9877-2946
Domenico Di Nardo, https://orcid.org/0000-0003-2848-402X
Alessia Fassari, https://orcid.org/0000-0001-8534-9823
Alessandro Gemini, https://orcid.org/0000-0001-6691-0881
Carlos Augusto Gomes, https://orcid.org/0000-0001-7774-0056
Gian Luca Grazi, https://orcid.org/0000-0002-3279-0313
Giuseppe Margani, https://orcid.org/0000-0002-1446-2631
Alessandro Mazzotta, https://orcid.org/0000-0001-7363-2592
Luca Morelli, https://orcid.org/0000-0002-7742-9556
Andrea Muratore, https://orcid.org/0000-0002-8049-6549
Fabrice Muscari, https://orcid.org/0000-0001-6754-1686
Edoardo Maria Muttillo, https://orcid.org/0000-0003-3562-0392
Alberto Patriti, https://orcid.org/0000-0003-2414-268X
Gaetano Piccolo, https://orcid.org/0000-0002-4942-7705
Luca Properzi, https://orcid.org/0009-0002-5309-2386
Alessandro Puzziello, https://orcid.org/0000-0002-1970-7386
Lucia Romano, https://orcid.org/0000-0003-0996-4490
Edoardo Rosso, https://orcid.org/0000-0001-6948-155X
Sara Saeidi, https://orcid.org/0000-0001-6215-6818
Andrea Sagnotta, https://orcid.org/0000-0002-0606-0317
Edoardo Saladino, https://orcid.org/0000-0003-0521-959X
Marcello Spampinato, https://orcid.org/0000-0003-4036-6819
Laurent Sulpice, https://orcid.org/0000-0002-8817-1685
Nádia Tenreiro, https://orcid.org/0000-0002-6869-0795
Paolo Ubiali, https://orcid.org/0000-0002-9277-442X
Riccardo Memeo, https://orcid.org/0000-0001-6623-668X

AUTHOR CONTRIBUTIONS

Conceptualization: GDT, FD, Graziano Ceccarelli, RM. Data curation: Fanny Massimi, FD, AA, SA, GLB, AB, CB, Antoine Castel, Andrea Celotti, Nicola Cillara, Nicola Cinardi, MC, Giuseppe Currò, AD, RDR, JD, ADC, FDM, AF, CAG, GLG, GM, Alessandro Mazzotta, LM, Andrea Muratore, Fabrice Muscari, EMM, AP, GP, LP, AP, LR, ER, SS, AS, ED, MGS, LS, NT, PU. Methodology: GDT, FD, RC, RM. Visualization: GDT, Fanny Massimi, FD. Writing - original draft: GDT, Fanny Massimi, FD. Writing - review & editing: all authors.

REFERENCES

1. Schnelldorfer T, Sarr MG. Alessandro Codivilla and the first pancreatoduodenectomy. Arch Surg 2009;144:1179-1184.
2. Whipple AO, Parsons WB, Mullins CR. Treatment of carcinoma of the ampulla of Vater. Ann Surg 1935;102:763-779.
3. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, et al.; International Study Group on Pancreatic Surgery (ISGPS). The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery 2017;161:584-591.
4. Klaiber U, Probst P, Knebel P, Contin P, Diener MK, Büchler MW, et al. Meta-analysis of complication rates for single-loop versus dual-loop (Roux-en-Y) with isolated pancreaticojejunostomy reconstruction after pancreaticoduodenectomy. Br J Surg 2015;102:331-340.
5. Deng LH, Xiong JJ, Xia Q. Isolated Roux-en-Y pancreaticojejunostomy versus conventional pancreaticojejunostomy after pancreaticoduodenectomy: a systematic review and meta-analysis. J Evid Based Med 2017;10:37-45.
6. Mobarak S, Tarazi M, Davé MS, Varley RJ, Stott MC, Baltatzis M, et al. Roux-en-Y versus single loop reconstruction in pancreaticoduodenectomy: a systematic review and meta-analysis. Int J Surg 2021;88:105923.
7. Ma F, Fan Y, Zhang L, Zhao Z, Nie Y, Chen M, et al. Roux-en-Y and Billroth II reconstruction after pancreaticoduodenectomy: a meta-analysis of complications. Biomed Res Int 2020;2020:6131968.
8. Schorn S, Demir IE, Vogel T, Schirren R, Reim D, Wilhelm D, et al. Mortality and postoperative complications after different types of surgical reconstruction following pancreaticoduodenectomy-a systematic review with meta-analysis. Langenbecks Arch Surg 2019;404:141-157.
9. Teng Y, Wang Y, Yang S, Nie G, Wen N, Zhang Y, et al. Surgery-related factors for pancreatic fistula after pancreatectomy: an umbrella review. Hepatobiliary Surg Nutr 2025;14:442-459.
10. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205-213.
11. Funovics JM, Zöch G, Wenzl E, Schulz F. Progress in reconstruction after resection of the head of the pancreas. Surg Gynecol Obstet 1987;164:545-548.
12. Del Chiaro M, Rangelova E, Segersvärd R, Arnelo U. Are there still indications for total pancreatectomy? Updates Surg 2016;68:257-263.
13. Aghalarov I, Herzog T, Uhl W, Belyaev O. A modified single-loop reconstruction after pancreaticoduodenectomy reduces severity of postoperative pancreatic fistula in high-risk patients. HPB (Oxford) 2018;20:676-683.
14. Yücesoy AN. A modified single jejunal loop reconstruction by performing proximal gastrojejunostomy after Whipple's pancreticoduodenectomy in a low-volume hospital. Ann Hepatobiliary Pancreat Surg 2019;23:65-68.
15. Machado MC, da Cunha JE, Bacchella T, Bove P. A modified technique for the reconstruction of the alimentary tract after pancreatoduodenectomy. Surg Gynecol Obstet 1976;143:271-272.

16. Jester AL, Chung CW, Becerra DC, Molly Kilbane E, House MG, Zyromski NJ, et al. The impact of hepaticojejunostomy leaks after pancreatoduodenectomy: a devastating source of morbidity and mortality. J Gastrointest Surg 2017;21:1017-1024.
17. Pescio G, Cariati E. A new reconstructive method after pancreaticoduodenectomy: the triple Roux on a "P" loop. Rationale and radionuclide scanning evaluation. HPB Surg 1996;9:223-227.
18. Grobmyer SR, Hollenbeck ST, Jaques DP, Jarnagin WR, DeMatteo R, Coit DG, et al. Roux-en-Y reconstruction after pancreaticoduodenectomy. Arch Surg 2008;143:1184-1188.
19. Morandi E, Corbellini C, Castoldi M, de Vuono A, Pisoni L, Vignati G. Comparison between two different reconstruction techniques after pancreatic head resection. Technical feasibility and clinical benefits. Minerva Surg 2021;76:90-96.
20. Clemente G, De Rose AM, Panettieri E, Ardito F, Murazio M, Nuzzo G, et al. Pancreatico-jejunostomy on isolated loop after pancreatico-duodenectomy: is it worthwhile? J Gastrointest Surg 2022;26:1205-1212.
21. Dai S, Peng Y, Wang G, Yin L, Yan H, Xi C, et al. Risk factors of delayed gastric emptying in patients after pancreaticoduodenectomy: a comprehensive systematic review and meta-analysis. Int J Surg 2023;109:2096-2119.
22. Li TY, Qin C, Zhao BB, Yang XY, Li ZR, Wang YY, et al. Risk stratification of clinically relevant delayed gastric emptying after pancreaticoduodenectomy. BMC Surg 2023;23:222.
23. Zhou Y, Hu B, Wei K, Si X. Braun anastomosis lowers the incidence of delayed gastric emptying following pancreaticoduodenectomy: a meta-analysis. BMC Gastroenterol 2018;18:176.
24. Xiao Y, Hao X, Yang Q, Li M, Wen J, Jiang C. Effect of Billroth-II versus Roux-en-Y reconstruction for gastrojejunostomy after pancreaticoduodenectomy on delayed gastric emptying: a meta-analysis of randomized controlled trials. J Hepatobiliary Pancreat Sci 2021;28:397-408.

Appendix 1. DoS-RAP Collaborative

Francesca D'Agostino, Antonello Deserra, Cristina Murru, Renata Pau (Cagliari, Italy); Giulia Impellizzeri, Riccardo Schillaci, Angelo Zappalà (Catania, Italy); Michele Ammendola (Catanzaro, Italy); Pierluigi Di Sebastiano (Pescara-Chieti, Italy); Martina Bonafede (Cremona, Italy); Federico Costanzo, Lorenzo Epis, Marco Filauro, Lisa Rossi (Genova, Italy); Felipe C. Gomes (Juiz de Fora, Brazil); Stefano D'Ugo, Norma De Palma Anna R. Libia, Tiziana Marchese (Lecce, Italy); Vito De Blasi, Tobias Schick (Le Mans, France); Soheil Ahmadyar, Mohsen Aliakbarian, Ali Esparham (Mashhad, Iran); Elisa Bertilone, Giuseppe Cuticone (Messina, Italy); Filippo Petrelli (Pesaro, Italy); Marcello Calabrò, Sofia L. Gamba, Giulia Marchiori (Pinerolo, Italy); Annalisa Comandatore, Gregorio Di Franco, Niccolò Furbetta, Simone Guadagni (Pisa, Italy); Silvia Lazzaro, Federica Maffeis, Jacqueline Velkoski (Pordenone, Italy); Paolo Amoretti, Gennaro Cascone, Elio Donnarumma, Andrea Loffredo (Salerno, Italy), Rabah Bouzouagh (Tizi Ouzou, Algeria); Yuri Macchitella, Roberto Merenda, Alfredo Piangerelli (Venezia, Italy); Tiago Castro, Margarida Dupont, Andrea Marcal, Daniela Martins (Vila Real, Portugal).