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A Feasible and Safe Invagination Technique for Pancreatogastrostomy After Pancreatoduodenectomy

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1. Abstract

1.1 Aims

Pancreatogastrostomy (PG) via invagination is a straightforward procedure that may be performed without the assistance of a highly experienced surgeon and has great short-term outcomes. This study aimed to describe updated surgical techniques and our initial experience following pancreaticoduodenectomy (PD).

1.2. Methods

In PG, a 6-cm longitudinal incision is created in the anterior wall of the stomachs lower body, and an Alexis wound retractor (Applied Medical, Rancho Santa Margarita, and USA) is inserted to extend the stomach wall, which simplifies PG. The Billroth I technique is then used to perform the gastrojejunostomy. A total of 88 patients (49 men and 39 women) underwent pancreatogastrostomy after subtotal stomach-preserving pancreatoduodenectomy (SSPPD) over the last decade, of which 36 had pancreatic cancer, 27 had cholangiocarcinoma, 12 had carcinoma of the papilla of Vater, 10 had intraductal papillary mucinous neoplasm (IPMN), and 3 had benign tumors. The primary endpoint was postoperative pancreatic fistula (POPF). All patients who underwent SSPPD were divided into two groups: non-fistula and grade A/B/C fistula.

1.3. Results

Postoperative morbidity was 25.8% (22 cases), with no deaths reported. Eleven patients (12.5%) demonstrated the development of POPF (grade A: 6; B: 3; C: 2). The pancreatic texture and diameter of the pancreatic duct were significant risk factors for the occurrence of POPF (P < 0.01).

1.4. Conclusion

Our modified PG technique demonstrated safe and reliable anastomosis with minimal morbidity and mortality after PD. However, studies with more subjects are warranted to confirm the validity of this surgical technique.

2. Introduction

The surgical mortality rate after pancreatoduodenectomy (PD) has been reduced to 3%–5%, although the frequency of postoperative morbidity remains high, ranging from 30% to 65% [1,2,3]. The development of pancreatic fistula is the most common cause of death and morbidity after PD, with a reported frequency ranging from 2% to 28% [4,5]. The surgical community has put in a lot of effort to avoid pancreatic leakage. Some studies have found that pancreatogastrostomy (PG) can be performed to prevent the formation of fistulas in pancreatojejunostomies (PJ) by anastomosing the pancreatic stump [6,7,8]. Several other PG techniques have also been devised, with immensely improved outcomes [9,10,11]. However, whether these type of procedures are superior to others remains unknown, as restoration of the residual pancreas is yet to be validated in recent prospective randomized research [8,12]. The purpose of this study was to as sess the risk factors for pancreatic fistulas following a modified PG technique that combines anastomosis between the pancreatic stump and the gastric wall using a technique that invaginates the free-end pancreatic remnant into the posterior gastric wall using an Alexis wound retractor. The Alexis wound retractor is a urethane device that provides retraction while removing an organ or specimen through a tiny incision. We present our modified PG technique and retrospective analysis of the short-term outcomes of patients who underwent PG following PD at our institution.

3. Materials and Methods

Between 2000 and 2018, one surgeon (M.I.) conducted conventional subtotal gastric-preserving PD (SSPPD) on 88 consecutive patients. Using invagination techniques, all pancreatic anastomoses were performed in one layer between the pancreatic remnant and the posterior gastric wall. The use of a wound protector for anastomosis in PG was another modification to our procedure. Following PG, an ante colic reconstruction and setting using the Billroth I technique were performed. The current investigation excluded patients who had undergone multiple visceral pancreatic resections. Preoperative clinical and demographic information, as well as operative factors, such as pancreatic depth, pancreatic duct diameter, pancreatic texture, amylase levels in drainage fluid and serum, postoperative course, and complications, were collected retrospectively using patients' files and operative records. All patients were split into two groups based on whether they had POPF or not. These surgical risks, as well as clinical and radiological characteristics associated with POPF, were compared between the two groups. According to the International Study Group on Pancreatic Fistula guidelines [13], a pancreatic fistula is defined as a drain output of any detectable amount of fluid on or after postoperative day 3 with amylase content more than three times the serum amylase activity. The pancreatic texture was classified as either hard or soft. The hardness of the pancreas was defined by the presence of histological fibrosis.

4. Surgical Technique

4.1. Preparation of Pancreatic Stump

Following excision of the pancreatic head and duodenum without preservation of the pylorus, the pancreatic remnant is separated from the surrounding retroperitoneal tissues for approximately 2 cm from its cut edge. After completing SSPPD, a longitudinal anterior gastrostomy is performed, with the distance between the various planes calculated until appropriate tension was obtained.

4.2. Pancreatogastrostomy Anastomosis

The Alexis wound retractor is introduced and secured through the anterior layer of the stomach. Following the completion of the wound retractor insertion, mild tension is created on the posterior layer of the stomach to facilitate the PG anastomosis (Figure 1). A transverse gastrotomy is performed on the stomach's posterior wall in line with the pancreatic stump's 2/3 diameter. 5–0 PDS sutures are used to secure the pancreas's anterior and posterior borders. Two stay sutures are brought anteriorly through the incision of the gastric posterior wall, and then the pancreas are inserted into the stomach and simply invaginated by at least 2–3 cm by placing minor traction on the sutures. The entire anastomotic rim may be regulated in this manner. Interrupted 5–0 PDS single-layer suturing is performed between about one centimeter off the pancreatic and the gastric walls (Figure 2). If necessary, the anastomoses are strengthened with additional sutures. A nasogastric tube is inserted so that pancreatic juice does not come into direct contact with the anastomoses.

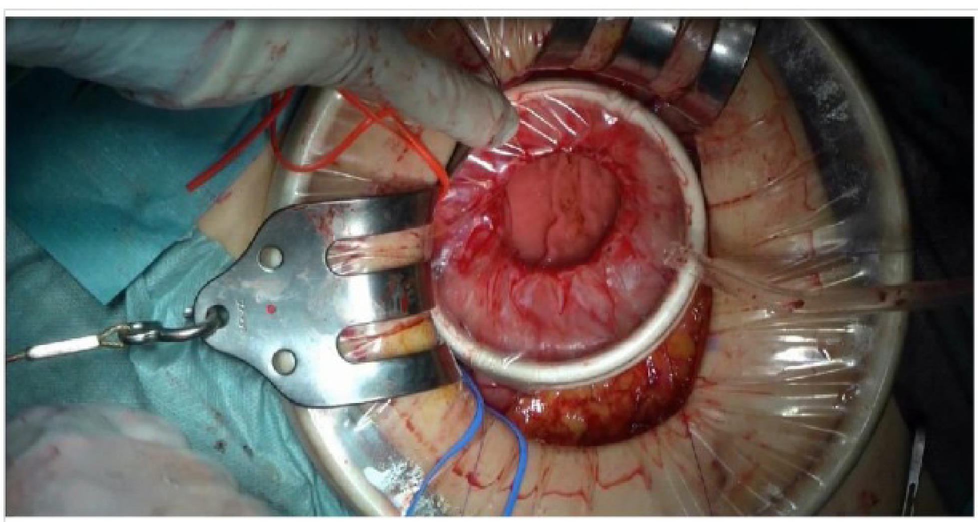

Figure 1: The Alexis wound retractor is placed through the anterior layer of the stomach to generate a sufficient tension on the posterior layer of the stomach.

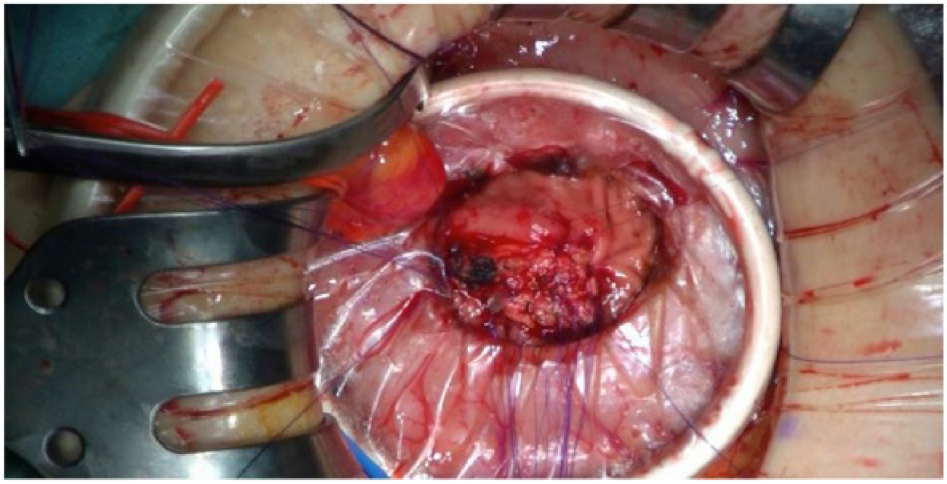

Figure 2: Intragastric invagination of the pancreas was fastened with PDS sutures.

4.3. Other Anastomoses

The gastrojejunostomy was performed using the Billroth I technique through the anterior gastric aperture situated between the distal gastric stump and the end of the jejunum using 25 or 28 G PC-EEA (Ethicone, London, United Kingdom). The anterior gastric wall opening was then closed using a linear gastrointestinal stapler, completing the PG anastomosis. Hepaticojejunostomy was performed 20 cm distal to the gastroenterostomy site via end-to-side anastomosis with or without a stent, and digestive continuity was then attained.

4.4. Statistical Analysis

Mean ± standard deviation was used to express the data. The Statistical Package for Social Science for Windows was used to conduct the statistical analysis (SPSS Inc; Chicago, IL, USA). The chi-squared test and Student's t-test were used to compare the patient characteristics and intraoperative and postoperative variables of the POPF and non-POPF groups. To find independent variables associated with POPF development, univariate and multivariate logistic analyses were used. $P < 0.05$ was deemed statistically significant.

5. Results

Of the patients included in the study, 57 were men and 31 were women. The average age was 71.8± 11.4 years, with a range of 43 to 86 years. Pancreatic cancer was the most frequent disease among the patients (n = 36), followed by extrahepatic biliary cancer (n = 27), ampullary cancer (n = 12), IPMN (n = 10), endocrine tumors (n = 2), and chronic pancreatitis (n = 1). The total operating time and blood loss for all patients were 429 ± 88 minutes and 806 ± 215 mL, respectively. Postoperative morbidity was 25.8% (22 cases), with no deaths reported. Overall, POPF development was found in 11 (12.5%) of all patients. According to the ISGPF, six patients received a grade A, three received a grade B, and two received a grade C. The rate of clinically relevant (CR) POPF was 5.7%. All patients with grades A and B were treated with nasogastric tube maintenance or reinsertion, antibiotics, drainage, and complete parental feeding. Two patients suffered bleeding, one from the cut surface of the pancreatic stump and the other from an aneurysm of the gastroduodenal artery stump, which was treated using gastroscopy and interventional radiology, respectively. Other intra-abdominal problems included intra-abdominal abscess in 5 (5.7%), delayed stomach emptying in 6 (6.8%), wound infection in 5 (5.7%), and large ascites in 2 (2.2%) patients; however, all patients were treated conservatively with nutritional assistance and antibiotic treatment. Pulmonary and cardiac complications included two cases of pneumonia and three of arrhythmias. Eighty-eight patients who underwent PD were divided into two groups: non-fistula (77 cases) and grade A/B/C fistula (11 cases). In terms of preoperative data, the two groups had similar baselines in terms of age, gender, BMI, pathological type, albumin level, coexisting disease, ASA level, and pre-biliary drainage clinicopathological data (Table 1). Furthermore, except for pancreatic texture, intra-operative variables such as operation duration, blood loss, stump thickness, and use of a pancreatic stent were not significantly related to the development of POPF as per univariate and multivariate analyses (Table 2, 3). Multiple analyses indicated that the only independent risk variables for POPF were pancreatic tissue texture and pancreatic duct diameter. The non-fistula group had 37 (48.0%) cases with soft tissue texture and 40 (52.0%) cases with hard tissue texture, whereas the fistula group had 10 (90.9%) cases with soft tissue texture and 1 (9.0%) case with hard tissue texture; the difference was statistically significant ($P < 0.01$). The POPF rate in the soft tissue texture group was 21.3% (10/47) and 2.4% (1/14) in the hard tissue texture group; this difference was likewise statistically significant. The diameter of the pancreatic duct was considerably lower in the POPF group than that in the non-fistula group (2.2 ± 1.2 mm vs. 3.2 ± 1.2 mm, $P = 0.01$). The thickness of the transected parenchyma was 16.1 ± 4.2 mm in the non-fistula group and 15.3 ± 4.3 mm in the fistula group, with no significant difference. The non-fistula group's postoperative hospital stay was considerably shorter than that of the fistula group (12.5 ± 3.5 days vs. 22.5 ± 3.7 days, $P < 0.01$). The median postoperative hospital stay was also lower in the hard tissue texture group than that in the soft tissue texture group because the rate of pancreatic leakage in patients with pancreas with soft tissue texture was greater than that in patients with hard tissue texture (13.5 ± 3.9 days vs. 21.5 ± 3.8 days, P < 0.05). The incidence of surgical site infection and intra-abdominal abscess was substantially higher in the fistula group (54.5% and 45.4%, respectively) than that in the non-fistula group (14.0% and 1.3%, respectively, P < 0.01).

Table1: Demographic data and characteristics of patients with non-POPF and POPF. BMI = Body mass index, ASA = American Society of Anesthesiologists.

	Non-Fistula group (n=77)	Fistula group (n=11)	P value
Age (Years)	71.5±11.2	72.3±12.2	0.74
Male/female	41/36	3-Aug	0.22
BMI	21.5±3.5	22.1±2.6	0.59
Pancreatitis (%)	3（3.9%)	1(9.1%)	0.44
Malignant/benign	65/12	1-Oct	0.47
Albumin level	3.5±0.3	3.6±0.3	0.3
Diabetes (%)	11 (14.3%)	2 (18.2%)	0.73
ASA level (I, Ⅱ/Ⅲ, Ⅳ)	69/8	1-Oct	0.89
Smoking (%)	25 (32.5%)	2 (18.1%)	0.34
Steroids (%)	3 (3.9%)	0 (0%)	0.51
Pre- biliary drainage (%)	51 (70.1%)	8 (72.7%)	0.86

Table 2: Comparing intra-operative and pathological pancreatic characteristics between the two groups.

	Non-Fistula group (n=77)	Fistula group (n=11)	P value
Mean operative time (min)	431±74	420±115	0.67
Mean operative blood loss (ml)	810±212	792±205	0.57
Blood transfusion (ml)	115±205	80±25	0.57
Pancreas tissue texture			
Soft	37	10	0.01
Hard	40	1	
Mean depth of pancreas (mm)	16.1±4.2	15.3±4.3	0.58
Mean diameter of duct (mm)	3.2±1.2	2.2±1.2	0.01
Use of pancreatic stent (%)	43 (55.8%)	7 (63.6%)	0.63

Table 3: Univariate and multivariate analysis of risk factors for all postoperative pancreatic fistula in the patients. BMI = Body mass index, ASA = American Society of Anesthesiologists, CI = confidence interval

Parameters	Univariate Relative risk (95% CI) P value	Multivariate Relative risk (95% CI) P value
Age (<70 vs. >71)	1.90 (0.91~3.56) 0.10	
Sex (male:female)	1.03 (0.05~1.61) 0.22	
BMI (<25.0 vs. >25.1)	1.56 (0.43~2.80) 0.47	
Benign/Malignant	1.31 (0.50~4.31) 1.02	
Pre-biliary drainage (+ vs. -)	1.13 (0.43~3.85) 0.85	
Operative time (<400 vs. >401)	1.05 (0.53~2.90) 0.73	
Blood loss (<800 vs. >801)	1.20 (0.43~3.21) 0.68	
ASA (Ⅰ, Ⅱ vs. Ⅲ,IV)	1.38 (0.63~2.90) 0.39	
Use of pancreatic stent (+ vs. -)	1.19 (0.59~2.01) 0.63	
Pancreatic depth (<15mm vs. >16mm)	1.83 (0.91~3.90) 0.12	
Pancreatic texture (soft vs. hard)	0.56 (0.21~0.90) 0.01	0.55 (0.21~0.91) 0.02
Pancreatic duct diameter (<3.0mm vs.3.1mm)	0.43 (0.02~0.85) 0.02	0.42 (0.02~0.84) 0.02

6. Discussion

In our study, grade B or C POPF was found in 5.9% of the patients with no mortality. According to statistics obtained from 8575 cases from a nationwide single-race population (Japanese), grade B or C POPF occurred in 13.2%, with a 2.8% in-hospital mortality rate [14]. PJ or PG is the most commonly used technique for pancreatic anastomosis following PD. However, there is still no agreement on which of the two anastomotic methods to use. Waugh and Clagett [15] introduced PG into clinical practice in 1946, and it is currently being re-evaluated as an alternate approach to the traditional PJ. Pancreatic enzymes inactivated by the stomach's acidic environment may also assist in avoiding auto-digestion of the anastomosis and aneurysm development of the gastroduodenal artery due to pancreatic fistula formation following PG. Furthermore, the pancreas' closeness to the posterior gastric wall allows for possibly less strain on the anastomosis and greater space between the anastomosis and the stump of the gastroduodenal artery in PG than that in PJ. Guerrini et al. [16] reported that a meta-analysis of eight RCTs describing 1,211 patients showed the PG group had a significantly lower incidence rate of postoperative pancreatic fistulas [OR 0.64 (95% confidence interval (CI) 0.46–0.86), p = 0.003], intra-abdominal abscesses [OR 0.53 (95% CI, 0.33–0.85), p = 0.009], and length of hospital stay [MD -1.62; (95% CI 2.63–0.61), p = 0.002] than the PJ group. Furthermore, a meta-analysis of 11 studies including 909 patients who underwent PG and 856 patients who underwent PJ published in 2019 by Jin Y et al. [4] revealed that POPF incidence was substantially lower in the PG group than that in the PJ group, whereas the incidence of grade B and C fistula was not statistically different between the two groups. Other studies, however, have found no significant differences in the incidence of POPF, total morbidity, and death between the PG and PJ groups [17,18,19]. End-to-side duct-to-mucosa anastomosis or end-to-side invagination methods are used for PG anastomosis. There are no randomized controlled trials of the various PG techniques in literature; however, some researchers demonstrated that the invagination approach was safer than duct-to mucosa technique in high-risk patients with a tiny pancreatic duct in soft tissue texture pancreas [20,21]. Furthermore, PG invagination enables the drainage of pancreatic juice produced from the cut surface, at which numerous branching ducts emerge. Despite the benefits of PG, we occasionally encountered POPF. POPF during PG invagination is considered to be caused by the relaxation of the gastric mucosa and the development of space between the gastric mucosa and the pancreatic parenchyma. The mucosa of the stomach was stretched in our modified approach utilizing an Alexis wound retractor, allowing for an easy uniformly sutured nodule between the gastric mucosa and pancreatic parenchyma, and therefore, the rate of POPF would be reduced. Although PJ and PG anastomoses are difficult to perform, Grobmyer SR et al. [22] demonstrated that an "ideal PJ anastomosis would meet the following technical criteria: applicable to all patients, easy to teach, and associated with a low rate of pancreatic anastomotic failure-related complications." In this regard, our method is the most preferred in PG. Despite the improved PG method used in this investigation, the only independent risk factors for POPF were pancreatic tissue texture and pancreatic duct diameter. Callery et al. [23] showed that a simple 10-point Fistula Risk Score (based on the short pancreatic duct, soft pancreatic tissue texture, high-risk pathology, and high operative blood volume) may accurately predict POPF following PD. Other studies have found that longer operating duration, a hospital with low volume of such cases, and diabetes may all be risk factors [24,25].

However, this technique has two major drawbacks. The first is that delayed gastric emptying occurs more frequently than PJ. The second is that due to the strong regeneration of the gastric mucosa, the main pancreatic duct (MPD) opening may get obstructed, leading to pancreatic function destruction, pancreatic atrophy, or dilatation of the MPD [27]. In recent retrospective investigations [4,11], PG groups had significantly greater postoperative atrophy of the pancreatic parenchyma and steatorrhea, as well as a higher risk of worsening diabetes when compared to PJ. However, Bassi et al. [6] has reported that PG using the invagination technique provides long-term patency of the main pancreatic duct with a reduced secretion of enzymes. Further examination of these long-term results is warranted.

There are certain limitations to this retrospective study that should be noted. First, we sought to alter PG to minimize POPF, but without a randomized controlled trial, it is impossible to verify the safety of any approach and its modifications. RCTs for appropriate surgical reconstructive procedures in PD should be conducted in facilities with a high volume of such cases. Furthermore, because of the limited sample size that underwent PG in this study, subgroup analysis based on surgical risk variables such as pancreatic texture, pancreatic ductal diameter, and diseases could not be performed. Larger trials are needed to determine whether the current technique can reduce POPF and improve quality of life. Third, PD is accompanied by severe upper jejunal motor abnormalities. We predicted that upper jejunal motor patterns following Billroth I PG would be superior to those in other kinds of anastomosis. We did not, however, examine whether postoperative motor abnormalities are less common after PG following PD.

7. Conclusions

Our findings revealed a very low POPF and no leakage-related mortality, showing that this approach is feasible and safe. When compared to "normal" PG, our "open" technique employing the Alexis wound retractor provides better visibility of the intragastric cavity and, as a result, more precise anastomosis performance. We believe that our modified PG is a straightforward and safe technique of rebuilding after PD. However, pancreatic texture and the diameter of the pancreatic duct were risk factors for the development of POPF in this study.

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