End-to-Side Penetrating-Suture Pancreaticojejunostomy: A Novel Anastomosis Technique

Yijun Chen, MB, Xuefeng Zhu, MM, Jianjun Huang, MB, Youngsheng Zhu, MB

Since Cattell and Whipple introduced the pancreatojejunostomy for pancreatoduodenectomy (PD), pancreatointestinal anastomotic failure (PAF) has been a persistent problem. Current literature shows that the incidence of pancreatic fistula ranges from 2% to 40%, with an associated mortality of up to 40% with severe grade C fistulas. Therefore, pancreatic fistulas associated with pancreatointestinal anastomosis contribute to a major part of the morbidity and mortality. To prevent failure of the pancreatointestinal anastomosis, a number of techniques have been designed based on modified versions of the techniques of Whipple, Child, Cattell, and others. Because no method has proven superior to another, continued development of anastomotic techniques is still needed. The pancreas is a solid parenchymal organ with secretory function delivered via a single duct. The pancreatointestinal anastomosis is constructed to connect a solid organ to a hollow abdominal viscus. Regardless of the methods of anastomosis, the goals are to drain the pancreatic duct into the intestinal lumen and to allow the pancreatic stump to fuse with the intestinal wall. Therefore, a successful pancreatointestinal anastomosis relies on the adhesion and healing between the pancreatic stump and the intestinal wall. At the same time, pancreatic juice from the pancreatic duct, as well as drainage from the pancreatic stump, should drain into the lumen of the intestine.

Based on these characteristics, we devised a novel pancreaticojejunostomy technique: Chen’s end-to-side penetrating-suture pancreaticojejunostomy (now called Chen’s PPJ). The design concept of Chen’s PPJ differs from traditional operations. It considers the pancreas stump a solid organ (instead of a tubular organ). It uses the pancreatic stump transecting surface (rather than anterior and posterior margins) to anastomose with the jejunal walls, and each suture penetrates the full thickness of the pancreatic stump and the anterior and posterior walls of the jejunal enterotomy. In addition, a stent into the pancreatic duct drains the pancreatic secretions across the enterotomy. This technique not only ensures a secure pancreatointestinal anastomosis, but also allows functional drainage of all pancreatic secretions into the intestinal lumen.

This study retrospectively analyzed the clinical data related to the application of Chen’s PPJ method at the Department of General Surgery, Taixing People’s Hospital. The aim of this study was to investigate the safety, reliability, and potential for universal application of this novel technique.

METHODS

Clinical data

In this study, we retrospectively analyzed 106 surgical cases using Chen’s PPD technique in our department, from April 2008 to February 2015. Our hospital’s Medical Ethics Committee unanimously approved application of Chen’s PPJ technique. Among these 106 patients, 55 were male and 51 were female. Mean age was 66 years (range 23 to 90 years). Pre-surgical and surgical data are shown in Tables 1 and 2, and surgical pathologic diagnoses are given in Table 3.

Radical PD was performed in all 106 cases. The excised portions included the head, neck, and uncinate process of the pancreas, duodenum, distal stomach, proximal jejunum, gallbladder, and common bile duct. The tissue around the head of the pancreas and common hepatic duct, and the lymph nodes within the hepatoduodenal ligament were also resected. Wedge or segmental resection of portal veins was performed on 11 patients whose portal veins were partially invaded by tumor. Some patients had undergone simultaneous operations for stage I rectocoelectomy for cancer or C-sections before PD surgery.

The Childs method was used in all cases for reconstruction of the digestive tract. Nasogastric tubes were placed after gastrojejunostomy, which extended through the anastomosis into the jejunal afferent loop. Finally, after peritoneal irrigation, drains were placed superior to the...
pancreaticojunostomy and posterior to the hepaticojejunostomy. Prophylactic octreotide was not used.

**End-to-side penetrating-suture pancreaticojunostomy procedure**

**Preparation of the pancreatic stump**

Transection was performed vertically, and careful hemostasis was achieved with electrocautery or suture. The main pancreatic duct was not dissected; a matching stent, 5 to 7 cm long, was inserted into the pancreatic duct remnant and secured with sutures at the opening of the pancreatic duct. No interlocking sutures were placed (Fig. 1).

**Preparation of the jejunum loop**

The end of the jejunal loop was closed. A jejunostomy was made with a full-thickness longitudinal incision on the antimesenteric side, 2 to 3 cm proximal to the end. The length of the jejunostomy was approximately 2 cm (1 cm less than the transverse diameter of the pancreatic transecting surface) (Fig. 1).

**Pancreaticojejunal anastomosis**

**Penetrating-suture.** Nonabsorbable interrupted suture was used. Each suture completely penetrated the pancreatic parenchyma from anterior to posterior, then from posterior to anterior traversing the full thickness of the jejunal posterior wall, and then the anterior wall (Fig. 2). The sutures were not knotted at this point.

The free margin of the suture was 0.8 to 1.0 cm, interval 0.5 cm, for a total of 6 to 8 sutures. Care should be taken to avoid injury to the main pancreatic duct. If the thickness of the pancreatic stump is ≥1.5 cm and 1 single suture cannot completely penetrate the pancreatic stump, the indirect suturing technique can be used. In this method, the needle entered the anterior wall of the pancreas, exited the middle of the transect of the pancreatic stump, and then reinserted into the pancreatic parenchyma to exit the posterior wall of the pancreatic stump. For jejunal wall sutures, the first and last sutures should be placed at the upper and lower edges of the jejunal ostomy on the outer side (Figs. 1 and 2).

**Fitting the jejunal incision to the pancreatic stump and tying the knots.** When all the stitches were placed, the jejunal incision was held against the cut surface of the pancreas closely. The pancreaticojejunal anastomosis should be a snug fit. Meanwhile, the stitches were tightened and knotted to ensure a watertight and intestinal wall introversive closure. The pancreatic duct stent passed between the sutures and extended into the jejunal lumen (Figs. 3 and 4).

### Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>History</th>
<th>Patients, n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥ 70 y</td>
<td>45</td>
<td>42.5</td>
</tr>
<tr>
<td>Jaundice</td>
<td>58</td>
<td>54.7</td>
</tr>
<tr>
<td>Past surgical history</td>
<td>6</td>
<td>5.7</td>
</tr>
<tr>
<td>Radial gastrectomy</td>
<td>6</td>
<td>5.7</td>
</tr>
<tr>
<td>Past medical history</td>
<td>41</td>
<td>38.7</td>
</tr>
<tr>
<td>Rectal adenocarcinoma</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Transverse colon carcinoma</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>24</td>
<td>22.6</td>
</tr>
<tr>
<td>Hypothyroidism</td>
<td>11</td>
<td>10.4</td>
</tr>
<tr>
<td>Malnutrition (body weight 34 kg)</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>ERCP pancreatitis</td>
<td>3</td>
<td>2.8</td>
</tr>
<tr>
<td>Pregnancy (7 mo)</td>
<td>1</td>
<td>0.9</td>
</tr>
</tbody>
</table>

### Table 2. Operative Data (n = 106)

<table>
<thead>
<tr>
<th>Operative parameter</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time, min, median (range)</td>
<td>300 (190–420)</td>
</tr>
<tr>
<td>PJ time, min, median (range)</td>
<td>8 (6–22)</td>
</tr>
<tr>
<td>Blood loss during operation, mL, median (range)</td>
<td>350 (200–800)</td>
</tr>
<tr>
<td>Cases required transfusion, n (%)</td>
<td>26 (24.5)</td>
</tr>
<tr>
<td>Transfusion volume, mL, median (range)</td>
<td>400 (300–600)</td>
</tr>
<tr>
<td>Pancreatic consistency, n</td>
<td>56</td>
</tr>
<tr>
<td>Soft</td>
<td>50</td>
</tr>
<tr>
<td>Firm</td>
<td>50</td>
</tr>
<tr>
<td>Diameter of pancreatic duct, mm, median (range)</td>
<td>2.8 (1–10)</td>
</tr>
<tr>
<td>Thickness of pancreas, mm, median (range)</td>
<td>16 (10–30)</td>
</tr>
<tr>
<td>Width of pancreas, mm, median (range)</td>
<td>34 (25–50)</td>
</tr>
<tr>
<td>Postoperative days in hospital, d, median (range)</td>
<td>17 (11–32)</td>
</tr>
</tbody>
</table>

**Abbreviations and Acronyms**

PAF = pancreatoenteric anastomotic failure
PD = pancreatoduodenectomy
POD = postoperative day
POPF = postoperative pancreatic fistula
PPJ = pancreaticojejunostomy

### Table 3. Postoperative Pathologic Diagnoses (n = 106)

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Patients, n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenocarcinoma of pancreatic head</td>
<td>41</td>
<td>38.7</td>
</tr>
<tr>
<td>Ampullary adenocarcinoma</td>
<td>16</td>
<td>15.1</td>
</tr>
<tr>
<td>Distal bile duct adenocarcinoma</td>
<td>21</td>
<td>19.8</td>
</tr>
<tr>
<td>Duodenal adenocarcinoma</td>
<td>19</td>
<td>17.9</td>
</tr>
<tr>
<td>Duodenal lipoma</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Pancreatic head cystic adenoma</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td>Chronic pancreatitis</td>
<td>3</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Reinforce sutures. Finally, additional interrupted sutures were placed between the pancreatic capsule, peri-pancreatic tissue, and the seromuscular layers of the jejunum for 1 circle. Reinforcement of sutures was not necessary if the pancreaticojejunal anastomosis was tight, or if there were tears in the pancreatic capsule. When stitching the posterior wall, 4-0 Prolene (Ethicon) suture should be used to avoid injury to the small veins of the pancreas.

Diagnostic criteria for postoperative pancreatic fistula

According to the International Study Group on Pancreatic Fistula (ISGPF), postoperative pancreatic fistula (POPF) can be defined as any measurable volume of drainage fluid on or after postoperative day (POD) 3 with its amylase content 3 times greater than the serum amylase activity. Three different grades of POPF (grades A, B, C) are defined according to the clinical impact on the patient’s hospital course. Grades B and C are clinically important, and grade C fistulas often signify PAFs.

Postoperative follow-up

Outpatient follow-up occurs 1 month after surgery with ultrasound, CT, or MRI.

RESULTS

All 106 cases used the PPJ method to complete the pancreaticojejunal anastomosis; 18 of these used 1-layer anastomosis. The median time for performing pancreaticojejunosonotomy was 8 minutes (range 6 to 22 minutes). Postoperative pancreatic fistula, based on the International Study Group on Pancreatic Fistula definition, occurred in 26 patients (occurrence rate 24.5%). Among these, grade A POPF occurred in 20 patients and grade B (the clinically significant POPF) occurred in 6 patients.
(occurrence rate only 5.6%). All patients healed with simple drainage, without NPO, enteral nutrition, or growth inhibitor therapies. One patient with a grade B pancreatic fistula had drainage output up to 450 mL/day. It was self-healed 3 months after surgery. Two patients had bile leak. In addition, there were 6 patients with delayed gastric emptying, and all resolved after conservative treatment. There were no cases of pancreatic anastomotic hemorrhage, and no patients required reoperation or died after surgery. The median postoperative hospital stay was 17 days (range 11 to 32 days).

Gastrointestinal tubes were usually removed at POD 5, and drains at the hepaticojejunostomy site were usually removed at POD 5 if there was no detected bile leak. Two patients had bile leak; their drains were removed 1 month after surgery. Drains at the pancreaticojejunostomy sites were usually removed at POD 7 to 10 if no leak was detected; for patients with POPF, the criteria for drain removal were drain output less than 10 mL/day for 3 consecutive days and absence of fluid collection adjacent to the anastomosis on the abdominal ultrasound or CT before drain removal. Twenty patients had grade A POPF, and their drains were removed at PODs 10 to 20. Another 6 patients with grade B POPF had their drains removed 21 to 90 days after surgery. Among the 106 patients, 98 patients were followed up as outpatients; duration follow-up ranged from 1 month to 7 years. None of the patients demonstrated significant pancreatic duct dilation on follow-up CTs or MRIs.

DISCUSSION

Pancreaticoenteric anastomosis is the critical step during pancreaticoduodenectomy. An ideal anastomosis technique should meet the following criteria simultaneously:

1. The anastomosis is tight and without leakage.
2. The pancreatic stump has close contact with the jejunostomy, which includes the pancreatic transecting surface and the jejunostomy walls as well as the pancreatic duct with the jejunal mucosal layer. The pancreatic transecting surface should not be exposed to the intestinal lumen. This will reduce the incidence of scar/stricture formation at the pancreatic duct opening.
3. Pancreatic juices and secretion from the pancreatic transecting surface should be introduced into the intestinal lumen in a timely and effective manner.
4. There should be a good blood supply to the pancreatic stump.
5. The technique should be suitable for all pancreatic stumps and not influenced by the consistency and size of the pancreas or the caliber of the pancreatic duct.
6. The technique is technically simple, easy to operate, and easy to learn.

The pancreas is a solid organ that is soft and fragile. It also has secretory function. Currently, the 2 main methods used to perform pancreaticojejunal anastomosis are the invagination technique and the “duct-to-mucosa” anastomosis technique. Both methods theoretically consider the pancreas as a tubular organ, and anastomose the margins of the pancreatic stump with the anterior and the posterior walls of the jejunum. These sutures involve a small portion of the pancreas tissue and are prone to tear or rupture of the pancreatic stump. Additionally, these kinds of anastomoses are fragile and require reinforcing sutures, which lead to damage to the pancreas and excessive leakage from the suture holes. Excessive sutures can also affect the blood supply and healing, and in severe cases, cause necrosis and anastomotic rupture. The invagination pancreaticojejunosotomy is relatively simple technically, and necrotic tissues and secretion can be drained into the intestine in a timely fashion, but the pancreatic transecting surface is exposed to the intestinal lumen, which may lead to erosion and even life-threatening hemorrhage. In later stages, scar stricture at the pancreatic duct opening may occur. This technique is not appropriate for patients with a large transecting surface of the pancreatic stump. Conventional “duct-to-mucosa” anastomosis has
good alignment of the tissue, but the operation is more complex, technically demanding, and the operators need certain clinical expertise. There is an enclosed space (dead space) between the pancreatic stump and the intestinal wall where pancreatic juice or exudates of pancreatic transection may accumulate and may result in anastomotic rupture. The success rate is low if the pancreatic duct diameter is less than 3 mm.

The design concept of Chen’s PPJ differs from that of traditional operations. It considers the pancreas stump as a solid organ (instead of a tubular organ). It uses the pancreatic stump transecting surface (rather than anterior and posterior margins) to anastomose with the jejunal walls, and each suture penetrates the full thickness of the pancreatic stump and then the jejunal walls. This method requires only 6 to 8 interrupted sutures to complete the anastomosis. It is technically simple, easy to master, and easy to use. It needs fewer sutures and causes less damage to the pancreas. The sutures involve more pancreas tissue, and the pancreas transecting surface is covered with the jejunal wall and therefore is less prone to tissue tear during suturing. The consistency of the pancreas is no longer an important factor, and the anastomosis is more stable. By anastomosing the pancreatic stump with the jejunal walls, hemostasis is easy to achieve, and the covered pancreatic stump surface is less prone to erosion or bleeding.

Using end-to-side anastomosis, the length of the jejuno-rectomy is adjustable based on the diameter of the pancreas stump. Therefore, the size of the pancreatic transection surface is no longer a limiting factor. Full-thickness jejunitomy drains the necrotic tissue and secretion from the pancreatic stump surface into the intestinal lumen as effectively as the invagination method does. The walls around the jejunitomy and protection support to the pancreatic duct and the stent, reducing the incidence of scar stricture formation around the pancreatic duct. Chen’s PPJ technique is suitable for all patients in whom the pancreatic ducts can be identified at the section surface. Chen’s PPJ creates an ideal pancreaticojejunal anastomosis because it has a short free edge at the pancreatic stump, uses fewer sutures, preserves blood supply to the pancreatic tissue, causes fewer hemorrhagic complications, and improves healing.

When performing the invagination anastomosis or “duct-to-mucosa” anastomosis, some operators used full-thickness suturing techniques in order to reduce the damage to the pancreas tissue. These modified techniques differ only slightly from conventional operations.

Currently, the PD postoperative death rate is below 5%, but the postoperative complication rate remains as high as 30% to 50%, and pancreatic fistula is the most common complication; its occurrence rate is 2% to 40%, and its related death rate may reach 40%. Risk factors for pancreatic fistula include general factors (age, jaundice, malnutrition, diabetes mellitus, etc.) and pathologic factors (pathologic diagnosis, pancreatic consistency, diameter of pancreatic duct, etc.), as well as operation factors (total operation time, blood loss volume, type of pancreaticoenteric anastomosis, etc). Among these, a soft pancreas and pancreatic duct diameter < 3 mm are widely recognized as the most significant risk factors. The cases presented in this study were continuous and nonselective, and these patients also had those risk factors mentioned earlier. The fact that none of our patients developed a grade C fistula suggests that a reliable and safe pancreaticoenteric method is the key to preventing PAF.

We reported 26 POPFs in this article, and all POPFs were simple pancreatic fistulas. The secretion is constituted exclusively of pancreatic juice. The mechanism of simple pancreatic fistulas is the same as distal pancreatectomy; simple pancreatic fistulas were caused by suture hole leakage of pancreatic juice after partial pancreatectomy, not associated with PAF.

Among these 106 patients, the consistency and size of the pancreas were different and the pancreatic duct diameter varied, but all used Chen’s PPJ technique for anastomosis. Eighteen patients had only single layer suture without reinforce sutures; these included 5 patients who had undergone radical gastrectomy with removal of the pancreatic capsules. Two patients, whose pancreatic duct diameters were > 6mm, had stitches to the pancreatic duct openings, and subsequently, the anterior and the posterior portions of the pancreatic tissues were sutured to the anterior and the posterior walls of the jejunum, respectively. Pancreatic ducts were identified in all of these patients, and a matching stent was placed in each patient. In the event that the pancreatic ducts were difficult to find during surgery, we advocate the use of the invagination pancreaticojejunitomy technique.

CONCLUSIONS

In summary, Chen’s PPJ is a novel surgical technique. It has a new design concept and a new suturing method. It is different from the traditional invagination pancreaticojejunal anastomosis and the “duct-to-mucosa” anastomosis techniques. It is a simple, reliable, and safe method to conduct anastomosis and can be used widely.

Author Contributions

Study conception and design: Chen
Acquisition of data: X Zhu, Huang
Analysis and interpretation of data: X Zhu, Y Zhu
Drafting of manuscript: Chen, X Zhu
Critical revision: Chen, X Zhu
REFERENCES