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A novel technique of pancreaticojejunostomy for laparoscopic pancreaticoduodenectomy

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Abstract

Background Pancreaticojejunostomy (PJ) reconstruction is the Achilles' heel of laparoscopic pancreaticoduodenectomy (LPD). However, only a few studies have focused on the performance of this difficult procedure laparoscopically.

Methods We present a safe and feasible technique of duct-to-mucosa pancreaticojejunostomy for LPD, named Bing's anastomosis. Our study included 238 cases of LPDs that underwent Bing's anastomosis. Data on the demographic characteristics, operative outcomes (total operative time, PJ duration, and estimated blood loss), and postoperative results (length of hospital stay, recovery of bowel function, and rates of postoperative morbidity and mortality) of the cases were prospectively collected and retrospectively analyzed.

Results Only one patient (0.4%) in our series required conversion to open surgery as a result of uncontrolled bleeding from the superior mesenteric artery. The average operative time was 358 min (220 min to 495 min). The mean duration for PJ was 23 min (19 min to 33 min). The mean estimated blood loss was 112 ml (50 ml to 800 ml). The overall incidence of pancreatic fistula was 21.4% and included 42 cases (17.6%) of biochemical leak, eight cases (3.4%) of Grade B, and one case (0.4%) of Grade C pancreatic fistulas. The 90-day mortality was 0.4%.

Conclusions Bing's anastomosis is a safe, reliable, and rapid PJ technique for LPD that is associated with favorable outcomes and a low risk of pancreatic fistula. However, its safety and feasibility should be verified by performing prospective randomized controlled trials at different institutions.

Keywords Laparoscopic · Pancreaticoduodenectomy · Pancreaticojejunostomy · Pancreatic fistula

Pancreaticoduodenectomy (PD) was first reported by Walther Kausch in 1901 [1]. This procedure is indicated for various diseases involving the pancreatic head or the periampullary region and is one of the most challenging procedures in gastrointestinal surgery. Although advances in surgical technique and perioperative management have substantially decreased the postoperative mortality and morbidity rates associated with PD, its morbidity rate still ranges from 32 to 52% [2–4]. Pancreatic fistula is a crucial complication and also the main cause of mortality among patients who underwent PD [5, 6]. Specifically, the occurrence of pancreatic fistulas may cause the majority of complications, including intra-abdominal fluid collection, abdominal abscess, hemorrhage, and possible death [7].

Numerous anastomotic methods and their modifications, including pancreaticogastrostomy, duct-to-mucosa anastomosis, and PD with or without external pancreatic duct drainage, have been proposed to decrease the rates of pancreatic fistula among patients undergoing LPD [8, 9]. Laparoscopic PD (LPD) was first reported in 1994 [10], and numerous studies have demonstrated that compared with open PD, LPD might be associated with shorter hospital stay, lower estimated blood loss, and superior short-term oncologic and long-term overall survival outcomes [11–13]. Similar to open surgery, pancreaticojejunostomy (PJ) is the most challenging of the three enteric anastomosis performed

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during LPD. Herein, we present Bing's anastomosis, a safe and feasible technique for duct-to-mucosa PJ for LPD based on our own experience.

Materials and methods

We performed our first case of LPD in November 2010. To date, we have performed more than 300 cases of LPDs. We began to perform LPDs using Bing's PJ in March 2015. Two hundreds and thirty-eight cases of LPDs were included in this study. Patients with vascular involvement were excluded in this study. All surgeries were performed by two surgeons (Dr. Peng: 223 cases; Dr. Cai: 15 cases) from a single surgical team. Data on the demographic characteristics (age, sex, body mass index, American Society of Anesthesiology, and histopathologic diagnosis), operative outcomes (total operative time, PJ duration, and estimated blood loss), and postoperative results (length of hospital stay, recovery of bowel function, and rates of postoperative morbidity and mortality) of the cases were prospectively collected and retrospectively analyzed. All patients were informed about the possible advantages and disadvantages of laparoscopic surgery, and informed consent was obtained.

Operative procedure

Patient position and trocar distribution

The patients were placed in the supine position. Anti-Trendelenburg position (30°–45°) was used. Five trocars were symmetrically distributed: One 10-mm umbilical trocar for the laparoscope port, two 12-mm trocars located at the right and left flank of rectus abdominis, and one 12-mm trocar and one 5-mm trocar distributed at the left and right midclavicular.

PJ procedure

The pancreas was dissected over the superior mesenteric vein using an ultrasonic scalpel, and the pancreatic stump remnant was dissected to approximately 1 cm. The main pancreatic duct was dissected using cold scissors. The complete hemostasis of the pancreatic stump was achieved prior to PJ using an electronic coagulator or suturing.

Bing's duct-to-mucosa PJ included four layers of sutures. The first layer of the anastomosis was performed between the posterior wall of the pancreas and the seromuscular layer of the jejunum. Running suturing was performed for this layer using 4-0 Prolene (approx. 25 cm in length). We did not tie the knot for the first and last stitches. Instead, we clipped the tail of the Prolene with a titanium clip to prevent its slippage (Figs. 1A, 2A). A plastic catheter was then inserted as an internal stent into the main pancreatic duct, and a hole was created in the jejunum using the electronic coagulator or the ultrasonic scalpel. The second layer of the anastomosis was created between the posterior wall of the main pancreatic duct and the full layer of the jejunum. A figure-eight suture was carried out for this layer by using 5-0 PDS suture (Figs. 1B, 2B). We tightened up the Prolene of the first layer to shorten the distance between the jejunum and pancreatic stump before tying the knot of the PDS suture. Meanwhile, the third layer of the anastomosis was made between the anterior wall of the main pancreatic duct and the anterior wall of the jejunum. Running suturing was applied for this layer using 5-0 PDS suture (Figs. 1C, 2C). Finally, the fourth layer of the anastomosis was made between the anterior wall of the pancreatic stump and the seromuscular layer of the jejunum using the previous Prolene for the first layer. We performed running suturing for this layer from the lower edge to the upper edge and tightened up the Prolene again. We then tied the knot to close the space between the pancreatic stump and the jejunum (Figs. 1D, 2D).

Definition

Pancreatic fistula was defined in accordance with the criteria set by the International Study Group on Pancreatic Fistula [14]. Delayed gastric emptying was defined as gastric stasis requiring nasogastric intubation for more than 7 days or the reinsertion of a nasogastric tube after the failure of postoperative feeding [15]. Mortality was defined as death that is directly or indirectly associated with operation and that occurred within 90 days of surgery. The length of hospital stay was calculated from the day of surgery to the day of discharge (including the day of discharge).

Results

The demographic characteristics of the patients included in our study are shown in Table 1. This study included 238 cases of LPD (135 male patients and 103 female patients) that underwent Bing's anastomosis. The mean age of these patients was 65.2 years (13–84 years). The average body mass index of the patients was 22.8 kg/m^2 (18.3–29.2 kg/m^2). The final pathological diagnoses included ampullary adenocarcinoma (75 cases), pancreatic ductal adenocarcinoma (47 cases), distal cholangiocarcinoma (39 cases), duodenal adenoma (20 cases), solid pseudopapillary tumor (16 cases), cystadenoma (16 cases), pancreatic neuroendocrine tumor (13 cases), chronic pancreatitis (six cases), neurilemmoma (three cases), and others (three cases).

The surgical outcomes and postoperative details were shown in Table 2. Only one patient (0.4%) in our series

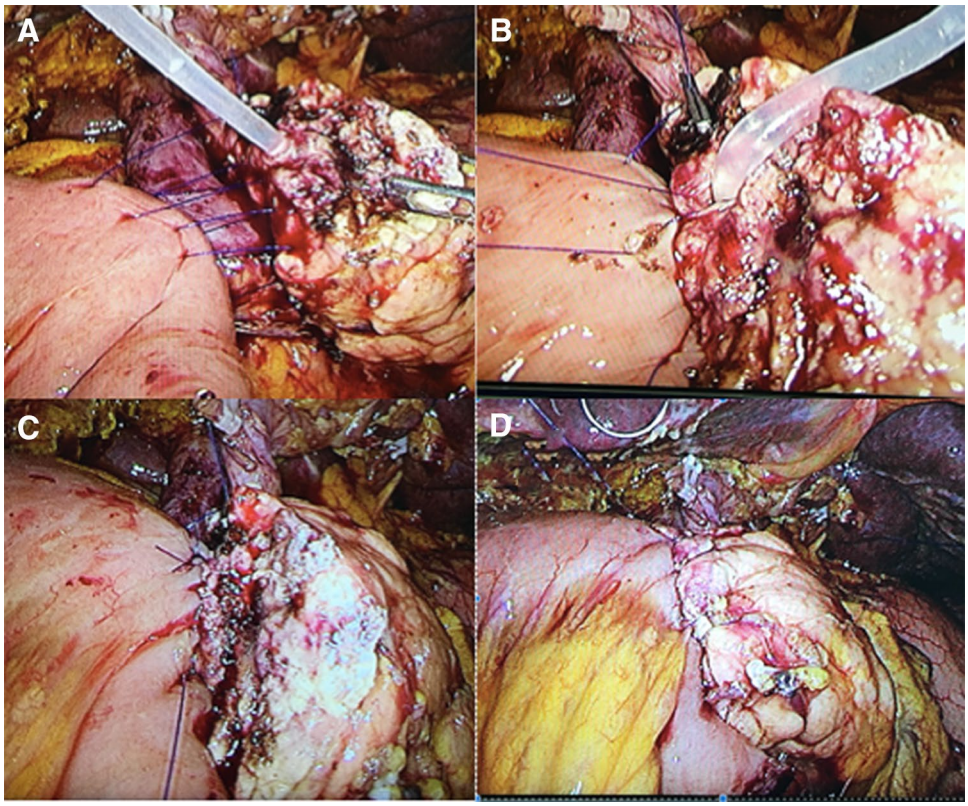

Fig. 1 Color pictures of pancreaticojejunostomy procedure. **A** The first layer: A running suture was performed between the posterior wall of the pancreatic stump and the posterior seromuscular layer of the jejunum. **B** The second layer: A figure-eight suture was performed between the posterior wall of the main pancreatic duct and the full layer of the jejunum. **C** The third layer: A running suture was performed between the anterior wall of the main pancreatic duct and the anterior wall of the jejunum. **D** The fourth layer: A running suture was performed between the anterior wall of the pancreatic stump and the seromuscular layer of the jejunum

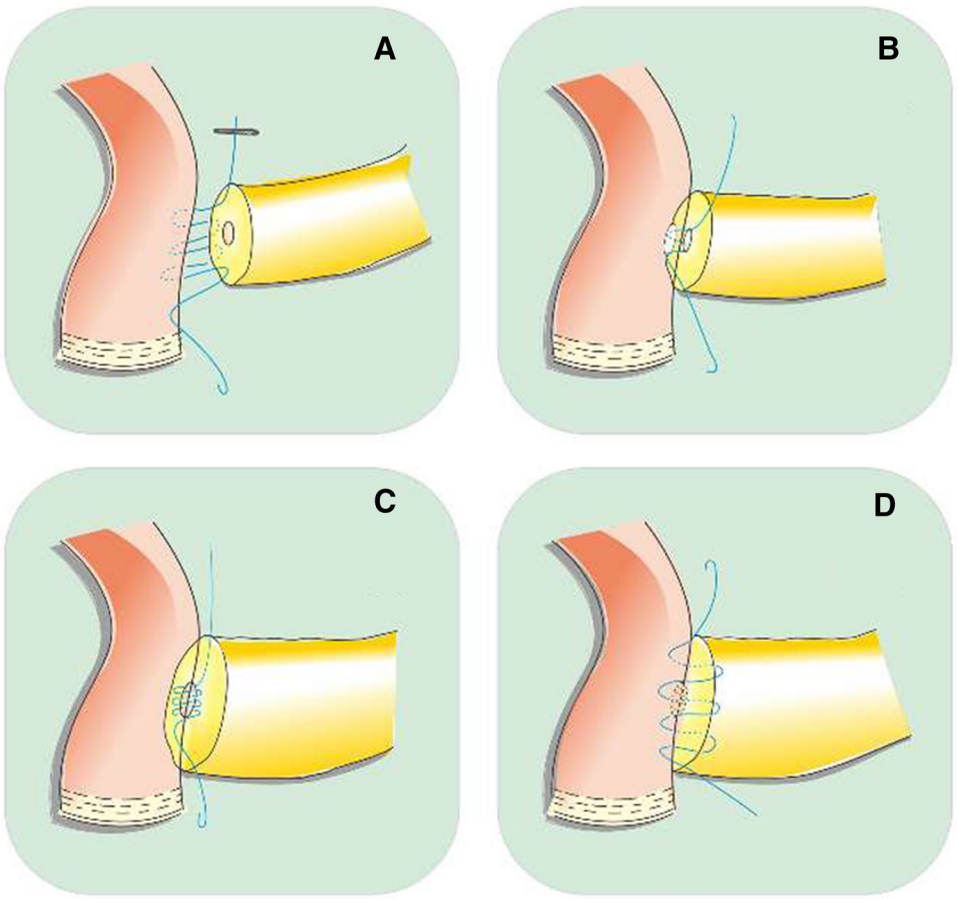

Fig. 2 Mode chart of pancreaticojejunostomy procedure. **A** The first layer: A running suture was performed between the posterior wall of the pancreatic stump and the posterior seromuscular layer of the jejunum. **B** The second layer: A figure-eight suture was performed between the posterior wall of the main pancreatic duct and the full layer of the jejunum. **C** The third layer: A running suture was performed between the anterior wall of the main pancreatic duct and the anterior wall of the jejunum. **D** The fourth layer: A running suture was performed between the anterior wall of the pancreatic stump and the seromuscular layer of the jejunum

Table 1 The demographic characteristics

Variables	
Cases	238
Age (years)[a]	65.2 (13–84)
Sex (male/female)	135/103
American Society of Anesthesiology	
II	217
III	21
Pathological diagnosis	
Ampullary adenocarcinoma	75
Pancreatic ductal adenocarcinoma	47
Distal cholangiocarcinoma	39
Duodenal adenoma	20
Solid pseudopapillary tumor	16
Cystadenoma	16
Pancreatic neuroendocrine tumor	13
Chronic pancreatitis	6
Neurilemmoma	3
Others	3

[a]Data are expressed as median and interquartile range

Table 2 The surgical outcomes and postoperative details

Variables	
Operative time (min)[a]	358 (220–495)
Duration for pancreaticojejunostomy (min)[a]	23 (19–33)
Estimated blood loss (ml)[a]	112 (50–800)
Conversion (*n*,%)	1 (0.4%)
Transfusion (*n*,%)	11 (4.6%)
Postoperative hospital stay (days)[a]	10.2 (5–19)
Time to first passage of flatus (days)[a]	2.2 (1–4)
Complications (*n*,%)	
Pancreatic fistula	51(21.4%)
Biochemical leak	42 (17.6%)
Grade B	8 (3.4%)
Grade C	1 (0.4%)
Bile leakage	6 (2.5%)
Delayed gastric emptying	17 (7.1%)
Postoperative bleeding	3 (1.3%)
Abdominal fluid collection	4 (1.7%)
Chylous fistula	5 (2.1%)

[a]Data are expressed as median and interquartile range

required conversion to open surgery due to uncontrolled bleeding from the superior mesenteric artery. The average operative time was 358 min (220–495 min). The mean PJ duration was 23 min (19–33 min). The mean estimated blood loss was 112 ml (50–800 ml). The overall incidence of pancreatic fistula was 21.4%, including 42 cases (17.6%) of biochemical leak, eight cases (3.4%) of Grade B, and one case (0.4%) of Grade C pancreatic fistulas. Seventeen patients (7.1%) suffered from delayed gastric emptying, which was treated with conservative therapy. Six patients (2.5%) suffered from bile leakage. Five patients (2.1%) suffered from chylous fistula, which was treated through conservative therapy. Four patients suffered from abdominal fluid collection. Among these patients, three required percutaneous drainage, and one required re-operation. Another patient required re-operation as a result of abdominal bleeding on the first postoperative day. One patient suffered from abdominal bleeding as a result of gastroduodenal artery pseudoaneurysm on the eleventh postoperative day. This patient underwent angiography and arterial embolization therapy and was eventually discharged on the eighteenth postoperative day. However, one patient died of abdominal bleeding on the tenth postoperative day. The 90-day mortality rate of this case series was 0.4%.

Discussion

LPD has been regarded as one of the most challenging procedures for minimally invasive gastrointestinal surgery since it was first reported by Gagner in 1994 [10]. Along with the improvement of surgical experience, LPD was reported as a safe and feasible procedure in several high-volume pancreatic centers. Similar to open surgery, however, PJ reconstruction is the Achilles' heel of LPD. Nevertheless, only a few studies have focused on the performance of this difficult procedure laparoscopically.

The best pancreatic anastomosis technique after PD remains controversial. Overall, although pancreaticogastrostomy may be associated with the lower occurrence of pancreatic fistula than PJ [16, 17], PJ remains the preferred method for pancreatic anastomosis after PD for most surgeons [18]. Two kinds of PJ techniques, duct-to-mucosa and invagination, were always debatable in terms of reducing pancreatic fistula rate. From a technical viewpoint, invagination is considerably easier to perform than the duct-to-mucosa technique. A meta-analysis has shown that the pancreatic fistula rate of duct-to-mucosa PJ is not superior to that of invagination PJ [19]. Nevertheless, duct-to-mucosa sutures are beneficial for the healing of anastomosis. Furthermore, the pancreatic stump could be covered by the seromuscular layer of the jejunum. This coverage may prevent bleeding from the pancreatic stump. Duct-to-mucosa PJ is a technically demanding procedure but is widely applied in LPD. Bing's anastomosis is a type of duct-to-mucosa PJ. Given the magnification effect of laparoscopy, performing precise duct-to-mucosa anastomosis is feasible even in cases with small pancreatic ducts. In our practice, Bing's anastomosis enables the performance of laparoscopic duct-to-mucosa PJ in cases wherein the main pancreatic duct is smaller than

3 mm. Locating the main pancreatic duct is essential in LPD. Generally, the main pancreatic duct is located in the upper posterior portion of the pancreatic parenchyma in the pancreatic neck. We, however, failed to locate the main pancreatic duct in just one patient. We used an ultrasonic scalpel to dissect the pancreatic parenchyma and cold scissors to dissect the pancreatic duct.

The application of running suturing in open PD is safe, reliable, rapid, and is associated with more favorable outcomes and a lower risk of pancreatic fistula than the application of interrupted suturing [20]. Compared with interrupted suturing, running suturing is an easier and more time-saving technique that provides a more even level of tension, causes less damage to the pancreatic parenchyma and duct, and prevents anomalous anastomotic blood circulation [21]. Running suturing can also enable the uniform tightening of the space between the pancreatic stump and the jejunal wall without leaving any dead space, thus preventing the retention of pancreatic juice [20]. The disadvantages of interrupted suturing in LPD are much more apparent than those of running suturing. In duct-to-mucosa PJ, we had to perform four layers of sutures. Interrupted suturing is time-consuming and easily damages the pancreatic parenchyma. Furthermore, untied interrupted sutures may become intertwined. However, if we knot every stitch, previously tied stitches may shorten the distance between the pancreatic stump and jejunum, thus hindering the placing of the next suture. In Bing's anastomosis, we applied running suture for the first layer, and we did not knot the first and last stitches. We also did not tighten the suture of first layer until we had finished the second layer of the PJ. This technique facilitates the anastomosis of the second layer, especially in cases wherein the main pancreatic duct is located in the posterior edge of the pancreatic stump. In Bing's anastomosis, we used a single Prolene to finish the anastomosis of the first and the fourth layer of PJ. This approach uniformly tightens the pancreatic stump and the jejunal wall without any dead space. The only passage from the pancreatic stump to the jejunum is the duct-to-mucosa anastomosis. Bing's anastomosis can prevent bleeding from the pancreatic stump and pancreatic fistula from small branches of the pancreatic duct. No bleeding was noted from the pancreatic stump in our series.

The essential criteria for an "ideal" PJ technique include universal applicability regardless of pancreatic duct size and pancreatic texture with a low rate of pancreatic fistula. Moreover, its application should be feasible, consistent, and repeatable across different surgeons and institutions. Bing's anastomosis is suitable for patients with different pancreatic duct sizes and pancreatic texture. It can also be safely and feasibly performed by surgeons who are still in the first stage of the learning curve. Another surgeon in the same team performed 15 cases of LPD using Bing's anastomosis. The surgical outcomes of these cases are shown in Table 3.

Table 3 Surgical outcomes of LPD for surgeon in his stage of learning curve

Variables	
Cases	15
Operative time (min)[a]	320 (230–450)
Duration for pancreaticojejunostomy (min)[a]	28 (21–34)
Estimated blood loss (ml)[a]	145 (50–200)
Blood transfusion (*n*,%)	0
Conversion (*n*,%)	0
Postoperative stay (days)[a]	11 (9–14)
Time to first passage of flatus (days)[a]	3 (2–4)
Complications (*n*,%)	
Pancreatic fistula	3
Biochemical leak	3 (20%)
Grade B	0
Grade C	0
Bile leakage	0
Delayed gastric emptying	1 (6.7%)
Postoperative bleeding	0
Abdominal fluid collection	1 (6.7%)
Chylous fistula	1 (6.7%)

[a]Data are expressed as median and interquartile range

Only three cases of biochemical leak or pancreatic fistula occurred in this small series. No patient suffered from Grade B or Grade C pancreatic fistula. The average pancreatic duct diameter was 3.2 mm (2–7 mm), and the average time for PJ was 28 min.

Our study is associated with several limitations. First, this study is not a prospective, randomized study that might be affected by any bias. Second, all operations were performed by a single team. Our institution is a high-volume center that performs minimally invasive pancreatic resections. The surgeon, Dr. Peng, already has extensive experience in minimally invasive surgeries before he performed LPD. To date, the outcomes of LPD are affected by institutional volume [22]. Therefore, the safety and the feasibility of this technique should be verified by performing prospective randomized controlled trials at different institutions.

Conclusion

Bing's anastomosis technique for LPD is safe, reliable, rapid, and associated with a low risk of pancreatic fistula. However, the safety and feasibility of this technique should be verified by performing prospective randomized controlled trials at different institutions.

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Compliance with ethical standards

Disclosures Dr. Yunqiang Cai, Hua Luo, Yongbin Li, Pan Gao, and Bing Peng have no conflicts of interest or financial ties to disclose.

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