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Our Contrivances to Diminish Complications After Pylorus-Preserving Pancreaticoduodenectomy

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The objective of this study is to diminish postoperative complications after pylorus-preserving pancreaticoduodenectomy. Pylorus-preserving pancreaticoduodenectomy is still associated with major complications, especially leakage at pancreatojejunostomy and delayed gastric emptying. Traditional pylorus-preserving pancreaticoduodenectomy was performed in group A, while the novel procedure, an antecolic vertical duodenojejunostomy and internal pancreatic drainage with omental wrapping, was performed in group B (n = 40 each). We compared the following characteristics between the 2 groups: operation time, blood loss, time required before removal of nasogastric tube and resumption of food intake, length of hospital stay, and postoperative complications. The novel procedure required less time and was associated with less blood loss (both $P <$ 0.0001). In the comparison of the 2 groups, group B showed less time for removal of nasogastric tubes and resumption of food intake, shorter hospital stays, and fewer postoperative complications (all $P < 0.0001$). The novel procedure appears to be a safe and effective alternative to traditional pancreaticoduodenectomy techniques.

Key words: Pylorus-preserving pancreaticoduodenectomy (PPPD) – Internal stent – Omental wrapping – Postoperative stay

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Pylorus-preserving pancreaticoduodenectomy (PPPD) has replaced conventional pancreaticoduodenectomy (PD) as the standard operation for both benign and malignant conditions.[1,2] Pylorus-preserving pancreaticoduodenectomy was first reported by Watson in 1944 and popularized by Traverso in 1978. Mortality related to PD has been reduced, or even eliminated[3–5]; however, in comparison with other abdominal operations such as gastrectomy and rectal surgery, PPPD has a high morbidity rate.[6–9] Pancreatic fistula is one of the most difficult complications to eradicate in both PD and PPPD. In addition, delayed gastric emptying is a specific complication of PPPD. These complications may extend the duration of hospital stay required after the operation.

Sugiyama *et al*[10] first reported that delayed gastric emptying can be prevented by a vertical duodenojejunostomy. Since then, antecolic reconstruction and vertical stomach reconstruction have also been reported to be useful procedures for minimizing the adverse effects in both pancreaticojejunostomy and pancreaticogastrostomy.[11,12] The likelihood of a pancreatic fistula can also be reduced, by a duct-to-mucosa pancreaticojejunostomy[3,13,14] and by the use of omental wrapping.[15] However, none of the studies have examined whether the complications after PPPD would be diminished if vertical reconstruction, antecolic reconstruction, internal drainage, and omental wrapping were simultaneously performed.

To address this problem, we developed a new reconstruction method for preventing delayed gastric emptying and pancreatic fistula. Here, we describe this new technique for the first time, and compare the efficacy of this technique with that of our classical method.

Methodology

We performed a retrospective study of 80 consecutive patients who underwent a PPPD reconstructed by the modified Child's method with an extended lymph node dissection (D2 dissection, according to the General Rules for the Study of Pancreatic Cancer in Japan). The patients were divided into 2 treatment groups. Group A included patients who had undergone conventional PPPD according to the modified child's method, with preservation of the right gastric artery, external biliary and pancreatic drainage, and instrumental duodenojejunostomy (Fig. 1a). Group B included patients who had undergone with the new reconstruction techniques, an antecolic vertical duodenojejunostomy, internal pancreatic drainage, and omental wrapping (Fig. 1b). All operations were either performed or supervised by T.S.

There were no statistically significant biases between the 2 groups with respect to age, sex, primary lesion, incidence of concurrent illness, method of biliary drainage, rate of portal vein reconstruction, or incidence of soft pancreas (Table 1). The following concurrent illnesses and conditions were observed in group A and group B: hypertension (group A: 8 versus group B: 6); diabetes mellitus (10 versus 12); chronic obstructive pulmonary disease (COPD; 5 versus 3); renal dysfunction (6 versus 4); a previous abdominal operation (6 versus 4); arrhythmia (5 versus 1); a previous myocardial infarction (3 versus 1); and others (8 versus 5).

To evaluate the effects of the procedure type on recovery time, we measured the following characteristics: the length of the hospital stay after the operation, the time at which the nasogastric tube could be removed, the length of time required until patients could resume eating, and the number of postoperative complications. These included pancreatic fistula, which was diagnosed according to the criteria of the International Study Group of Pancreatic Surgery (ISGPS), and delayed gastric emptying, which was diagnosed: when the excretion of gastric juice from the nasogastric tube exceeded 300 mL/day at the end of 10 days; when the nasogastric tube had to be reinserted because of vomiting; or when the patient was incapable of tolerating a regular diet after the postoperative day 14.

The nasogastric tube could be removed when it excreted less than 100 mL of gastric juice per day, and the patient was then permitted to start water intake. If the patient showed no obvious abnormalities after water intake for 1 to 2 days, food intake was resumed.

Pancreaticojejunostomy

During the surgical procedure for group A, the pancreas was resected with a scalpel, after which a pancreatic stent tube (Sumitomo Bakelite Company, Tokyo, Japan) was placed through the jejunal limb in order to provide external drainage. The stent tube was fixed to the pancreatic duct by a ligature to allow completely external drainage. As shown in Fig. 2, the parenchyma of the pancreas was sutured to the jejunal limb with an interrupted 3-0 hexafluoropropylene-vinylidene fluoride (PVDF, Pronova, Ethicon,

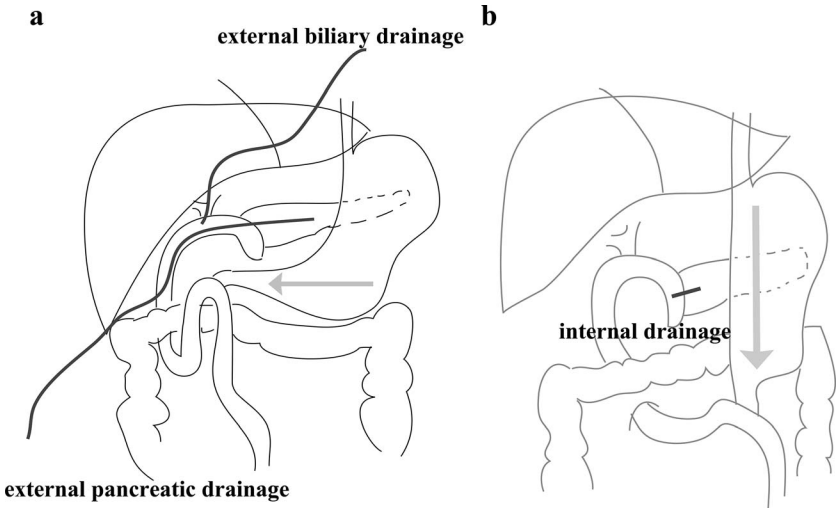

Fig. 1 Schematic of the reconstruction after PPPD. (a) Our conventional reconstruction with external pancreatic and biliary drainage. As the right gastric artery is preserved, the passage of food in the stomach is horizontal to the pyloric ring. (b) Our novel reconstruction. Passage of food in the stomach is vertical to the pyloric ring. Internal pancreatic drainage has been employed.

New Brunswick, New Jersey) in 2 layers. This suturing between the parenchyma of the pancreas and the jejunum was performed using the same method as that used in our novel reconstruction. No omental wrapping was used.

During the surgical procedure for group B, the pancreas was resected with coagulating shears. The proximal jejunum was divided near the ligament of Treitz. The divided proximal jejunum was brought through a newly opened hole in the transverse

Table 1 Patients' demographic and clinical characteristics

	Group A (n = 40)	Group B (n = 40)	*P*
Age (range)[a]	63.6 ± 11.4 (26–85)	67.0 ± 9.1 (47–82)	NS
Sex			NS
Male, %	22, 55.0	25, 62.5	
Female, %	18, 45.0	15, 37.5	
Disease			NS
Panc ca, %	15, 37.5	8, 20.0	
Biliary ca, %	19, 47.5	20, 50.0	
IPMN, %	3, 7.5	8, 20.0	
Others, %	3, 7.5	4, 10.0	
Current illness[b]			NS
+, %	27, 67.5	25, 62.5	
–, %	13, 32.5	15, 37.5	
Biliary drainage			NS
None	9, 22.5	11, 27.5	
EBD	24, 60.0	27, 67.5	
PTCD	7, 17.5	2, 5.0	
Soft pancreas			NS
+, %	17, 42.5	23, 57.5	
–, %	23, 57.5	17, 42.5	
Duration of operation, min[a]	463 ± 89	362 ± 89	<0.0001
Blood loss, g[a]	1068 ± 602	570 ± 249	<0.0001
Blood transfusion			NS
+, %	7, 17.5	1, 2.5	
–, %	33, 82.5	39, 97.5	
Portal vein reconstruction			NS
+, %	3, 7.5	3, 7.5	
–, %	37, 92.5	37, 92.5	

Biliary ca, biliary tract cancer; EBD, endoscopic biliary drainage; IPMN, intraductal papillary mucinous neoplasm of the pancreas; NS: not significant; Panc ca, pancreatic cancer; PTCD, percutaneous transhepatic cholangio-drainage.

[a]Values are mean ± SD.

[b]Except for jaundice and liver dysfunction.

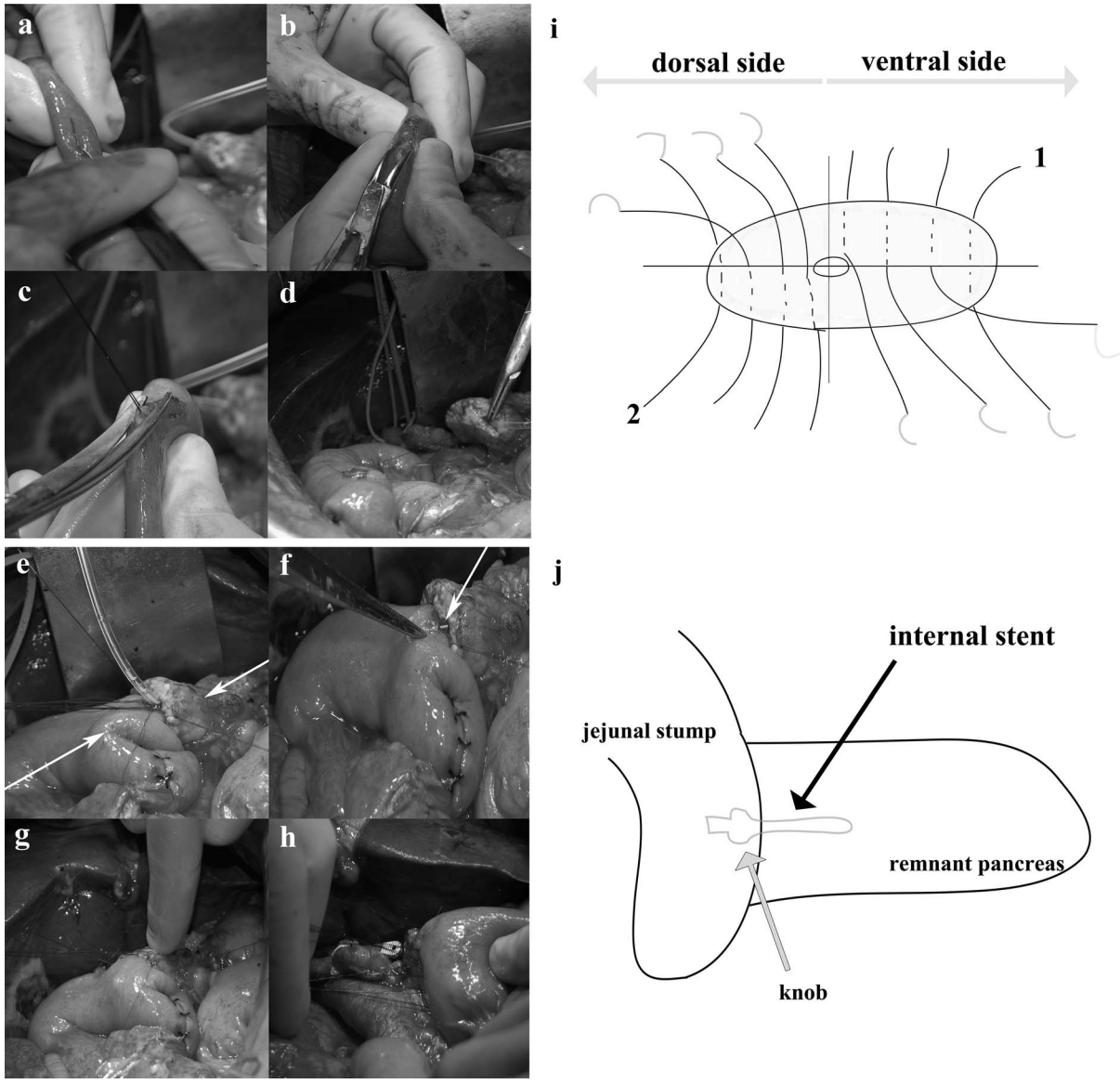

Fig. 2 Operation procedures during the PPPD. (a) The seromuscular layer of the jejunum was cut with a scalpel. (b) The muscular layer of the jejunum was divided using mosquito Péan forceps. (c) A small hole was made adjacent to the pancreatic duct using scissors. A stay suture was pulled to make the hole smaller. (d) During duct-to-mucosa pancreaticojejunostomy, the pancreatic duct was never touched directly. A space to suture the pancreatic duct was produced by moving the inserted pancreatic tube. (e) The posterior wall suturing of the pancreatic duct was finished. The right arrow shows the pancreatic remnant and the left shows the jejunal stump. The pancreatic tube was not yet cut. (f) A cut was made 4 cm from the top of the pancreatic tube. A knob 3 cm away from the top was inserted into the jejunum to avoid straying into the pancreatic remnant. The arrow shows where the lost stent was inserted. (g) The ventral side of the pancreas was sutured to the jejunal seromuscular layer. (h) The dorsal side of the pancreas was sutured to the jejunum. (i) The schematic of the suturing between the pancreatic parenchyma and the jejunum. The right half shows the ventral side of the pancreas and the left half shows the dorsal side. It is important to ensure that no dead space is reserved between the pancreas and the jejunum, taking care not to suture the pancreatic duct. (j) Schematic of the internal stent at the pancreaticojejunostomy. A knob of the internal stent was placed in the jejunum so as to prevent migrating into the pancreatic remnant.

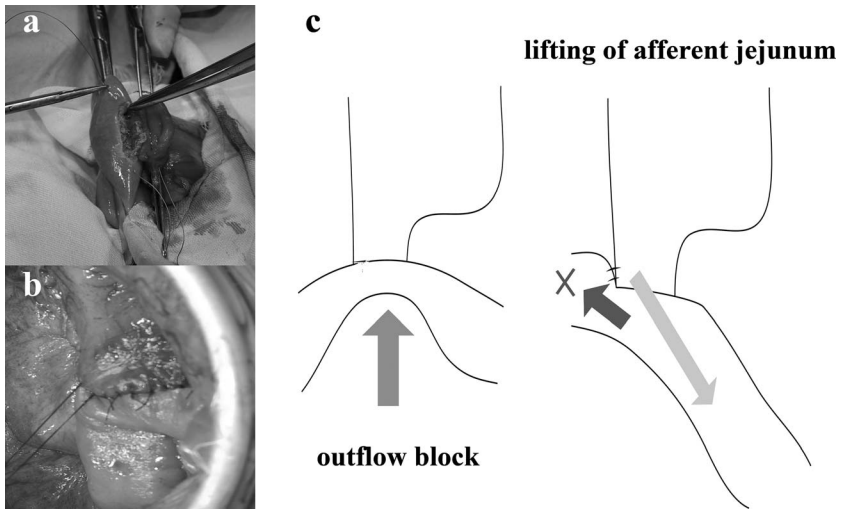

Fig. 3 Operation procedure during duodenojejunostomy. (a) A suture with 2-mm bite and 5-mm pitch was applied to the jejunum, and one with 3-mm bite and 5-mm pitch was applied to the duodenum. (b) The seromuscular layer of the afferent jejunum and remnant duodenum were sutured to prevent reflux into the afferent jejunum, as in Billroth II anastomosis. (c) The left half shows an outflow block occurring when a suture with a wider bite was applied to the jejunum. The right half shows the schematic of the lifting of the afferent jejunum. The food from the stomach goes down the efferent jejunum by the lifting of the afferent jejunum.

mesocolon, after which a cut was made in the seromuscular layer of the jejunum (Fig. 2a, 2b). A small (2–5 mm) hole was made in the jejunal mucosa adjacent to the pancreatic duct (Fig. 2c). After insertion of a pancreatic stent tube (Sumitomo Bakelite Company), a duct-to-mucosa anastomosis was performed using, an average of 8 to 10 interrupted 5-0 polydioxanone sutures (PDS II; Ethicon) without directly touching the pancreatic duct. Space for suturing was made by moving the stent tube (Fig. 2d, 2e). After posterior wall suturing, a cut was made 4 cm from the top of the pancreatic tube in order to make an internal stent. A knob located 3 cm away from the top was inserted into the jejunum to avoid straying into the pancreatic remnant (Fig. 2f, 2j). The internal stent was fixed using a posterior suture, followed by anterior wall suturing. The seromuscular layer of the jejunum was sutured to the pancreatic parenchyma with interrupted 3-0 PVDF (Ethicon; Fig. 2g–i).

Cholangiojejunostomy

When performing cholangiojejunostomy for patients in group A, we used a retrograde transhepatic biliary drainage tube (Sumitomo Bakelite Company) as shown in Fig. 1a. The cholangiojejunostomy was performed using interrupted 4-0 sutures (Ethicon).

In group B, the cholangiojejunostomy was performed using interrupted 4-0 sutures (Ethicon) without external drainage. When the 2 bile ducts had to be manipulated into 1 anastomotic orifice, an internal stent with a length of 3 cm was inserted into the smaller duct. A hole with approximately the same size as the bile duct was made on the jejunal limb. Before starting the anastomosis, four 5-0 sutures (Ethicon) were placed at 90° intervals around the hole for the anastomosis so as to include all layers of the jejunum into the suturing.

Antecolic vertical duodenojejunostomy

In group A, the right gastric artery was preserved and end-to-side duodenojejunostomy was performed using a suturing device (Premium Plus EEA; Covidien, Dublin, Ireland) without Braun anastomosis (Fig. 1a).

In group B, the right gastric artery was resected, and duodenojejunostomy was performed by Gambee's method with interrupted 3-0 polyglactin 910 Sutures (Coated Vicryl; Ethicon) without Braun anastomosis (Fig. 3a). To avoid blocking outflow at the anastomosis, a suture with a 2-mm bite and a 5-mm pitch was applied to the jejunum, and a suture with a 3-mm bite and a 5-mm pitch was applied to the duodenum (Fig. 3c). We used the antecolic route, which allowed better stomach motility in our preliminary study (data not shown). To prevent reflux into the afferent route, 2 to 3 sutures were placed between the seromuscular layer of the afferent jejunum and the duodenum (Fig. 3b).

After performing the other anastomoses, an omental wrapping was placed around the pancreaticojejunostomy via the retrogastric route (Fig. 4). This step differs from that employed in the previously reported technique, in which the omentum had been placed in front of the splanchnic vessels.[11,15]

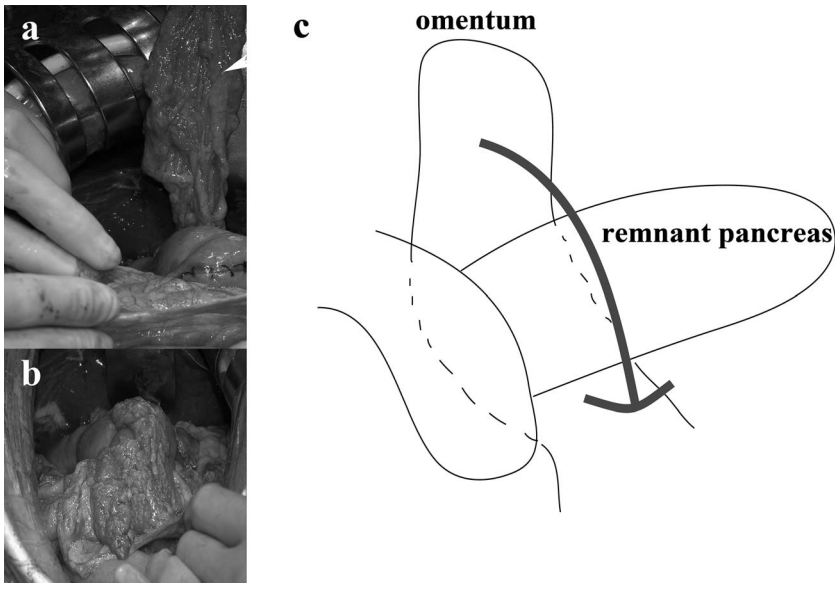

Fig. 4 Operation procedure during an omental wrapping. (a) The tip of the omentum was taken out behind the pancreaticojejunostomy via a retrogastric route. (b) The pancreaticojejunostomy was wrapped with the omentum. When the omentum was too thick to be taken out behind the anastomosis, a certain degree of trimming was required. (c) The schematic of the omental wrapping.

Statistical analysis

Values were expressed as mean ± standard deviation or standard error of the mean (SEM), and as a range, when appropriate. Student's *t*-tests, χ^2 tests, and Fisher's exact tests were used to investigate the differences between the 2 treatment groups. Significance was defined as $P < 0.05$.

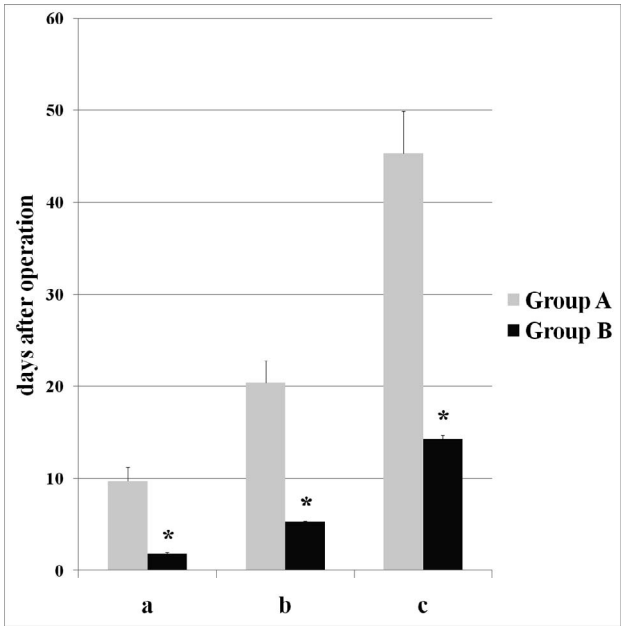

Fig. 5 Comparisons of postoperative characteristics between the 2 treatment groups. (a) Length of time required before the nasogastric tube could be removed. (b) Length of time before food intake could resume. (c) Length of hospital stay required. All data are presented as mean ± SEM. The asterisk (*) indicates $P <$ 0.0001.

Results

Operations performed using the new technique required significantly less time to complete (group B: 362 ± 89 minutes versus group A: 463 ± 89 minutes; $P < 0.0001$). The new technique was also associated with significantly less intraoperative blood loss (570 ± 249 g versus 1068 ± 602 g; $P <$ 0.0001). Operative mortality in both groups was zero.

After pylorus-preserving pancreaticoduodenectomy, patients in group A required a nasogastric tube for more time than patients in group B (9.7 ± 1.5 days versus 1.8 ± 0.2 days, respectively; $P <$ 0.0001), could not begin eating solid food (e.g., rice porridge) until much later (20.4 ± 2.4 days versus 5.3 ± 0.1 days, respectively; $P < 0.0001$), and required longer postoperative hospital stays (45.3 ± 4.6 days versus 14.3 ± 0.4 days, respectively; $P <$ 0.0001; Fig. 5). While none of the patients in group A could eat a regular diet until 14 days after the operation, all patients in group B could eat a regular diet by 7 days after resumption of food intake. All inserted drainage tubes could be withdrawn within 7 days after the operation in group B, but none of the drainage tubes could be removed within 7 days after the operation in group A because the excretion from the tubes did not reduce to less than 100 mL/day.

The rate of the occurrence of postoperative complications in group A (n = 21 patients, 52.5%)

Table 2 Complications associated with procedure

	Group A (n = 40)	Group B (n = 40)	*P*
Surgical complication	$P < 0.0001$		
+, %	21, 52.5	2, 5.0	
–, %	19, 47.5	38, 95.0	
Details			
Pancreatic fistula, %	6, 15.0	0, 0.0	0.0255
Delayed gastric emptying, %	17, 42.5	0, 0.0	<0.0001
Biliary leakage, %	3, 7.5	0, 0.0	NS
Leakage of duodenojejunostomy, %	1, 2.5	0, 0.0	NS
Ileus, %	6, 15.0	0, 0.0	0.0255
Pneumonia, %	0, 0.0	1, 2.5	NS
Wound infection, %	2, 5.0	1, 2.5	NS

was significantly higher than that in group B (n = 4 patients; 10.0%; $P < 0.0001$; Table 2). No patients in group B experienced a pancreatic fistula or delayed gastric emptying. However, pancreatic fistula and delayed gastric emptying occurred in 6 (15.0%) and 17 (42.5%) patients in group A, respectively ($P = 0.0255$, and $P < 0.0001$, respectively).

Discussion

We found that our new method for PPPD was quicker, caused lower levels of blood loss, facilitated faster recovery, and was associated with fewer postoperative complications. This is an encouraging finding because although the hospital mortality rates associated with PPPD have markedly decreased to less than 4% in high-volume centers, the procedure continues to be associated with high rates (up to 40%) of postoperative complications. For instance, patients who undergo PPPD may show insufficient anastomoses (pancreaticojejunostomy, pancreaticogastrostomy, cholangiojejunostomy, duodenojejunostomy or gastrojejunostomy) and delayed gastric emptying. In our study, the patients who underwent the novel reconstruction experienced no delayed gastric emptying or pancreatic fistula.

Many attempts have been made to reduce the delayed gastric emptying rates. The most favorable surgical improvement among these is the vertical antecolic reconstruction performed during gastro- or duodenojejunostomy.[10–12] Sugiyama *et al*[10] has reported that, despite being atonic with decreased peristalsis, the stomach functions well as a passive conduit through which food empties into the jejunum under the influence of gravitational force alone. Our data support this argument. We also added 1 or 2 seromuscular sutures to the afferent jejunum during duodenojejunostomy. It is unclear whether this is one of the factors that reduced the incidence of delayed gastric emptying; regardless, the addition of this technique was useful and did not cause any adverse events, which lead us to encourage its use. There has been a debate on whether the pylorus should be preserved when performing pancreaticoduodenectomy, in order to prevent delayed gastric emptying.[8,11,12,16] Furthermore, there has been a report that nasogastric drainage may be unnecessary after pylorus preserving pancreaticoduodenectomy.[17] Our data indicate that pylorus-preservation did not cause delayed gastric emptying. This might support postoperative management without nasogastric drainage. However, skeletonization around the pylorus, which may occur as a result of resecting the right gastric artery, might cause circulatory disturbances in the pylorus. In group B, 1 patient experienced minor leakage at the duodenojejunostomy. Thus, if possible, the supraduodenal artery and its minute branches should be preserved. After we preserved the supraduodenal artery, no leakage occurred at this site.

Pancreatic fistula is one of the most severe complications after PPPD. There are 2 main methods that are used for anastomosis: pancreaticogastrostomy and pancreaticojejunostomy. Pancreaticogastrostomy was justified by several reports indicating that this method reduces the rate of anastomotic insufficiency.[18–20] Because insufficient pancreaticogastrostomy prevents commencement of oral intake and therefore increases the required length of hospital stay, we chose to use pancreaticojejunostomy as our new reconstruction approach.

Scalpels, ultrasonic curettage devices, and coagulating shears have all been reported as useful instruments for performing pancreatic resections. However, although coagulating shears have been reported to be useful for preventing bleeding and pancreatic fistulas, their benefits remain controversial.[21–23] We suspect that our use of coagulating shears may be one of the factors that contributed to the low level of intraoperative blood loss and pancreatic fistula observed in group B. However, the reduction in blood loss could also be attributed to the shorter duration of the operation and to the overall simplicity of the procedure, which did not require external pancreatic and biliary drainage. Thus, to more fully understand whether the coagulating shears contributed to the success of the procedure used in group B, it will be necessary to conduct a prospective randomized controlled study.

The use of external drainage, internal drainage, or no stents for pancreatic drainage is still controversial. To the best of our knowledge, there are only 2 randomized controlled studies that investigated this issue. Poon *et al*[24] reported that the leakage rate of pancreaticojejunostomies performed with external drainage of the pancreatic duct with a stent was lower than that in the no-stent group. Tani *et al*[25] reported that the incidence of pancreatic fistulas was not different between external and internal drainage. On the other side, our work also supports the results of the study by Tani *et al*,[25] who suggested that internal pancreatic drainage simplifies postoperative management and shortens postoperative stays. Taken together, internal drainage seems to have certain advantages. As for using omental wrapping, Satoi *et al*[15] reported that the occurrence of pancreatic fistulas in the patients who underwent pancreaticojejunostomies with Kakita's method and omental wrapping was significantly lower (6%) than that in the group who underwent pancreaticojejunostomies with the dunking method (19%). As our patients who underwent the novel reconstruction experienced no pancreatic fistulas, our data seem to confirm the usefulness of the omental wrapping.

Our new reconstruction method was associated with no major post-PPPD complications, reduced the duration of nasogastric tube use, allowed meal intake to resume more rapidly, and reduced the length of postoperative stays; therefore, we conclude that it is an improvement over the classical techniques and warrants further research. A randomized control study is required to establish the value of the new reconstruction method.

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