Early outcome of different techniques for pancreatic anastomosis in pancreaticoduodenectomy

Hazem Zakaria, Hossam Soliman, Wael Abd-Elkawy, Amr Sadek, Esam Salah Eldeen

Department of Hepatopancreatobiliary and Liver Transplant, National Liver Institute (NLI), Menoufia University, Menoufia, Egypt

Correspondence to Wael Abd-Elkawy, MD, Department of Hepatopancreatobiliary and Liver Transplant, National Liver Institute (NLI), Menoufia 32951, Egypt
Tel: +01063205254;
e-mail: waelsameir@gmail.com

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Background
The ideal technical pancreatic reconstruction following pancreaticoduodenectomy (PD) is still debated, and postoperative pancreatic fistula (POPF) is one of the most common complications after PD. The aim of the study was to assess the surgical outcomes of four techniques of pancreatic anastomosis: duct-to-mucosa pancreaticojejunostomy (DMPJ), invagination (binding) pancreaticojejunostomy (IPJ), duct-to-mucosa pancreaticogastrostomy (DMPG), and invagination pancreaticogastrostomy (IPG).
Patients and methods
Consecutive patients treated by PD at our center were randomized into either group. The primary outcome measure was the rate of POPF, delay gastric emptying (DGE), and postpancreatictomy hemorrhage (PPH), and secondary outcomes included operative time, postoperative morbidity, and mortality using the Clavien–Dindo score.
Results
A total of 120 patients treated with PD were randomized. POPF developed in 9/42 patients in DMPJ, 4/27 patients in IPJ, 8/26 patients in DMPG, and 6/25 patients in IPG (P=0.428). Delayed gastric emptying developed in 14/42 patients in DMPJ, 7/27 patients in IPJ, 9/26 patients in DMPG, and 6/25 patients in IPG (P=0.065). Postpancreatictomy hemorrhage developed in 3/42 patients in DMPJ, 2/27 patients in IPJ, 3/26 patients in DMPG, and 3/25 patients in IPG (P=0.670). The median operative time was significantly shorter in IPG (370±78.6) and DMPG (420.9±69.16 min) than IPJ (422.4±90.8) and DMPJ (458.5±84.3) (P=0.003). There was no statistically significant difference regarding the Clavien–Dindo score.
Conclusion
There are many pancreatoenteric anastomosis techniques either in the jejunum or stomach and it should depend on the surgeon's experience, the size of the pancreatic duct, and the texture of the pancreas. IPG and IPJ are easier to perform than DMPG and DMPJ, especially in the small pancreatic duct.

Keywords:
pancreatic anastomosis, pancreatic fistula, pancreaticoduodenectomy

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Introduction

Despite the increased indications and the reduction in mortality, morbidity after pancreaticoduodenectomy (PD) can approach 50% [1]. The morbidity and mortality after PD are usually related to the surgical management of the pancreatic stump. The postoperative pancreatic fistula (POPF) is the most important complication, the incidence of which ranges from 2.5 to 25% [2,3]. Several methods and techniques of pancreatoenteric anastomosis (PEA) have been proposed to reduce the rate of POPF including either pancreaticojejunostomy (PJ) or pancreaticogastrostomy (PG), and several modifications of techniques have been developed, including the site of jejunum used (end vs. side), type of anastomosis (invagination vs. duct-to-mucosa), use of an isolated Roux-en-Y limb, and use of fibrin glue and pancreatic duct stenting, but the best technique is still a subject of debate [4–7]. Duct to mucosa and invagination are the two classic techniques in both the PJ and PG types. Many studies have compared these techniques, but still, no consensus exists regarding their surgical outcomes [8–10].

The aim of the study was to assess the effectiveness and the surgical outcomes of the main four techniques of PEA after PD, which were performed by established fixed surgeons for each method.

Patients and methods

Patients

Consecutive patients who were treated by PD at the Surgery department of National Liver Institute,

Menoufia, Egypt, during the period from the first of May 2016 to the end of June 2021, were eligible for the study. The exclusion criteria included any patients with locally advanced periampullary tumor, metastases, and patients of extreme age above 80 years. Informed consent was obtained from all patients to be included in this study, after a careful explanation of the disease and the possible treatment options with its complications. The study was approved by the local ethical committee. All patients were subjected to careful history taking, clinical examination, routine laboratory investigation, and tumor markers such as CEA and CA19-9, an abdominal ultrasound, magnetic resonance cholangiopancreatography, and an abdominal computed tomography.

Randomization

All procedures were performed by the same team of experienced surgeons in National Liver Institute for each type using the same technique, same approach, and same anastomotic fashion to avoid technical bias. The patients included in the study were randomized into one of the four techniques according to the surgeon's groups.

Operative techniques

There was no perioperative infusion of somatostatin analogs or use of adhesive sealants. All patients had two closed drains placed at the time of operation near the pancreatic anastomosis.

Duct-to-mucosa pancreaticojejunostomy group

The duct-to-mucosa pancreaticojejunostomy (DMPJ) was performed by the two-layer end-to-side PJ. The pancreatic capsule and the jejunal serosa were anastomosed by interrupted prolene suture 3/0 to form the outer layer in both the anterior and posterior walls of the anastomosis. Jejunostomy was done matched to the main pancreatic duct (MPD) diameter. The inner layer duct to mucosa was performed in eight to twelve stitches with 5/0 PDS. A pancreatic duct stent was inserted during the anastomosis to allow an easy and accurate suture placement, ensure an adequate pancreatic duct exposure, and protect the opposite wall from being inadvertently held by needles.

Invagination (binding) pancreaticojejunostomy group

The invagination pancreaticojejunostomy (IPJ) was performed as an end-to-end (binding) procedure as proposed by Peng *et al.* [11,12]. The jejunal wall was pressed to the intussuscepted pancreatic stump by sutures placed similarly to a ligature. First, the 3 cm of the pancreatic stump was isolated from the surrounding tissues, the corresponding 3 cm of the intestinal wall was everted by a few stitches and the mucosa of this part was cauterized. Then, the pancreatic stump was attached to the jejunum by sutures placed on the edge of the everted mucosa. The jejunum was carefully compressed by a ligature placed around the intestine, 1.5–2 cm from the proximal end of the intussuscepted pancreatic stump.

Duct-to-mucosa pancreaticogastrostomy group

The duct-to-mucosa pancreaticogastrostomy (DMPG) was performed by the two-layer end-to-side PG. A polyethylene 5-cm feeding tube, 5.0- or 7.5-Fr was introduced into the MPD to ensure its patency. Then, a stab 5-mm transverse full-thickness incision was made in the posterior wall of the stomach opposite to the MPD end. Next, anastomosis between the MPD and the gastric mucosa was done using 4/0 prolene sutures at the four quarters. Four 3/0 prolene sutures were secured between the capsule of the pancreas about 2 cm away from the edge line and about 1 cm deep in the pancreatic tissue and the corresponding area of the seromuscular layer of the posterior wall of the stomach.

Invagination pancreaticogastrostomy group

The pancreatic remnant was mobilized to provide a 3–5-cm stump for burying into the stomach without tension. Then, single interrupted monofilament 4/0 sutures were placed through the anterior part of the pancreatic capsule (parallel to the axis of the pancreas, 1 cm from the cut edge) and through the seromuscular layer of the stomach. A transverse full-thickness incision was created in the posterior gastric wall proximal to the antrum, with a length of at most 2/3rd the diameter of the pancreatic stump, to ensure tight adherence of the gastric wall to the pancreatic remnant. The posterior stomach wall was pushed over the pancreatic remnant. Then multiple mattress sutures were taken with prolene 2/0 on the posterior wall around the pancreatic stump.

Data collected

Preoperative data included patients' age, sex, weight, symptoms, and signs; ASA physical status; comorbidities; laboratory tests; tumor markers; and preoperative biliary drainage. Intraoperative data included tumor size, MPD diameter, the texture of the pancreas, operative time, blood loss, and blood transfusion. Postoperative data included postoperative complications [POPF, DGE, and PPH], postoperative stay, re-exploration, hospital mortality, postoperative pathology, surgical safety margins, and postoperative interventions.

Assessments

POPF was defined by the International Study Group of Pancreatic Fistula (ISGPF) as any measurable volume of fluid on or after postoperative day (POD) 3 with amylase content greater than three times the serum amylase activity [13]. According to the new grading by the International Study Group on Pancreatic Surgery (ISGPS) [14,15], the outcomes were divided into 'biochemical leak', 'B' and 'C' grades. The formerly 'grade A' biochemical leak was no longer considered a

true pancreatic fistula or an actual complication, so was called a 'biochemical fistula,' without a clinical effect or deviation in the normal postoperative pathway or postoperative stay. DGE was defined by ISGPS as the inability to tolerate a solid diet on POD 7, prolonged nasogastric intubation until third POD, or the need for reinsertion of a nasogastric tube for persistent vomiting by POD 3. The outcomes were divided into grades 'A,', 'B,' and 'C' [16]. PPH was defined by ISGPS by three parameters, including onset, location, and severity. The onset is either early (< or=24 h after the end of the operation) or late (>24 h), the location is either intraluminal or extraluminal, and the severity of bleeding may be either mild or severe. The outcomes were divided into grades 'A,' 'B,' and 'C' [17]. The secondary outcomes were operative time, postoperative hospital stay, and postoperative morbidities (pancreatitis and biliary leakage). Complications were graded according to their severity on a validated five-point scale using the Clavien–Dindo complication classification system (grades I, II, IIIa–b, Iva–b, and V) [18].

Follow up

Follow-up was carried out at 1 week, 3 months, 6 months, and then after 1 year postoperatively. Statistical analysis was done using IBM SPSS statistics for windows, Version 23.0 (Armonk, NY: IBM Corp.). Descriptive statistics were calculated and described as median (range) for continuous variables. Categorical variables were represented using percentages. The Student *t* test for paired samples was used to detect differences in the means of continuous variables, and the χ^2 test was used for categorical variables. *P* values less than 0.05 were significant.

Results

Preoperative data

A total of 120 patients who underwent PD were eligible and included in the study. Of them, 75 (62.5%) were men and 45 (37.5%) were women. The median age was 55.5 years. The preoperative data of groups are presented in Table 1.

Intraoperative data

The intraoperative data were comparable in both groups regarding tumor size, MPD diameter, the texture of the pancreas, the median intraoperative blood loss, and blood transfusion (Table 2). The mean total operative time was 458.5 min in the DMPJ group, 422.4 min in the IPJ group, 420.96 min in the DMPG group, and 370 min in the invagination pancreaticogastrostomy (IPG) group (*P*=0.003). However, the mean operative time for the pancreatic anastomosis was 44.62 min in the DMPJ group, 40.74 min in the IPJ group, 43.85 min in the DMPG group, and 42.2 min in the IPG group (*P*=0.437).

Postoperative data

There were no significant differences among the four groups regarding the postoperative data (Table 3). POPF developed in nine (21.4%) patients in the DMPJ group, four (14.8%) patients in the IPJ group, eight (30.7%) patients in the DMPG group, and six (24%) patients in the IPG group (*P*=0.428). Ultrasound-guided tubal drainage for the intra-abdominal collection was required in three (7.1%) patients in the DMPJ group, no patient in the IPJ group, four (15.4%) patients in the DMPG group, and four (16%) patients in the IPG group (*P*=0.139).

Histopathological data

Regarding histopathological examination, there was no statistical difference among the four groups (Table 4).

Mortality

The hospital mortality in this study was four (3.33%) patients, with one patient in each group (*P*=0.139). The causes of death were sepsis and multiorgan failure after re-exploration for pancreatic leakage and lavage in two (1.67%) patients, cerebral stroke in one (0.83%) patient, and sudden cardiac arrest in one (0.83%) patient.

Risk factors for POPF

In univariate analysis of the potential risk factors (preoperative, intraoperative, and postoperative) for POPF were diameter of MPD (*P*-value 0.047), texture of the pancreas (*P*-value 0.030), operative time (*P*-value 0.017), and the blood loss (*P*-value 0.046). While in multivariate analysis there was no independent risk factors for POPF.

Discussion

The safe pancreatic anastomosis after PD continues to be a stump for the pancreatic surgeon even at high-volume centers. Although PJ is the most common method for PEA, several techniques and modifications of pancreatic anastomoses have been proposed [8–10]. Despite the lowering of the mortality rate to 5%, postoperative complications are still high up to 50% [1]. POPF remains the most important cause of morbidity and contributes significantly to a prolonged hospital stay, increased costs, and mortality [2,3]. Intra-abdominal abscess, bleeding, and sepsis are common sequelae of POPF, which have been associated with a high mortality rate. Many studies have demonstrated that many factors are significantly associated with POPF, including obesity, cirrhotic liver, soft pancreas, small MPD diameter, location of the pancreatic duct within 3-mm distance from the posterior edge, the technique, and type of pancreatic reconstruction [19–24].

Ideally, the pancreatic reconstruction should decrease not only the risk of POPF but also its severity if occurred

Table 1 The preoperative data of the groups

	DMPJ (*N*=42) [*n* (%)]	IPJ (*N*=27) [*n* (%)]	DMPG (*N*=26) [*n* (%)]	IPG (*N*=25) [*n* (%)]	*P* value
Age (years)					
Mean±SD	56.10±10.08	56.85±10.42	56.31±10.45	56.64±8.47	0.990
Range	38–73	28–35	42–74	75–73	
Sex					
Male	26 (61.9)	19 (70.4)	16 (61.5)	14 (56)	0.758
Female	16 (38.1)	8 (29.6)	10 (38.5)	11 (44)	
Weight (kg)					
Mean±SD	77.02±9.74	73.07±11.64	73.19±12.69	81.52±7.61	0.13
Range	55–90	50–90	49–95	65–95	
ASA physical status					
ASA I	11 (26.2)	7 (25.9)	5 (19.2)	3 (12)	0.647
ASA II	27 (64.3)	19 (70.4)	20 (76.9)	21 (84)	
ASA III	4 (9.5)	1 (3.7)	1 (3.8)	1 (4)	
Loss of weight	24 (57.1)	15 (55.6)	18 (69.2)	17 (68)	0.605
Jaundice	34 (81)	17 (63)	19 (73.1)	23 (92)	0.076
DM	20 (47.6)	9 (33.3)	14 (53.8)	12 (48)	0.480
HTN	16 (38.1)	9 (33.3)	14 (53.8)	9 (36)	0.422
Cardio-vascular disease	8 (19)	4 (14.8)	5 (19.2)	3 (12)	0.861
Smoking	11 (26.2)	6 (22.2)	7 (26.9)	6 (24)	0.976
Pulmonary disease	3 (7.1)	0	1 (3.8)	0	0.295
HCV	7 (16.7)	4 (14.8)	5 (19.2)	5 (20)	0.957
Total bilirubin (mg/dl)					
Median	7.9	4.1	8.2	8	0.218
Range	0.2–29	0.37–26	0.2–30	1.8–22	
Direct bilirubin (mg/dl)					
Median	3.1	2.1	5.8	3.5	0.167
Range	0.1–20	0.17–20	0.1–9.3	0.8–-12	
Albumin (g/dl)					
Mean±SD	3.56±0.53	3.6±0.61	3.45±0.33	3.38±0.34	0.429
Range	2.2–4.5	2.3–4.8	3.1–4.5	2.7–3.9	
AFP (ng/ml)					
Median	5	2.7	6.6	12.2	0.383
Range	0.3–126	1.13–67	1–126	0.3–34	
CA19.9 (U/ml)					
Median	242.5	327.5	551	230	0.133
Range	0.6–3965	20.7–12	1–3013	12.4–5564	
CEA (ng/ml)					
Median	3.2	2.24	3.01	3.71	0.373
Range	2 -21.8	0.5–9.79	2.2–3.82	3.71–3.71	
Tumor size (cm)					
Median	4.5	3.8	4.1	2.7	0.687
Range	1–6.8	1.8–5.7	0.7–6.2	1.5–7.5	
Preoperative drainage					
PTD	6 (14.3)	2 (7.4)	2 (7.7)	2 (8)	0.488
Stent	10 (23.8)	10 (37)	8 (30.8)	5 (20)	

DMPG, duct-to-mucosa pancreaticogastrostomy; DMPJ, duct-to-mucosa pancreaticojejunostomy; IPG, invagination pancreaticogastrostomy; IPJ, invagination (binding) pancreaticojejunostomy.

and maintain pancreatic function. PJ and PG are the commonly preferred method of reconstruction after PD. To prevent POPF after PD, there have been many technical modifications for pancreatic reconstruction.

Some studies showed that the PJ anastomoses were associated with a lower rate of POPF and severity with a decrease in postoperative hospital stay than PG anastomoses [4,25,26], whereas other studies showed the opposed issue [27–29], but actually some studies showed that were no statistical differences between PJ and PG [30–34]. In our study, there was no significant difference regarding POPF between both techniques.

Regarding the comparison between the duct-to-mucosa technique and the invagination technique, some studies showed that the duct-to-mucosa techniques were associated with a lower rate of POPF in the low-risk

Table 2 The intraoperative data of the groups

	DMPJ (*N*=42) [*n* (%)]	IPJ (*N*=27) [*n* (%)]	DMPG (*N*=26) [*n* (%)]	IPG (*N*=25) [*n* (%)]	*P* value
Method of reconstruction					
PD	8 (19)	8 (29.6)	5 (19.2)	6 (24)	0.737
PPPD	34 (81)	19 (70.4)	21 (80.8)	19 (76)	
Diameter of MPD (mm)					
3	12 (28.6)	9 (33.3)	6 (23.1)	7 (28)	0.876
>3	30 (71.4)	18 (66.7)	20 (76.9)	18 (72)	
Texture of pancreas					
Hard	26 (61.9)	14 (51.9)	18 (69.2)	12 (48)	0.383
Soft	16 (38.1)	13 (48.1)	8 (30.8)	13 (52)	
Anastomosis time (min)					
Mean±SD	44.62±9.3	40.74±7.6	43.85±11.9	42.2±11.8	0.437
Range	30–60	30–65	30–70	25–60	
Operative time (min)					
Mean±SD	458.5±84.3	422.4±90.8	420.96±69.1	370±78.6	0.003*
Range	330–720	270–615	245–565	240–540	
Blood loss (ml)					
Mean±SD	726.2±407.3	555.6±237.5	592.3±281.3	740±423.3	0.116
Range	200–2000	200–1000	200–1300	200–1700	
Blood transfusion (unit)					
No	8 (19)	12 (44.4)	7 (26.9)	4 (16)	0.067
Yes	34 (81)	15 (55.6)	19 (73.1)	21 (84)	

DMPG, duct-to-mucosa pancreaticogastrostomy; DMPJ, duct-to-mucosa pancreaticojejunostomy; IPG, invagination pancreaticogastrostomy; IPJ, invagination (binding) pancreaticojejunostomy; MPD, main pancreatic duct; PD, pancreaticoduodenectomy.

patients with dilated pancreatic duct or firm pancreas, whereas invagination techniques were safer in the high-risk patients with small pancreatic duct or soft pancreas [6,7,9,24]. Several studies reported a lower POPF in the duct-to-mucosa group than in the invagination group [28]. However, the advantage was not found in patients with soft pancreatic stumps [35,36]. Meta-analysis studies showed that the rate of POPF was not statistically different between the duct-to-mucosa group and the Invagination group [30,33,37]. In our study, no significant difference regarding POPF was found between both techniques.

In our study, the severity of POPF was noticed more in DMPJ with no significant differences. No pancreatic reconstruction technique after PD was found to be applicable to all types of pancreatic stumps. Tailored pancreatic reconstruction is the best way to overcome the complications related to the type of reconstruction, especially with small MPD and a soft fragile pancreas [38,39]. In our study, the univariate analysis of the potential risk factors for POPF were diameter of MPD (*P*-value 0.047), texture of the pancreas (*P*-value 0.030), operative time (*P*-value 0.017), and the blood loss (*P*-value 0.046). The same results presented by many studies where the soft friable pancreatic tissue can be problematic for invagination as the parenchymal laceration and ischemia of the stump can occur because of extensive sutures and compression which lead to POPF. The small MPD makes duct-to-mucosa difficult and liable to inaccurate suture placement and obstruction. In duct-to-mucosa, the mucosal folds and edema formed around the opening of the MPD make it liable to the obstruction and development of pancreatitis and anastomotic stenosis. However, a potential space between the jejunal serosa and pancreatic stump may cause the accumulation of pancreatic juice because of the accessory pancreatic duct [40].

In our study, the DGE was reported in 36 (30%) patients; 14/42 patients in DMPJ, 7/27 patients in IPJ, 9/26 patients in DMPG, and 6/25 patients in IPG (*P* value 0.065). The incidence of DGE was reported to in other studies widely range from 11 to 57%, and the overall postoperative DGE rate in most randomized control trials was 17.4%, with no significant differences between the different techniques [33]. Although the ISGPS criteria were strict regarding the definition and grading of DGE, they did not address the etiology. DGE is strongly linked to the occurrence of other postoperative complications, especially POPF. However, in some cases, DGE occurs in the absence of any associated complications 'primary DGE,' and the exact etiology and pathogenesis of it have been a field of controversy and hypotheses. Several hypotheses have been postulated in a trial to understand the pathogenesis of primary DGE in such cases. These include antroduodenal ischemia, low plasma motilin levels, peripancreatic inflammation, twist in the gastrojejunostomy, aggressive lymphadenectomy, and pancreatic fibrosis [41].

Table 3 The postoperative data of the groups

	DMPJ (*N*=42) [*n* (%)]	IPJ (*N*=27) [*n* (%)]	DMPG (*N*=26) [*n* (%)]	IPG (*N*=25) [*n* (%)]	*P* value
POPF					
Grade B	7 (16.7)	3 (11.1)	6 (23.1)	5 (20)	0.428
Grade C	2 (4.8)	1 (3.7)	2 (7.7)	1 (4)	
Total	9 (21.4)	4 (14.8)	8 (30.7)	6 (24)	
DGE					
Grade A	6 (14.3)	4 (14.8)	5 (19.2)	5 (20)	0.065
Grade B	6 (14.3)	3 (11.1)	3 (11.5)	1 (4)	
Grade C	2 (4.8)	0	1 (3.8)	0	
Total	14 (33.3)	7 (25.9)	9 (34.6)	6 (16)	
PPH					
Grade A	2 (4.8)	1 (3.7)	1 (3.8)	1 (4)	0.670
Grade B	0	0	0	0	
Grade C	1 (2.4)	1(3.7)	2 (7.7)	2 (8)	
Total	3 (7.1)	2 (7.4)	3 (11.5)	3 (12)	
Bile leak	0	0		0	–
GIT leak	1 (2.4)	0	2 (7.7)	0	0.240
Wound infection	6 (14.3)	3 (11.1)	2 (7.7)	5 (20)	0.609
Pulmonary	10 (23.8)	3 (11.1)	1 (3.8)	3 (12)	0.122
Reoperation	2 (4.8)	1 (3.7)	4 (15.4)	2 (8)	0.052
Clavien–Dindo score					
0	13 (31)	14 (51.9)	9 (36)	9 (36)	0.139
I	14 (33.3)	3 (11.1)	7 (26.9)	3 (12)	
II	10 (23.8)	8 (29.6)	2 (7.7)	7 (28)	
IIIa	3 (7.1)	0	4 (15.4)	4 (16)	
IIIb	1 (2.4)	1 (3.7)	3 (11.5)	0	
IVa	0	0	0	1 (4)	
IVb	0	0	0	0	
V	1 (2.4)	1 (3.7)	1 (3.8)	1 (4)	
ICU stays (days)					
Median	1	1	1	1	0.057
Range	1–12	1–5	1–7	1–8	
Hospital stays (days)					
Mean±SD	13.24±6.15	10.30±2.81	14.69±7.12	12.68±6.67	0.058
Range	7–35	8–18	7–30	7–34	
Survival					
Dead	16 (38.1)	7 (25.9)	14 (53.8)	9 (36)	0.216
Alive	26 (61.9)	20 (74.1)	12 (46.2)	16 (64)	

DGE, delayed gastric emptying; DMPG, duct-to-mucosa pancreaticogastrostomy; DMPJ, duct-to-mucosa pancreaticojejunostomy; IPG, invagination pancreaticogastrostomy; IPJ, invagination (binding) pancreaticojejunostomy; POPF, postoperative pancreatic fistula; PPH, postpancreatictomy hemorrhage.

In our study, the PPH was reported in 11 (9.17%) patients; 3/42 patients in DMPJ, 2/27 patients in IPJ, 3/26 patients in DMPG, and 3/25 patients in IPG (*P*-value 0.670). The PPH was categorized according to time, severity, and site of bleeding. Extraluminal PPH was significantly associated with POPF, such as erosion bleeding from the visceral arteries, which was successfully managed by laparotomy or angiography with interventional radiology (coil embolization, and stenting) in most cases, to avoid technically difficult reoperation, damage to sensitive anastomotic regions, and systemic inflammatory response resulting from operative trauma. Intraluminal PPH was associated with PG, which was usually treated by upper gastrointestinal endoscopy with failure rate during the first 10 postoperative days because stomach and bowel distension from gas insufflation can potentially damage PEA and bilioenteric anastomoses. In our study, the Grade C, was more frequent in the PG group and all cases treated with non-operative procedures [42].

In our study, we reported significant difference in the overall operative time with no difference in the anastomotic time , the median operative time was significantly shorter in IPG (370 ± 78.6) and DMPG (420.96 min ± 69.1) than IPJ (422.4 ± 90.8) and DMPJ (458.5 ± 84.3) (*P*-value 0.003). This was explained by differences between the surgeons' experiences in each group. There was also evidence of a learning effect over time with increasing numbers of pancreatic resections over time. The surgeon's experience and surgical volume were important factors in yielding the best outcomes [43,44].

Table 4 The histopathological data of the groups

	DMPJ (*N*=42) [*n* (%)]	IPJ (*N*=27) [*n* (%)]	DMPG (*N*=26) [*n* (%)]	IPG (*N*=25) [*n* (%)]	*P* value
Histopathological examination					
Adenocarcinoma	40 (95.2)	24 (88.9)	25 (96.2)	23 (92)	0.681
Chronic pancreatitis	1 (2.4)	1 (3.7)	0	0	0.642
Cystadeno-carcinoma	0	1 (3.7)	0	0	0.324
Mucinous cystic neoplasm	0	1 (3.7)	0	0	0.324
Retention cyst	1 (2.4)	0	0	0	0.599
GIST	0	0	0	1 (4)	0.280
Lymphoma	0	0	1 (3.8)	0	0.302
Neuroendocrine carcinoma	0	0	0	1 (4)	0.280
Origin of the tumor					
Pancreatic	28 (66.7)	20 (74.1)	17 (65.4)	16 (64)	0.864
Ampullary	11 (26.2)	7 (25.9)	8 (30.8)	5 (20)	0.840
Duodenal	2 (4.8)	0	0	3 (12)	0.107
CBD	1 (2.4)	0	1 (3.8)	1 (4)	0.773
Differentiation of malignant tumors					
Well	12 (28.6)	4 (14.8)	7 (26.9)	3 (12)	0.503
Moderate	20 (47.6)	15 (55.6)	14 (53.8)	19 (76)	
Poor	7 (16.7)	6 (22.2)	5 (19.2)	3 (12)	
Type of the tumor					
Malignant	40 (95.2)	25 (92.6)	26 (100)	24 (96)	0.598
Benign	2 (4.8)	2 (7.4)	0	1 (4)	
Consistency of the tumor					
Solid	41 (97.6)	25 (92.6)	25 (96.2)	25 (100)	0.495
Cyst	1 (2.4)	2 (7.4)	1 (3.8)	0	
Lymph mode invasion	18 (42.8)	12 (44.4)	12 (46.1)	10 (40)	0.271
Vascular invasion	11 (26.2)	4 (14.8)	8 (30.8)	6 (24)	0.640
Perineural invasion	24 (57.1)	13 (48.1)	18 (69.2)	14 (56)	0.629
Margins					
R0	30 (71.4)	21 (77.8)	18 (69.2)	19 (76)	0.881
R1	12 (28.6)	6 (22.2)	8 (30.8)	6 (24)	
R2	0	0	0	0	
Size (cm)					
Mean±SD	3.25±1.33	3.5±1.32	3.25±1.58	3.5±1.57	0.836
Range	1.0–7.0	1.5–7.5	1.0–6.0	1.0–8.0	

DMPG, duct-to-mucosa pancreaticogastrostomy; DMPJ, duct-to-mucosa pancreaticojejunostomy; IPG, invagination pancreaticogastrostomy; IPJ, invagination (binding) pancreaticojejunostomy.

Conclusion

There are many PEA techniques either in the jejunum or stomach, and it should depend on surgeon's experience, the diameter of the MPD, and the texture of the pancreas. POPF was not statistically different among the four types of PEAs (DMPJ group, IPJ group, DMPG group, and IPG group). Grades B and C POPFs were noticed more in DMPJ, with no significant differences. As reconstruction by PG was associated with more intraluminal bleeding events, we recommend careful suture hemostasis and routine perioperative proton inhibitor therapy. IPG and IPJ are easier to perform than DMPG and DMPJ, especially in the small pancreatic duct. We revealed that no significant differences were found among the four groups according to the ISGPS definitions of the PD complications such as POPF, DGE, and PPH, which remain a particular concern for pancreatic surgeons even in high-volume centers.

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Conflicts of interest

There are no conflicts of interest.

References

1 Kleespies A, Albertsmeier M, Obeidat F, Seelier H, Jauch KWBC, Kleespies A, *et al*. The challenge of pancreatic anastomosis. Langenbeck's Arch Surg 2008; 393:459–471.

2 Cullen JJ, Sarr MG, Ilstrup DM. Pancreatic anastomotic leak after pancreaticoduodenectomy: incidence, significance, and management. Am J Surg 1994; 168:295–298.

3 Conzo G, Gambardella C, Tartaglia E, Sciascia V, Mauriello C, Napolitano S, *et al*. Pancreatic fistula following pancreatoduodenectomy. Evaluation of different surgical approaches in the management of pancreatic stump. Literature review. Int J Surg 2015; 21(S1):S4–S9.

4 Yeo CJ, Cameron JL, Maher MM, Sauter PK, Zahurak ML, Talamini MA, *et al*. A prospective randomized trial of pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy. Ann Surg 1995; 222:580–588.

5 Mocellin S, Briarava M, Yuan Y, Pilati P. Anastomosis to stomach versus anastomosis to jejunum for reconstructing the pancreatic stump after pancreaticodudenectomy. Cochrane Database Syst Rev 2020; 5:1–17.

6 Zhang X, Dong X, Liu P, Yan Y, Wei Y, Zechner D, *et al*. Binding versus conventional pancreaticojejunostomy in preventing postoperative pancreatic fistula : a systematic review and meta-analysis. Dig Surg. 2017; 34:265–280.

7 El Nakeeb A, El Hemaly M, Askr W, Abd Ellatif M, Hamed H, Elghawalby A, *et al*. Comparative study between duct to mucosa and invagination pancreaticojejunostomy after pancreaticoduodenectomy: a prospective randomized study. Int J Surg 2015; 16:1–6.

8 Kusnierz K, Mrowiec S, Lampe P. A comparison of two invagination techniques for pancreatojejunostomy after pancreatoduodenectomy. Gastroenterol Res Pract 2015; 2015:894292.

9 You S, Jian P, Wang W, Hong DF, Bin Y, Yi L, *et al*. Binding pancreaticoenteric anastomosis : from binding pancreaticojejunostomy to binding pancreaticogastrostomy. Updates Surg 2011; 63:69–74.

10 Peng SY, Wang JW, Lau WY, Cai XJ, Mou YP, Liu YP, *et al*. Conventional versus binding pancreaticojejunostomy after pancreaticoduodenectomy: a prospective randomized trial. Ann Surg 2007; 245:692–698.

11 Yingbin L, Wang J, Xu B, Li H, Zhe T, Fang H, Wu Y. Peng's pancreaticojejunal anastomosis (binding pancreaticojejunostomy) for the pancreatoduodenectomy – a new procedure ensuring no leakage. Chin German J Clin Oncol 2002; 1:65–67.

12 Peng SY, Wang JW, Li JT, Mou YP, Liu YB, Cai XJ. Binding pancreaticojejunostomy – a safe and reliable anastomosis procedure. HPB 2004; 6:154–160.

13 Bassi C, Dervenis C, Butturini G, Fingerhut A, Yeo C, Izbicki J, *et al*. Postoperative pancreatic fistula: an international study group (ISGPF) definition. Surgery 2005; 138:8–13.

14 Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, *et al*. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surg (United States) 2017; 161:584–591.

15 Pulvirenti A, Ramera M, Bassi C. Modifications in the International Study Group for Pancreatic Surgery (ISGPS) definition of postoperative pancreatic fistula. Transl Gastroenterol Hepatol 2017; 2:107.

16 Wente MN, Bassi C, Dervenis C, Fingerhut A. Delayed gastric emptying (DGE) after pancreatic surgery : a suggested definition by the International Study Group of Pancreatic Surgery (ISGPS). J Surg 2007; 142:761–768.

17 Wente MN, Veit JA, Bassi C, Dervenis C, Fingerhut A, Gouma DJ, *et al*. Postpancreatectomy hemorrhage (PPH)– An International Study Group of Pancreatic Surgery (ISGPS) definition. Surgery 2007; 142:20–25.

18 DeOliveira ML, Winter JM, Schafer M, Cunningham SC, Cameron JL, Yeo CJ, *et al*. Assessment of complications after pancreatic surgery: a novel grading system applied to 633 patients undergoing pancreaticoduodenectomy. Ann Surg 2006; 244:931–937.

19 Olakowski M, Grudzińska E, Mrowiec S. Pancreaticojejunostomy—a review of modern techniques. Langenbeck's Arch Surg 2020; 405:13–22.

20 Sandini M, Malleo G, Gianotti L. Scores for prediction of fistula after pancreatoduodenectomy: a systematic review. Dig Surg 2016; 33:392–400.

21 Giuseppe M, Alessandra P, Giovanni M, Giovanni B, Roberto S, Claudio B. Diagnosis and management of postoperative pancreatic fistula. Langenbeck's Arch Surg 2014; 399:801–810.

22 Nahm CB, Connor SJ, Samra JS, Mittal A. Postoperative pancreatic fistula: a review of traditional and emerging concepts. Clin Exp Gastroenterol 2018; 11:105–118.

23 Zakaria HM, Mohamed A, Alsebaey A, Omar H, ELazab D, Gaballa NK. Prognostic factors following pancreaticoduodenectomy for pancreatic ductal adenocarcinoma. Int Surg J 2018; 5:3877.

24 Zakaria H, Sallam AN, Ayoub II, Gad EH, Taha M, Roshdy MR, *et al*. Prognostic factors for long-term survival after pancreaticoduodenectomy for periampullary adenocarcinoma. A retrospective cohort study. Ann Med Surg 2020; 57:321–327.

25 Ecker BL, Mcmillan ÃMT, Asbun ÃHJ, Ball CG, Bassi C, Beane JD, *et al*. Characterization and optimal management of high-risk pancreatic anastomoses during pancreatoduodenectomy. Ann Surg 2018; 267:608–616.

26 El Nakeeb A, Hamdy E, Sultan AM, Salah T, Askr W, Ezzat H, *et al*. Isolated Roux loop pancreaticojejunostomy versus pancreaticogastrostomy after pancreaticoduodenectomy: a prospective randomized study. HPB 2014; 16:713–722.

27 Xiong JJ, Tan CL, Szatmary P, Huang W, Ke NW, Hu WM, *et al*. Meta-analysis of pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy. Br J Surg. 2014; 6:1196–1208.

28 Hun J, Byung KÆ, Yoo M, Hong ÆJ. Which method should we select for pancreatic anastomosis after pancreaticoduodenectomy?. World J Surg 2009; (33):326–332.

29 Que W, Fang H, Yan B, Li J, Guo W, Zhai W, *et al*. Pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy: a meta-analysis of randomized controlled trials. Am J Surg 2015; 209:1074–1082.

30 Yang SH, Dou KF, Sharma N, Song WJ. The methods of reconstruction of pancreatic digestive continuity after pancreaticoduodenectomy: a meta-analysis of randomized controlled trials. World J Surg 2011; 35:2290–2297.

31 Pan J, Ge X, Zhou W, Zhong X, Gu L, Zhu H, *et al*. Comparison of clinical outcomes between mesh-reinforced pancreatojejunostomy and pancreatogastrostomy following pancreaticoduodenectomy: a cohort study. World J Surg Oncol 2018; 16:1–7.

32 Barreto SG, Shukla PJ. Different types of pancreatico-enteric anastomosis. Transl Gastroenterol Hepatol. 2017; 2(NOV):2–12.

33 Wang W, Zhang Z, Gu C, Liu Q, Liang Z, He W, Jianping Chen JL. The optimal choice for pancreatic anastomosis after pancreaticoduodenectomy: a network meta-anaysis of randomaized control trails. Int J Surg 2018; 57:111–116.

34 Cheng Y, Briarava M, Lai M, Wang X, Tu B, Cheng N, *et al*. Pancreaticojejunostomy versus pancreaticogastrostomy reconstruction for the prevention of postoperative pancreatic fistula following pancreaticoduodenectomy. Cochrane Database Syst Rev 2017; 9:1–69.

35 Berger AC, Howard TJ, Kennedy EP, Sauter PK, Bower-Cherry M, Dutkevitch S, *et al*. Does type of pancreaticojejunostomy after pancreaticoduodenectomy decrease rate of pancreatic fistula? A randomized, prospective, dual-institution trial. J Am Coll Surg 2009; 208:738–749.

36 Langrehr JM, Bahra M, Jacob D, Glanemann M, Neuhaus P. Prospective randomized comparison between a new mattress technique and Cattell (duct-to-mucosa) pancreaticojejunostomy for pancreatic resection. World J Surg 2005; 29:1111–1119.

37 Hua J, He Z, Qian D, Meng H, Zhou B, Song Z. Duct-to-mucosa versus invagination pancreaticojejunostomy following pancreaticoduodenectomy: a systematic review and meta-analysis. J Gastrointest Surg 2015; 19:1900–1909.

38 Patel AC, Yagnik VD. Evaluation of risk factors for postoperative pancreatic fistula following pancreaticoduodenectomy. Formos J Surg 2019; 52:76–83.

39 El Nakeeb A, Salah T, Sultan A, El Hemaly M, Askr W, Ezzat H, *et al*. Pancreatic anastomotic leakage after pancreaticoduodenectomy. Risk factors, clinical predictors, and management (single center experience). World J Surg 2013; 37:1405–1418.

40 Zhu B, Geng L, Ma YG, Zhang YJ, Wu MC. Combined invagination and duct-to-mucosa techniques with modifcations: a new method of pancreaticojejunal anastomosis. Hepatobiliary Pancreat Dis Int 2011; 10:422–427.

41 El Nakeeb A, Askr W, Mahdy Y, Elgawalby A, El Sorogy M, Abu Zeied M, *et al*. Delayed gastric emptying after pancreaticoduodenectomy. risk factors, predictors of severity and outcome. A single center experience of 588 cases. J Gastrointest Surg 2015; 19:1093–1100.

42 Wellner UF, Kulemann B, Lapshyn H, Hoeppner J, Sick O, Makowiec F, *et al*. Postpancreatectomy hemorrhage — incidence, treatment, and risk factors in over 1,000 pancreatic resections. Gastrointest Surgrointest Surg 2014; 18:464–475.

43 Kennedy EP, Yeo CJ. Dunking pancreaticojejunostomy versus duct-to-mucosa anastomosis. J Hepato-Biliary-Pancreatic Sci 2011; 18:769–774.

44 Zakaria HM, Stauffer JA, Raimondo M, Woodward TA, Wallace MB, Asbun HJ. Total pancreatectomy: Short- and long-term outcomes at a high-volume pancreas center. World J Gastrointest Surg 2016; 8:634.