



ORIGINAL ARTICLE

Modified Blumgart anastomosis without pancreatic duct-to-jejunum mucosa anastomosis for pancreatoduodenectomy: a feasible and safe novel technique

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ABSTRACT

Objective: This study proposed a modified Blumgart anastomosis (m-BA) that uses a firm ligation of the main pancreatic duct with a supporting tube to replace the pancreatic duct-to-jejunum mucosa anastomosis, with the aim of simplifying the complicated steps of the conventional BA (c-BA). Thus, we observe if a difference in the risk of postoperative pancreatic fistula (POPF) exists between the two methods.

Methods: The m-BA anastomosis method has been used since 2010. From October 2011 to October 2015, 147 patients who underwent pancreatoduodenectomy (PD) using BA in Tianjin Medical University Cancer Institute and Hospital were enrolled in this study. According to the type of pancreatojejunostomy (PJ), 50 patients underwent m-BA and 97 received c-BA. The two patient cohorts were compared prospectively to some extent but not randomized, and the evaluated variables were operation time, the incidence rate of POPF, and other perioperative complications.

Results: The operation time showed no significant difference ($P > 0.05$) between the two groups, but the time of duct-to-mucosa anastomosis in the m-BA group was much shorter than that in the c-BA group ($P < 0.001$). The incidence rate of clinically relevant POPF was 12.0% (6/50) in the modified group and 10.3% (10/97) in the conventional group ($P > 0.05$), which means that the modified anastomosis method did not cause additional pancreatic leakage. The mean length of postoperative hospital stay of the m-BA group was 23 days, and that of the c-BA group was 22 days ($P > 0.05$).

Conclusions: Compared with the conventional BA, we suggest that the modified BA is a feasible, safe, and effective operation method for P J of PD with no sacrifice of surgical quality. In the multivariate analysis, we also found that body mass index ($\geq 25 \text{ kg/m}^2$) increased the risk of POPF.

KEYWORDS

Pancreatoduodenectomy; pancreatojejunostomy; modified Blumgart anastomosis; postoperative complications; postoperative pancreatic fistula

Introduction

Pancreatoduodenectomy (PD) applied as a standard surgical approach for both benign and malignant tumors of the pancreatic head and periampullary carcinoma has benefitted most patients. In the last two decades, the popularization of PD certainly profits from not the improvement of surgical techniques and instruments but the perioperative management significantly reducing the mortality rate after PD. Furthermore, several large medical records have nearly

reached a zero mortality rate^{1, 2}. However, many patients must endure the complications after operation, which include pancreatic fistula, delayed gastric emptying, postoperative pancreatic fistula (POPF)-related hemorrhage, intra-abdominal and pleural effusions, wound infection, bacteremia, and septic shock. Although the incidence of postoperative complications showed a downward trend, the desired result is still difficult to achieve^{3, 4}. POPF is considered as the most common and threatening complication, which can cause potential secondary infection, long-term hospitalization, and serious economic burden⁵. Numerous relevant literatures have reported that the occurrence of POPF is not only related to the patients' own features such as higher body mass index (BMI), soft texture of the pancreas, small pancreatic duct diameter, and high

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blood loss⁶⁻⁸, but is also influenced by the anastomosis method in pancreatojejunostomy (PJ)⁹⁻¹¹. Thus, the most urgent issue in improving postoperative condition is the development of a safer and more effective anastomotic method.

Currently, various anastomotic techniques and differences still exist in PJ. Blumgart anastomosis (BA) using a U-suture technique has attracted great attention and has been proved to be a common and effective technique¹²⁻¹⁴. On the basis of the limitation of complex operation procedures in the conventional BA (c-BA), many surgical specialists simplified the procedures and achieved satisfactory results^{5, 15, 16}. In our study, to improve the original method, we made a further change by using firm ligation of a supporting tube and the main pancreatic duct to replace the pancreatic duct-to-jejunum mucosa anastomosis of the c-BA.

In this study, we attentively present the m-BA in detail. Furthermore, we made a synthetic comparison of the m-BA and c-BA to analyze the advantages of the m-BA in improving the surgical procedure and postoperative complications.

Patients and methods

Patient selection

Between October 2011 and October 2015, 147 consecutive patients who underwent PD using BA in the Department of Hepatobiliary Surgery at Tianjin Medical University Cancer Institute and Hospital were enrolled in this study. According to the type of PJ, 50 patients underwent the modified BA (m-BA; the modified group) and the remaining 97 patients underwent the conventional BA (c-BA; the conventional group) in this retrospective study. No invasion of the superior mesenteric vessels, and distant and portal vein metastases were found in all the patients. The two patient cohorts were compared, and the evaluated variables were operation time, the incidence rate of POPF, postoperative hospital stay (POHS), and other perioperative complications.

Surgical technique

All the 147 patients underwent the standard PD performed by experienced chief physicians. The patients in the m-BA group underwent operation by our principal researcher, and in the other group, the operation was performed by two experienced surgeons in our department. The primary lesions were either distal common bile duct or periampullary carcinomas without vascular invasion. The surgical

procedure of the c-BA was similar to the classic technique reported previously¹²⁻¹⁴. Between the modified group or conventional group, no substantial differences in gastrointestinal anastomosis and cholangiojejunostomy were found, except for pancreatojejunostomy. Two drainage tubes were respectively placed at the underside of the pancreatojejunostomy and cholangiojejunostomy by routine.

Modified Blumgart anastomosis

(1) Mobilization of the main pancreatic duct (MPD): mutilation of the pancreatic parenchyma was performed with an electrothome. Small bleeding spots and small branches of pancreatic ducts according to its thickness were managed with electrical coagulation or ligated with 5-0 monofilament stitches. The MPD was freed carefully with a clamp technique, and its length was adequately up to 1–1.5 cm. (2) Placement and fixation of the MPD supporting tube: a small opening was cut with ophthalmic forceps on the side wall of the exposed MPD, and then a short anesthetic extension tube was inserted in the MPD in advance from the opening, acting as the internal stent, which used to drain the pancreatic fluid to the intestinal tract through a small opening in the jejunum (**Figure 1A**). To fully fix the internal stent and MPD, a 5-0 polypropylene suture that transverse sutured the pancreatic parenchyma was entwined for 2–4 rounds on the overlapping parts of the internal stent and MPD, and then fastened (**Figure 1B and 2**). (3) Establishment of U-sutures: five or six double-armed 3-0 polypropylene sutures were pierced through the pancreatic stump from front to back, nearly 1 cm lateral to the previous sutures, and then reverted through the posterior part of the pancreatic stump after the seromuscular layer of the jejunum was bitten (**Figure 1C**). The sutures should be clear of the MPD to avoid unnecessary damage. U-sutures were placed without tightening on the surface of the pancreas and held with rubber shod clamps separately. (4) Tightening of the U-sutures: One needle of the double-armed 3-0 polypropylene sutures was longitudinally sutured through the seromuscular layer of the jejunum (**Figure 1D**). The previous U-sutures were tightened gently and knotted in case of laceration of the pancreas. Here, we used the ventral wall of the jejunum to cover the pancreatic stump (**Figure 1E**).

Postoperative management and assessment of POPF

The vital sign and drainage of each tube were carefully

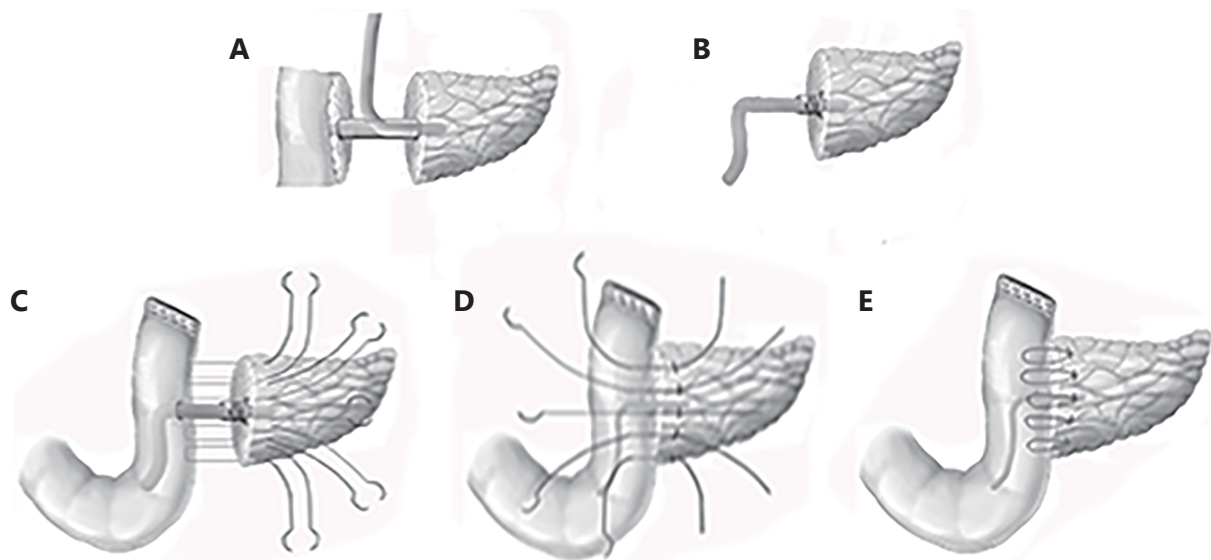


Figure 1 The operation sketch map of the modified Blumgart anastomosis. (A) The MPD was freed adequately up to 1–1.5 cm and then a short anesthetic extension tube was inserted in the MPD through the opening cut in advance. (B) A 5–0 polypropylene suture that transverse sutured the pancreatic parenchyma was entwined 2–4 laps on the overlapping parts of the internal stent and the MPD, then fasten it. (C-E) The establishment of the U-sutures.

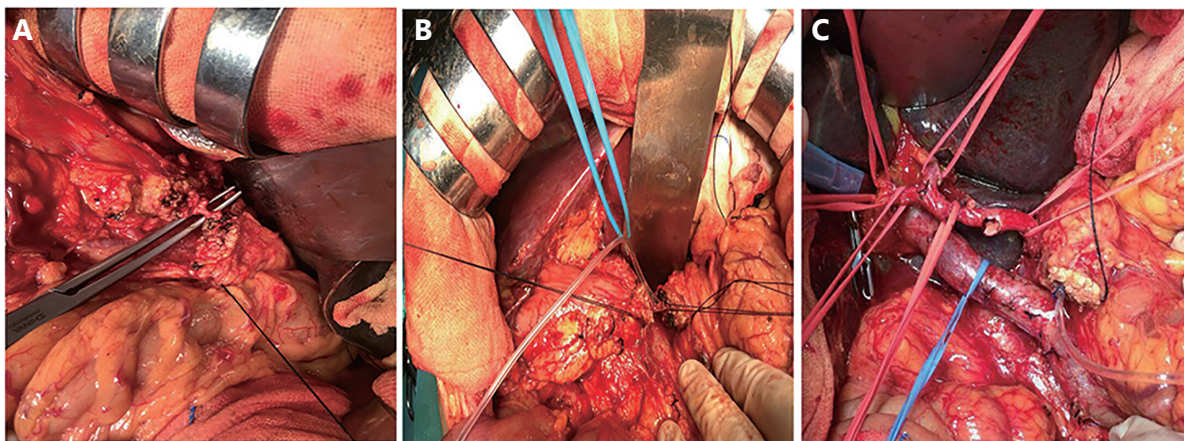


Figure 2 The operation pictures. (A) The mobilization of the main pancreatic duct (MPD). (B) The supporting tube was inserted in MPD from the side wall opening. (C) To make the internal stent and the MPD fully fixed, a 5–0 polypropylene suture that transverse sutured the pancreatic transaction was entwined 2–4 laps on the overlapping parts of the internal stent and the MPD, then fasten it.

monitored postoperatively. Prophylactic antibiotics, including second- or third-generation cephalosporin, was routinely administered, but postoperative administration of octreotide was not conventional. On the first postoperative day, bacterial examination, including aerobic and anaerobic bacterial cultures, of drainage fluid was routinely performed. At 3, 5, and 7 days, the amylase levels were measured. Blood culture, routine blood test, and abdominal ultrasonography were immediately performed if the patient had a fever. POPF

was diagnosed and graded in accordance with the International Study Group on Pancreatic Fistula (ISGPF) classification 2016¹⁷. Biochemical fistula POPF was defined as “measurable fluid output on or after postoperative day 3, with an amylase content higher than 3 times the upper normal serum level,” which has no impact on the normal postoperative pathway and POHS. Clinically significant POPF are of grades B and C. Grade B POPF requires a change in the management of the expected postoperative pathway.

Whenever reoperation is needed or organ failure occurs, the fistula shifts to a grade C POPF.

Data collection and outcome measures

The clinical related data collected and analyzed included age, sex, preoperative serum albumin, BMI, and preoperative biliary drainage. The following factors associated with POPF due to the operation were also recorded attentively: pancreatic texture, diameter of the MPD, pathological diagnosis, operation time, blood loss volume, and perioperative blood transfusion. The main end points were the incidence rate of clinically significant POPF according to the ISGPF definition and the duration of POHS. The secondary end point included some postoperative complications (delayed gastric emptying, POPF-related hemorrhage, intra-abdominal and pleural effusions, wound infection, bacteremia, septic shock, and in-hospital mortality) and readmission within 30 days after discharge.

Statistical analysis

All statistical analyses were performed using SPSS version 23.0 (IBM, USA). Continuous variables were expressed as mean \pm SD and compared using the Student's *t*-test. The Chi-square test and Fisher exact test were applied to the categorical variables. The factors associated with POPF were evaluated in the univariate and multivariate analyses by using the Chi-square test and logistic regression analysis, respectively. A *P*-value of <0.05 was considered statistically significant.

Results

Patient demographic

The patient's demographic characteristics are shown in **Table 1**. No significant differences in the main variables, namely age, sex ratio, BMI, preoperative serum albumin level, pancreatic texture, pathological diagnosis, operation time, blood loss volume, and perioperative blood transfusion, were found. Our statistical results demonstrate that a MPD of <3 mm accounted for a larger proportion in the m-BA group than in the c-BA group (32.0% vs 12.0%, $P = 0.004$). Moreover, most people in the m-BA group received preoperative biliary drainage (17.5% vs 44.0%, $P < 0.001$). The duct-to-mucosa anastomosis time in the m-BA group was 11 ± 1 min, which was apparently shorter than that in the c-BA group (32 ± 4 min, $P < 0.001$). Operation time

showed no significant difference between the two groups ($P > 0.05$), which may be due to the time of duct-to-mucosa anastomosis being just a part of the entire operation time.

Postoperative complications

The postoperative complications in the two groups are shown in **Table 2**. POPF occurred in 6 patients in the m-BA group, among whom were 6 (12.0%) and 0 with ISGPF grade B and C POPF. In the c-BA group, 10 patients had a pancreatic fistula, and 10 (10.3%) and 0 had ISGPF grade B and C POPF, respectively. No significant difference in the incidence of clinically relevant POPF was found between the two groups ($P > 0.05$). In addition, the incidence rates of other postoperative complications, including delayed gastric emptying, POPF-related hemorrhage, intra-abdominal and pleural effusions, wound infection, bacteremia, and septic shock, were essentially similar between the two groups ($P > 0.05$). No in-hospital death occurred in the m-BA group, while one patient died of infection caused by POPF in the c-BA group. The POHS durations in the m-BA and c-BA groups were 23 ± 8 and 22 ± 10 days, respectively, showing no significant difference ($P > 0.05$).

Risk factors for POPF

The risk factors for POPF are shown in **Table 3**. The univariate analysis revealed that BMI (≥ 25 kg/m²; $P = 0.009$) and MPD diameter (<3 mm; $P = 0.019$) were associated with POPF. However, the multivariate analysis revealed that only BMI (≥ 25 kg/m²; $P = 0.046$) was an independent risk factor for clinically significant POPF. We particularly wanted to confirm that the anastomosis methods were not related to the occurrence of pancreatic leakage ($P > 0.05$). However, as described earlier, the time in the m-BA group was much shorter than that in the c-BA group, with a significant difference ($P < 0.001$).

Discussion

POPF is one of the most challenging complications that are closely related to perioperative death in PD. Even in centers with high volume of pancreatic surgical cases, absolute safety is difficult to achieve. To reduce the occurrence of POPF, many domestic and foreign experts have performed numerous anastomotic and gastrointestinal reconstruction techniques¹⁸⁻²⁰. In recent years, BA, which uses the jejunum as a buffer pad to prevent pancreatic laceration when knotting the sutures, has gradually stood out and has been

Table 1 Demographic, characteristics and operational indexes of the patients

Characteristics	Conventional group (n=97)	Modified group (n=50)	P
Age, years			0.068
<65	57 (58.8%)	37 (74.0%)	
≥65	40 (41.2%)	13 (26.0%)	
Gender (male/female)	58/39	30/20	0.981
BMI (kg/m ²)			
<25	64 (66.0%)	34 (68.0%)	0.806
≥25	33 (34.0%)	16 (32.0%)	
ALB (g/L)			
<40	44 (45.6%)	23 (46.0%)	0.941
≥40	53 (54.4%)	27 (54.0%)	
Preoperative biliary drainage	17 (17.5%)	21 (42.9%)	0.001
Disease			
PC	36 (37.1%)	14 (28.0%)	0.601
DBC	15 (15.5%)	12 (24.0%)	
DC	15 (15.5%)	10 (20.0%)	
AC	12 (12.4%)	6 (12.0%)	
Others	19 (19.6%)	8 (16%)	
Operation			
Pancreaticojejunostomy anastomosis time, min (mean±SD)	32±4	11±1	<0.001
Surgical time (min)			0.276
<300	55 (56.7%)	33 (66.0%)	
≥300	42 (43.3%)	17 (34.0%)	
Blood loss (mL)			0.941
<400	72 (74.2%)	37 (74.0%)	
≥400	25 (25.8%)	13 (26.0%)	
Blood transfusion, yes	68 (70.1%)	20 (40.0%)	<0.001
Pancreatic texture			
Hard	58 (59.8%)	25 (50.0%)	0.257
Soft	39 (40.2%)	25 (50.0%)	
MPD (mm)			
<3	12 (12.4%)	16 (32.0%)	0.004
≥3	85 (87.6%)	34 (68.0%)	

PC: pancreatic cancer; DBC: distal bile duct cancer; DC: duodenal carcinoma; AC: ampullary carcinoma; MPD: main pancreatic duct; BA: Blumgart anastomosis.

accepted increasingly by more medical centers¹³. To further simplify the rigmarole of BA, Oda et al.¹⁶ tightened U-sutures after duct-to-mucosa anastomosis without knotting them and then took two needles, respectively passing them through the seromuscular antimesenteric edge of the jejunum and

bringing the jejunum to cover the front of the pancreatic cut edge to finish knotting, which was defined as the one-step Blumgart method. Fujii et al,⁵ on the basis of the method of Oda et al,¹⁶ attempted to further reduce the U-sutures to 1 to 3 sutures, making it a safe and simple method.

Table 2 Pancreatic fistula and perioperative complications of pancreatoduodenectomy patients

	Conventional group (n=97)	Modified group (n=50)	P
Pancreatic fistula (ISGPF)			0.682
None	87 (89.7%)	44 (88.0%)	
B	9 (9.3%)	6 (12.0%)	
C	1 (1.0%)	0	
Delayed gastric emptying	7 (7.2%)	4 (8.0%)	0.864
POPF related hemorrhage	0	0	NA
Intra-abdominal effusion	19 (19.6%)	6 (12.0%)	0.246
Pleural effusion	10 (10.3%)	2 (4%)	0.186
Bacteremia	4 (4.1%)	1 (2.0%)	0.501
Wound infection	1 (1.0%)	0	0.471
Septic shock	1 (1.0%)	1 (2.0%)	0.631
Readmission	1 (1.0%)	0	0.471
In-hospital mortality	1 (1.0%)	0	0.471
POHS	22±10	23±8	0.289

POPF: postoperative pancreatic fistula; POHS: postoperative hospital stay

BA has been applied in PD since 2010 in our department. We noticed that during BA, duct-to-mucosa anastomosis was quite difficult to successfully perform in a relatively narrow space, especially when confronting a relatively small pancreatic duct. More seriously, the tightening of the suture may cause tearing of the fragile pancreatic duct, which increases the possibility of POPF. Lastly, a discontinuous pinhole of the MPD may become a potential outflow channel that increases the risk of pancreatic leakage when the pancreatic duct pressure increased. On the basis of the above-mentioned considerations, we modified the original method of duct-to-mucosa anastomosis. The advantages of the m-BA are mainly as follows: (1) we first freed the main pancreatic duct and then placed the supporting tube in to support and fully secure the MPD, which had adequate operation space; (2) the m-BA simplified the process of duct-to-mucosa anastomosis and shortened the time while also avoiding tearing of the MPD to minimize a potential POPF; (3) owing to a certain free length of the MPD into the jejunum, the supporting tube will flow directly into the jejunum in spite of a small amount of pancreatic leakage.

This study was conducted to compare the m-BA with the c-BA for the first time. We analyzed and compared operation time, the incidence rate of clinically relevant POPF, and the POHS of the two groups. For the operation time, the mean time in the m-BA group was shorter than that in the c-BA group; however, the smaller time gap between the two

groups was masked by the lengthy operation procedure. The incidence of clinical relevant POPF was similar between the two groups (12% vs 10.3%), which was consistent with previous reports^{21, 22}. There were no significant differences in POHS duration and other complications of the two groups. In summary, the m-BA, as a convenient method for duct-to-mucosa anastomosis, did not increase the risk of pancreatic leakage and related complications.

In addition, we analyzed the factors that influenced the incidence of POPF. In the univariate analysis, BMI, and MPD diameter were associated with POPF. Furthermore, the multivariate analysis revealed that only BMI was a significant factor. However, the influences of preoperative biliary drainage, pancreatic texture, anastomosis method (m-BA), operation time, intraoperative blood loss, perioperative blood transfusion, and pathological diagnosis of POPF were not significant. The correlation between BMI and POPF is still controversial. Del Chiaro et al.²³ mentioned that obesity increased not only the risk of POPF but also the difficulty of operation and blood loss, but some literatures considered that no necessary correlation existed between BMI and POPF^{24, 25}. Our study shows that BMI was associated with POPF both in the univariate and multivariate analyses. Moreover, our study also found a significant correlation between pancreatic duct diameter and POPF in the univariate analysis, while that in the multivariate analysis was not significant. This may be related to the routine use of a

Table 3 Risk factors of POPF

Factors	n	POPF rate (%)	Univariate		Multivariate		
			χ^2	P	HR	95% CI	P
Sex			0.052	0.820			
Male	10	62.5					
Female	6	37.5					
Age (year)			0.461	0.497			
<65	9	56.3					
≥65	7	43.8					
BMI (kg/m ²)			6.873	0.009			
<25	6	37.5					
≥25	10	62.5			3.682	1.235-10.979	0.019
ALB (g/L)			0.024	0.876			
<40	7	43.8					
≥40	9	56.2					
Preoperative biliary drainage (yes)				0.455			
no	13	81.3	0.558				
yes	3	18.7					
Pancreatic texture			0.266	0.755			
Hard	10	62.5					
Soft	6	37.5					
MPD (mm)			3.965	0.046			
<3	6	37.5			2.664	0.848-8.371	0.094
≥3	10	62.5					
Anastomosis method			0.097	0.755			
Conventional	10	62.5					
Modified	6	37.5					
Surgical time (min)			0.590	0.442			
<300	11	68.8					
≥300	5	31.2					
Blood loss (mL)			1.271	0.260			
<400	10	62.5					
≥400	6	37.5					
Perioperative blood transfusion			1.712	0.191			
No	4	25.0					
Yes	12	75.0					
Pathological diagnosis			24.258	0.760			
PC	5	31.3					
DBC	3	18.8					
DC	6	37.6					
AC	1	6.3					
Others	1	6.3					

supporting tube in MPD²⁶. In conclusion, patient characteristics play an important role in POPF.

The m-BA has no distinct advantage over c-BA in reducing the rate of pancreatic fistula. Many factors affect pancreatic fistula, one of which is anastomotic mode. In addition, c-BA has significantly reduced the incidence of pancreatic fistula¹²⁻¹⁴, which is difficult to surpass. Patient characteristics also play an important role in POPF. The m-BA is equal to the c-BA in terms of the incidence rate of pancreatic fistula, but it is simple, reliable, and suitable for any type of pancreatic fistula. Moreover, it requires a short learning period and has been applied to robotic pancreatoduodenectomy safely and feasibly. Compared with the multicenter randomized controlled study, the evidence from our prospective (to some extent) but not randomized study might not be adequately sufficient. However, the safety and effectiveness of the m-BA is apparent and irreplaceable. Our study has limitations that need further improvement, including the small number of study cases. A single-center randomized controlled study is probably best to further confirm our conclusion.

As we mentioned earlier, the m-BA using firm ligation of the supporting tube and MPD to replace the pancreatic duct-to-mucosa anastomosis is a simple, safe, and reliable operation method without sacrifice of surgical quality. In conclusion, the m-BA has a relatively high clinical value to reduce the duct-to-mucosa anastomosis time with no increased risk of POPF.

Conflict of interest statement

No potential conflicts of interest are disclosed.

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