Modified Blumgart versus modified Heidelberg technique for pancreatic anastomosis in pancreaticoduodenectomy, which is more effective?

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Received: 11 August 2023
Revised: 24 August 2023
Accepted: 27 August 2023
Published: 7 December 2023

The Egyptian Journal of Surgery 2023, 42:892–903

Introduction
Leakage from pancreatic anastomosis is the main cause of postoperative mortality and morbidity after pancreaticoduodenectomy (PD). Advanced studies suggested Blumgart anastomosis (BA) and modified BA (m-BA) as a technique that may minimize major complications after PD. This study compares m-BA with modified Heidelberg anastomosis (m-HA) for pancreaticojejunostomy (PJ) after PD as a single-center experience.
Methods
A total of 46 patients who underwent PD at Ain Shams University Hospitals between January 2021 and February 2023 were enrolled in this research. The patients were categorized into two groups according to the anastomosis type. 24 patients underwent anastomosis using m-BA (group A) and 22 patients underwent anastomosis using m-HA (group B). The primary outcome is postoperative pancreatic fistula (POPF), bleeding, and mortality. The secondary outcome is the duration of the procedure, the number of sutures used, and other complications.
Results
The demographic and all preoperative data were insignificantly different between both groups. The operative time was significantly less in m-BA group as the time of the pancreatic anastomosis was significantly lower (21.08±3.5 min) in comparison to m-HA (69.32±8.4 min) *P* value less than 0.001.
The polydioxanone suture (PDS) threads consumed were significantly less in m-BA in comparison to m-HA (median (IQR) 9 (9–9) and 28 (26–30), respectively, *P* value < 0.001)
POPF was less in the m-BA group than m-HA (16.7 and 31.8%, respectively, *P* value 0.229) and postpancreatectomy hemorrhage (16.7% and 22.7%, respectively, *P* value 0.609), and the POPF in the soft pancreas was much less in m-BA (10% and 50%, respectively, *P* value 0.051), although statistically insignificant but it is clinically significant.
Conclusion
The m-BA technique can provide a better solution for pancreatic remnant management with less POPF, especially in soft pancreas with high fistula risk score, however, a small sample size may be the cause of the statistically insignificant difference, so larger studies are required. Nevertheless, m-BA consumes a lower number of PDS sutures with much lower cost and also less operative time.

Keywords:
modified Blumgart, modified Heidelberg, pancreatic fistula

Egyptian J Surgery 42:892–903

1110-1121

Introduction

Pancreaticoduodenectomy (PD) is a surgical procedure for benign and malignant neoplasm of the pancreatic head, duodenum, ampulla of Vater, and common bile duct. Pancreaticoenterostomy after PD is termed the 'Achilles' heel' as it provokes the most hazardous cause of postoperative morbidity amongst all visceral anastomoses, which is pancreatic fistula (PF) [1,2].

Although mortality has declined to less than 5% due to advancements in the techniques of resection as well as improvement in the postsurgical ICU care and procedures of intervention radiology, there are still many studies that state the high rate of complications ranging 30% to 50% even in centers of excellence [3].

A lot of complications such as postpancreatectomy hemorrhage (PPH), delayed gastric emptying (DGE), PF, and infections are associated with PD [4]. Clinically relevant postoperative pancreatic fistula

(CR-POPF) is a potentially critical, life- threatening complication and is the major cause of postoperative morbidity after PD ranging from 5-20% [2], associated with intra-abdominal abscess formation or fluid collection, bleeding, the occasional need for re-exploration, and possible mortality [5]. Re-intervention may be essential to decrease the risk of postoperative mortality due to POPF associated infection and/or intraluminal or extraluminal hemorrhage [4].

There is still a wide conflict regarding the best technique of pancreatic-enteric anastomosis [6,7]. However, there is no significant difference in the CR-POPF rate between pancreaticojejunostomy (PJ) and pancreaticogastrostomy (PG) according to many meta-analyses done about randomized control trials (RCTs) on that topic [8,9].

An ideal technique for the pancreatic stump reconstruction should result in zero rate of leakage whatever the pancreatic duct size and texture, and furthermore, should be easily performed and more time saving.

Of the most widely used techniques of PJ, Heidelberg (HA) and Blumgart anastomosis (BA) techniques and their modifications. Recently, some studies have suggested that BA technique and its modifications seemed to decrease the occurrence of POPF and overall complications, showing less postoperative mortality rate (1-3%) [10], re-exploration rate (5–7%) and an better POPF rate (15–20%) [11–14].

On the basis of these assumptions, the target of the present study is to compare modified Blumgart anastomosis (m-BA) to modified Heidelberg duct-to-mucosa anastomosis both with internal stent.

Methodology

Type of study: retrospective

Study period; January 2021 to February 2023

Sample size and site: All the procedures were done in Ain Shams university hospitals. 46 patients were divided into two group; group A: 24 patients underwent m-BA and group B: 22 patients underwent m-HA

Study endpoints: The primary outcomes were the occurrence of CR-POPF and the overall mortality rate. The secondary endpoints were time, cost and other early postoperative complications.

Inclusion criteria

(1) All patients undergoing PD (Whipple's operation) either for benign or malignant condition.

Exclusion criteria

(1) Age below 16 years.
(2) ASA score 3 or 4.
(3) Extended resection of other organs (colon or liver).
(4) Vanished or extremely small (~1 mm) pancreatic duct.

Technique

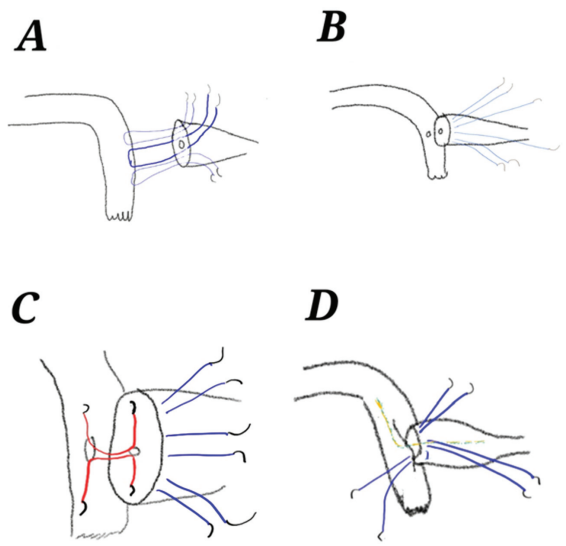
The PJ is divided into two main techniques: the duct-to-mucosa anastomosis, and the invagination or 'dunking'. Both m-BA and m-HA are considered subtypes of the duct-to-mucosa.

Technique of modified m-BA.

LH Blumgart, in 2010, presented an easy technique for performing a PJ which gathered the principles of duct-to-mucosa anastomosis with the invagination technique of the pancreatic stump by means of the jejunal covering of the cut surface of the pancreas [11].

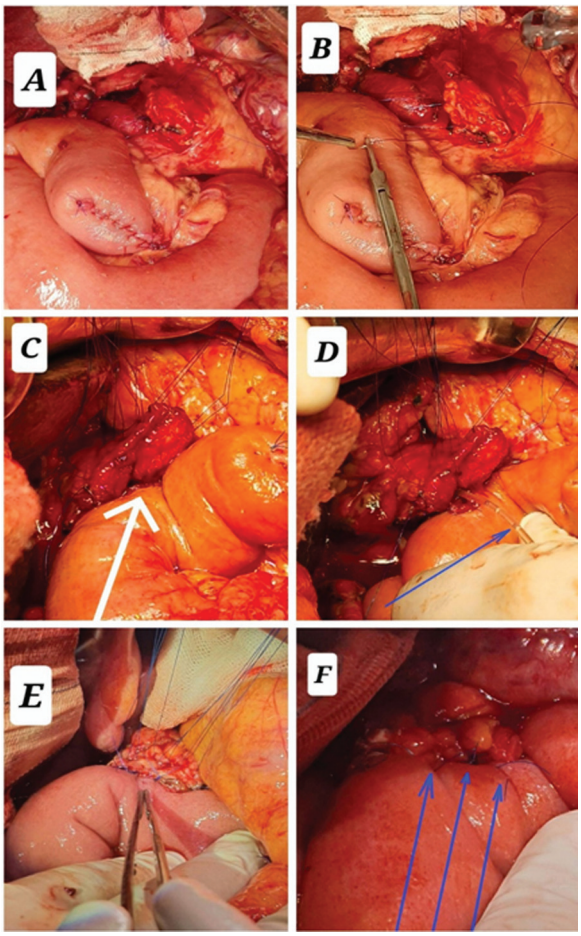
Three U-shaped sutures taken transpancreatic were sited about 1 cm distal to the cut edge of the pancreas going from front to back with 4/0 PDS (needle 26 mm) suture with the middle stitch surrounding the duct. Three double-needle sutures were utilized (Fig. 1a). The seromuscular posterior wall of the jejunum was used, nearer the mesenteric edge, and 1–1.5 cm horizontal seromuscular sutures were taken. then reverted from back to front through the parenchyma completing the U. These outer sutures are left free, and the needles should not be cut (Fig. 1b). A duct-to-mucosa anastomosis was done over an internal stent (Nelaton catheter) about 10-15 cm length, 6-8 fr after creating a small opening (about 2–3 mm) in the jejunal loop (A duct to mucosa anastomosis was done with size 5-0 PDS at 12, 2, 4, 6, 8, and 10 O'clock positions of the pancreatic duct and jejunum) (Fig. 1c). The free needles of the transpancreatic U-sutures were then passed through the seromuscular layer of the front wall of the jejunal loop in a horizontal manner. Each of the U sutures was sited at a distance of 5 to 10 mm from one before. So at the end (Fig. 1d), the jejunal serosa completely cover the pancreatic stump as the seromuscular layer of the jejunum should cover the pancreatic surface, both anteriorly and posteriorly [15] (Fig. 2).

Figure 1



Steps of modified Blumgart anastomosis. (a) the start of the ″U″ sutures in the seromuscular of the intestine and through the full thickness of the pancreas. (b) Approximation of the intestine and pancreas. (c) A duct-to-mucosa anastomosis over the stent (d) Completion and knotting the U sutures

Figure 2



(a) The first U suture, (b) the third U suture in the intestine, (c) White arrow: the posterior layer duct to mucosa. (d) blue arrow: the stent. (e) anterior layer, (f) the ligation of the three blue arrows: the 3 U sutures.

The modification we added to the technique is that the middle suture encircles the duct, so we use stent to ensure patency of the duct (not to collapse during tying of the knot).

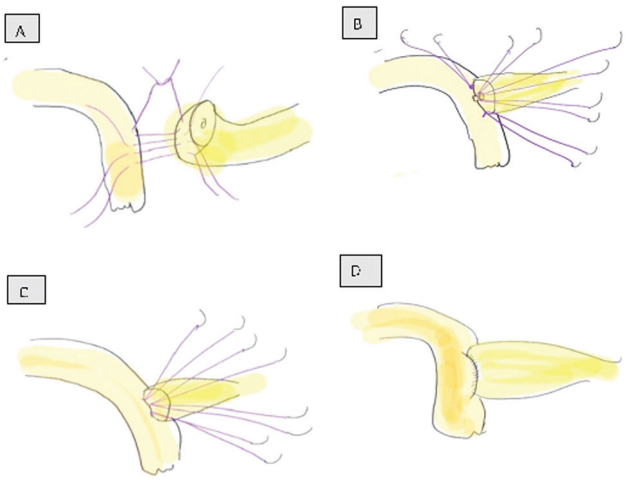
Technique of modified Heidelberg anastomosis (m-HA)

The beginning of the anastomosis is hanging the pancreatic duct with 4-0 or 5-0 PDS sutures. First, sutures are taken in the anterior wall of the duct at 10, 12, and 2 O' clock position in an outside-to-inside direction (more sutures can be used in wide ducts), traversing the whole thickness of pancreatic parenchyma from anterior surface of the pancreas till it exits from the anterior ductal wall.

In the same manner, sutures are taken in the posterior ductal wall at 4, 6, and 8 O' clock position from inside to outside (more sutures can be used in wide ducts) traversing the parenchyma behind the posterior ductal wall and exiting from the posterior surface of the pancreas. All these sutures are not tied and are left without cutting their needles.

Next, the fourth or the most posterior interrupted sutures are taken approximating the posterior surface of the pancreas to the seromuscular layer of the jejunal loop (Fig. 3a). These sutures are knotted and needles cut. A small hole in the jejunal loop is made against the opening of the main pancreatic duct. As we proceed, the sutures previously taken in posterior ductal wall are utilized by passing the needle outside-in into the posterior jejunal wall so that the third layer is accomplished (Fig. 3b). Now, 1 or 2 interrupted sutures are used to approximate the posterior cut

Figure 3



Layers of the modified Heidelberg anastomosis. (a) Ligating the fourth layer of the anastomosis, (b) after ligating the third layer, (c) the second layer, (d) after completing the anastomosis by ligating the first layer.

margin of pancreas to the seromuscular wall of jejunum (on each side of the duct). Then internal stent (Nelaton catheter) about 10-15 cm length, 6-8 fr is inserted. In a similar fashion, the anterior pancreatic cut surface is approximated to the anterior jejunal wall, integrating the anterior ductal sutures, completing the second layer (Fig. 3c).

At the end, the first layer is made by taking interrupted sutures from the anterior surface of pancreas into the seromuscular layer of jejunum (Fig. 3d). Finally, the accomplished anastomosis is an end-to-side duct-to-mucosa anastomosis with an outer seromuscular layer and inner full thickness one [7] (Fig. 4).

Postoperative management

The output of the drain was daily measured. Amylase was measured in the drains' output on the third, fifth, and seventh postoperative day (POD). We removed The drains when the amount was less than 50 mL, and the fluid amylase level was normal after the seventh POD. When the bowel sounds were audible, we removed the nasogastric tube, especially when the output was less than 200 mL. As for the urinary catheter, it was removed on POD 1. Fluid oral intake was started on second day postoperative and increased gradually to the soft diet as much as tolerated.

Follow-up for 3 month was done. 1 week after discharge; follow-up pelviabdominal ultrasound to exclude any collection, complete blood count (CBC) and C-reactive protein (CRP) to exclude any infection. Then clinical follow up till the end of the 3rd month, if any aberration occurred further investigations were done.

Definitions

Postoperative pancreatic fistula (POPF)

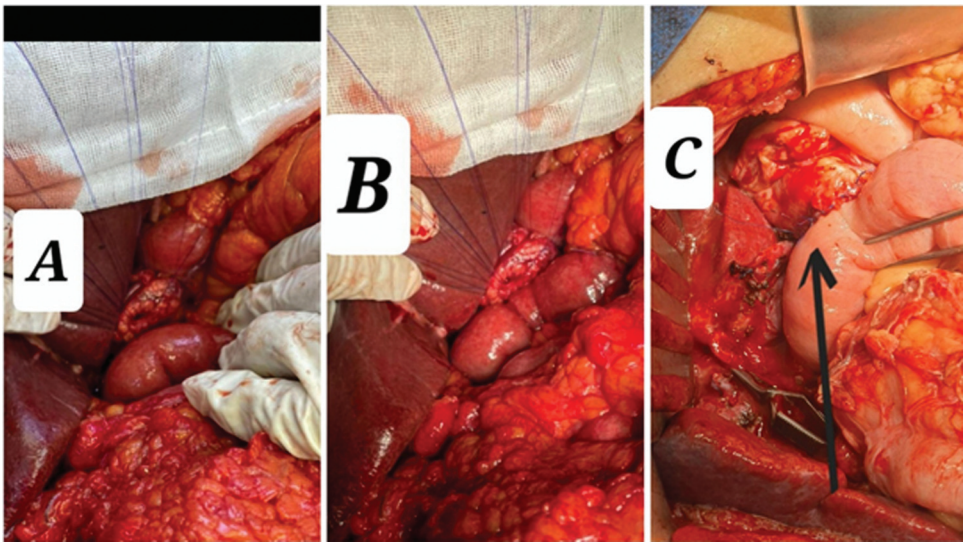
The International Study Group on Pancreatic Fistula (ISGPF) defined the POPF as any measurable amount of drain fluid on or after third day postoperative, in which the amylase level is higher than 3 times the upper limit of normal serum level. Grade A-POPF was redefined in 2016 as biochemical leakage (BL), as it has no clinical impact. Grade B-POPF necessitates change in the management, drains are either left in place for more than 21 days or replaced through percutaneous or endoscopic access, and the Grade C-POPF refers to leakage that requires re-exploration or leads to organ failure and/or death directly related to the PF [16]. Group B and C are referred to as CR-POPF.

All those with POPF received 100 mg subcutaneous Octreotide, 3 times per day for one week.

Delayed gastric emptying (DGE)

It is the inability to restore the standard diet by the end of the first week postoperative. According to ISGPS 2016, Grade A; NGT required more than 4- 7 days or re-insertion after POD 3 or inability to tolerate solid oral intake after POD 7 and maybe associated with vomiting, gastric distension or use of prokinetics. Grade B; NGT required more than 8-14 days or reinsertion after POD 7 or inability to tolerate solid oral intake after 14 POD and associated with vomiting,

Figure 4



(a) Hanging the duct anteriorly, (b) after ligating the posterior seromuscular layer, (c) the black arrow: the first layer after termination of the anastomosis.

gastric distension or use of prokinetics. Grade C; NGT required more than 2 weeks or re-insertion after POD 14 or inability to tolerate solid oral intake after POD 21 and associated with vomiting, gastric distension or use of prokinetics [17].

Postpancreatectomy hemorrhage (PPH)

Three different grades (A, B, and C) are defined according to the time of onset (early; within 24 h or late; more than 24 h), site of bleeding (intra or extraluminal), severity (mild or sever), and clinical impact. Grade A; mild early, intra or extraluminal bleeding with good general condition. Grade B; severe early or late intra- or extraluminal bleeding but the general condition is well or intermediate. Grade C; severe late intra or extraluminal bleeding but the general condition is severely impaired and may be life threatening [17].

Pancreatic texture was evaluated by the experienced surgeons in research team by palpating the pancreatic parenchyma and was classified to be soft or firm to hard.

Vascular relations: encasement of the portal vein and/or superior mesenteric vein, reconstruction is done by 1ry resection-anastomosis with no interposition graft.

Intraabdominal abscess or fluid collection was detected by postoperative computed tomography (CT) scans.

An original fistula risk score was assigned by calculating perioperative and postoperative parameters after giving them points; like the texture of the pancreatic gland, nature of the pathology, the diameter of the main pancreatic duct, and the volume of blood loss intraoperative. It is a 10-point risk score in which patients with scores of 0-2 points have negligible risk of CR-POPF, scores of 3-6 have low risk (less than 10%), 7-8 intermediate risk (10-20%), while fistulas occurred maximum in all patients with scores of 9 or 10 [18]

Postoperative mortality definition is number of postoperative deaths in the first 30 days or during the same hospital admission.

Postoperative morbidity was stated by the Clavien-Dindo classification [19], severe complications were defined as grade III or more. The other parameters were analysed, such as the date of drain removal, and the number of patients who underwent percutaneous drainage of intraabdominal collection.

Results

Data were analyzed using Statistical package for Social Science (SPSS) version 27.0, Quantitative data were expressed as mean±standard deviation (SD) or Median (IQR) when needed. Qualitative data were given expression to frequency and percentage.

The following tests were utilized:

(1) Independent-samples *t*-test of significance was used to compare between two means.
(2) Chi-square (χ^2) test of significance was used for comparing proportions between two qualitative parameters.
(3) More independent variables, that best anticipate the value of the dependent variable.
(4) The confidence interval was set to 95% and the margin of accepted error was set to 5%. So, the *P*-value was considered significant as the following:
(5) Probability (*P* value)
    (a) *P* value less than 0.05 was considered significant.

Demographics

Groups were comparable in demographic data (in terms of age, sex, ASA and BMI) and preoperative presentation and oncological parameters (tumor size, site) and there were no statistically significant difference between groups (*P* value > 0.05) (Table 1).

As regard operative details; the duration of the anastomosis showed highly significant difference (Fig. 5) and as a result the overall duration of the operation was significantly less in m-BA (Fig. 6). Also the number of PDS sutures used was significantly less in m-BA (Fig. 7**)**. As a result of both the overall cost will be less in m-BA.

Blood loss in m-BA was less, may be due to shorter duration of the anastomosis so that blood loss from the cut surface will be less. However it is statistically insignificant (Table 2).

Postoperative sequale and complications are shown in Table 3, the most important outcome is the POPF; in m-BA the number of cases (16.7%), max amount of pancreatic fluid in drain/24 hr (205+/- 221.6 CC) and even the rate of CR-POPF (12.5%) are less than in m-HA. Although the difference is insignificant statistically but these items collectively represent a clinical significance.

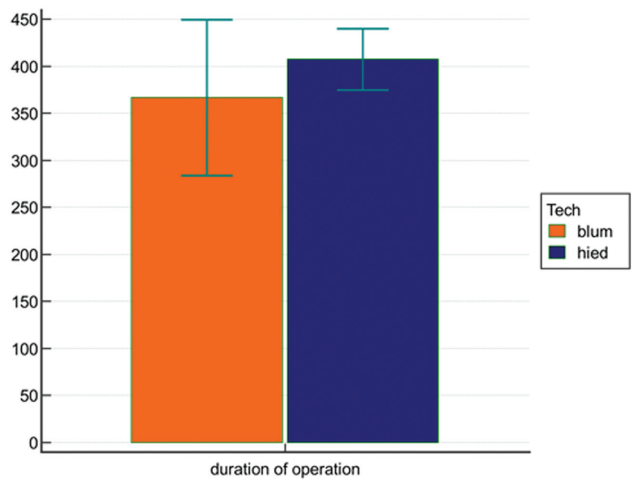
PPH is very similar in both groups, however it is the cause of re-explorations in both groups as well as the

Table 1 Comparison between groups as regard demographic and preoperative data

	Blumgart group (*n*=24)	Hiedelberg group (*n*=22)	*P* value
Age (y)	57.17±12.9	59.36±11.5	0.547^{t}
BMI	31.00±4.7	31.45±4.9	0.750^{t}
Sex			
Female	13 54.2%	13 59.1%	0.736 $^{\chi 2}$
Male	11 45.8%	9 40.9%	
ASA			
I	7 29.2%	7 31.8%	0.845 $^{\chi 2}$
II	17 70.8%	15 68.2%	
Comorbidities			
Cardiac	1 4.2%	1 4.5%	
DM	7 29.2%	9 40.9%	0.661 $^{\chi 2}$
HTN	4 16.7%	5 22.7%	
Free	12 50.0%	7 31.8%	
Site of the tumor			
Ampullary	8 33.3%	5 22.7%	
Duodenal	4 16.7%	3 13.6%	0.945 $^{\chi 2}$
Lower end CBD	3 12.5%	4 18.2%	
Pancreatic head mass	9 37.5%	10 45.5%	
Size of the tumor (cm)	3.32±1.4	3.21±1.4	0.806 ^{t}
CA19-9 (IU/mL)	961.25±2161.6	1013.64±2252.5	0.936 ^{t}
Vascular relation	3 12.5%	4 18.2%	0.592 $^{\chi 2}$
Neo-adjuvant	1 4.2%	3 13.6%	0.255 $^{\chi 2}$
Preoperative labs			
Hb (gm/dl)	10.58±0.6	10.59±0.7	0.969 ^{t}
TLC (10^9/L)	7.60±2.3	7.61±2.3	0.989 ^{t}
Bilirubin (mg/dl)	4.75±2.6	4.55±2.5	0.789 ^{t}
Albumin (gm/dl)	3.60±0.4	3.56±0.4	0.765 ^{t}
Biliary drainage			
No	5 20.8%	3 13.6%	
ERCP	14 58.3%	14 63.6%	0.813 $^{\chi 2}$
PTC	5 20.8%	5 22.7%	
Presentation			
Obstructive jaundice	19 79.2%	19 86.4%	0.52 $^{\chi 2}$
Gastric outlet obstruction	4 16.7%	3 13.6%	0.775 $^{\chi 2}$
Mass	2 8.3%	1 4.5%	0.603 $^{\chi 2}$
Pain	9 37.5%	9 40.9%	0.813 $^{\chi 2}$

Data expressed as mean±SD, proportion, T=student *t* test, χ^2=chi square.

Figure 5



Shows duration of pancreatic anastomosis (min).

Figure 6

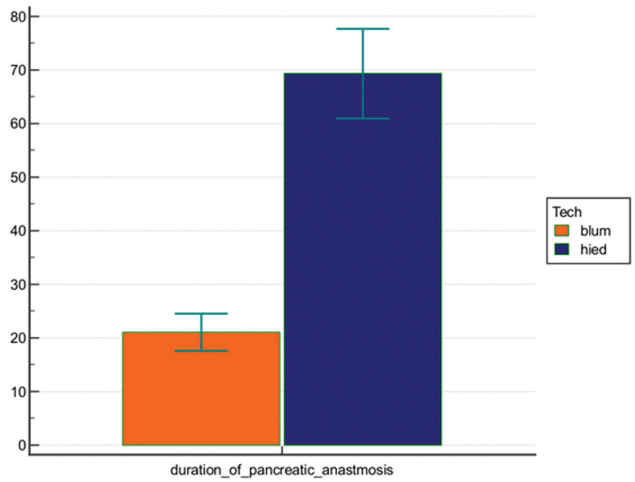
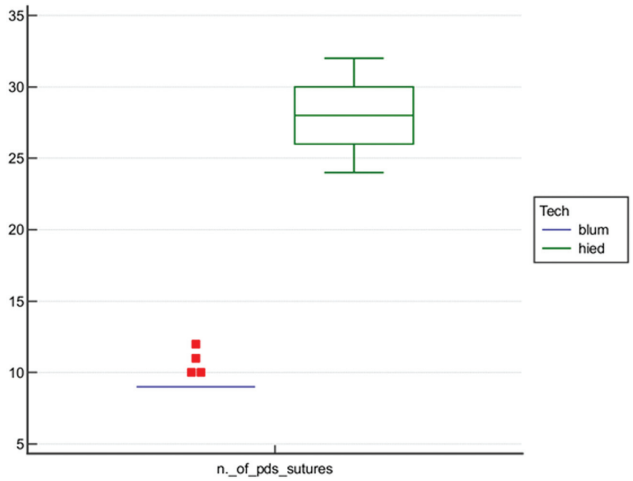


Diagram shows duration of operation (min).

Figure 7



Number of polydioxanone suture (PDS) sutures used in the anastomosis.

single case of mortality in each group. The bleeding was secondary to POPF grade C in both. Embolization was tried in the case of PPH grade C in m-BA group but it failed.

Sever complications according to Clavien-Dindo classification was 16.6% in m-BA and 31%.8% in m-HA but still the difference is insignificant.

When comparing the POPF in both groups in relation to the texture; on one hand (Table 4), in group A the POPF was less in soft pancreas (25%), but in group B the POPF was less in firm pancreas (28.6%). However, the difference is insignificant in both groups.

On the other hand (Table 5), when expressing the same data but in different manner, the POPF in firm pancreas was slightly less in m-HA (insignificant difference). Nevertheless, the POPF in soft pancreas was much less in m-BA (although statistically insignificant but clinically significant) (Table 6).

According to fistula risk score; the m-BA technique showed much less POPF (57%) in high and intermediate risk zone patients than the other group in which 100% of the cases had POPF.

But still it is statistically insignificant.

Discussion

Multiple studies regarding the operative techniques of the pancreaticoenterostomy tried to improve POPF incidence after PD. Many of them were RCTs with significant results comparing PJ versus PG [20–24], invagination versus duct-to-mucosa anastomosis [25,26] and external stent versus internal stent [27,28] and also stentless versus external stent have been described [15,29], some of them stated that usage of external stent in the pancreatic duct has decreased the rates of CR-POPF [30,31]. Nevertheless, a literature review done by Strobel *et al.* [32] about different techniques of pancreaticoenterostomy showed that POPF rates are seldom affected by the

Table 2 Comparison between groups in operative details

Operative data	Blumgart group (*n*=24)	Hiedelberg group (*n*=22)	*P* value
Duration of operation (min)	366.63±83.0	407.27±32.4	**0.037** ^{t}
Duration of pancreatic anastomosis (min)	21.08±3.5	69.32±8.4	<**0.001** ^{t}
Blood loss (CC)			
Median (IQR) range	200 (170-370) {100-900}	275 (200-400) {100-1000}	0.07 ^{z}
Blood transfusion (pRBCs units)			
0	18 75.0%	18 81.8%	
1	4 16.7%	2 9.1%	0.748 $^{\chi 2}$
2	2 8.3%	2 9.1%	
Vascular reconstruction	2 8.3%	4 18.2%	0.322 $^{\chi 2}$
Texture of the pancreas			
Firm	14 58.3%	12 54.5%	0.796 $^{\chi 2}$
Soft	10 41.7%	10 45.5%	
Pancreatic duct size			
< 3 mm	7 29.2%	5 22.7%	
>10 mm	5 20.8%	3 13.6%	0.637 $^{\chi 2}$
3–10 mm	12 50.0%	14 63.6%	
No. PDS sutures			
Median (IQR) range	9(9-9) {9-12}	28(26-30) {24-32}	<**0.001**^{z}
Fistula risk score			
Median (IQR) range	4(3-7) {0-9}	3 (1-5) {0-9}	0.175 ^{z}

Data expressed as mean±SD, proportion, median (IQR){range}, T=student t test, χ^2=chi square z= Mann Whitney test.

Table 3 Comparison between groups as regard postoperative data

Postoperative data	Blumgart group (*n*=24)	Hiedelberg group (*n*=22)	*P* value
ICU stay (d)			
Median (IQR) range	2 (1-2) {1-5}	2 (1-2) {1-7}	0.822 ^{z}
Inpatient stay (d)			
Median (IQR) range	11.5 (8-13) {7-18}	10.5 (8-13) {7-22}	0.773 ^{z}
Delayed gastric emptying (DGE)			
Grade A	5 20.8%	6 27.3%	
Grade B	4 16.7%	5 22.7%	0.853 ^{x2}
Grade C	1 4.2%	1 4.5%	
No	14 58.3%	10 45.5%	
POPF (no. cases)	4 16.7%	7 31.8%	0.229 ^{x2}
Pancreatic leak max amount (CC/24 h)	205.00±221.6	228.57±177.6	0.850 ^{t}
POPF grade (ISGPS)			
Biochemical leak (BL)	1 4.2%	2 9.1%	
B	1 4.2%	3 13.6%	0.58 ^{x2}
C	2 8.3%	2 9.1%	
CR-POPF (grade B+ C)	3 12.5%	5 22.7%	
Biliary leak (n. of cases)	1 4.2%	2 9.1%	0.499 ^{x2}
Chyle leak (no. cases)	1 4.2%	1 4.5%	0.95 ^{x2}
Gastric intestinal leak (no. cases)	0 0.0%	1 4.5%	0.291 ^{x2}
Bleeding (no. cases)	4 16.7%	5 22.7%	0.609 ^{x2}
Grade of bleeding (ISGPS)			
A	2 8.3%	2 9.1%	
B	1 4.2%	1 4.5%	0.921 ^{x2}
C	1 4.2%	2 9.1%	
Bleeding treatment			
Blood transfusion	2 8.3%	3 13.6%	0.837 ^{x2}
Conservative	2 8.3%	2 9.1%	
Wound infection	9 37.5%	8 36.4%	0.936 ^{x2}
Abdominal collection	9 37.5%	8 36.4%	0.936 ^{x2}
Pigtail for abdominal collection	2 8.3%	2 9.1%	0.988 ^{x2}
Other complications			
Burst abdomen	0 0.0%	1 4.5%	
Chest infection	1 4.2%	1 4.5%	0.535 ^{x2}
DVT	0 0.0%	1 4.5%	
Stroke	1 4.2%	0	
Re-exploration	1 4.2%	2 9.1%	0.499 ^{x2}
Mortality	1 4.2%	1 4.5%	0.95 ^{x2}
Clavien-Dindo			
0	3 12.5%	5 22.7%	
1	14 58.3%	8 36.4%	
2	4 16.7%	2 9.1%	
3	1 4.2%	4 18.2%	0.478 ^{x2}
3a	1 4.2%	1 4.5%	
4	1 4.2%	1 4.5%	
5	1 4.2%	1 4.5%	
Sever complications (grade 3–5)	4 16.6%	7 (31.8%)	
Postoperative labs			
Lowest Hb (gm/dl)	10.24±1.1	10.24±1.3	0.998 ^{t}
Bilirubin (mg/dl)	4.75±2.6	4.55±2.5	0.789 ^{t}
TLC (10^9/L)	10 (8–11.5) 5–20	10 (10–10) 6–28	0.296 ^{z}
Highest CRP (mg/dl)	15 (5–27.5) 1–56	10 (5–30) 3–60	0.765 ^{z}

Data expressed as mean±SD, proportion, median (IQR)(range), T=student t test, χ^2=chi square z= Mann–Whitney test.

site of pancreatic anastomosis (either jejunum or stomach) or type of suturing method, and usage of stent (e.g., internal or external) for the anastomosis.

However, Worldwide, PJ is the most favored method of performing pancreaticoenterostomy [7]. Although presence of numerous studies about different methods

Table 4 Incidence of POPF in both groups in correlation to texture

Technique	POPF		Total	*P* value
	No	Yes		
m-Blumgert				
Firm				
Count	11	3	14	0.459 ^{x2}
% within POPF	55.0%	75.0%	58.3%	
Soft				
Count	9	1	10	
% within POPF	45.0%	25.0%	41.7%	
Total				
Count	20	4	24	
% within POPF	100.0%	100.0%	100.0%	
m-Hiedelberg				
Firm				
Count	10	2	12	0.095 ^{x2}
% within POPF	66.7%	28.6%	54.5%	
Soft				
Count	5	5	10	
% within POPF	33.3%	71.4%	45.5%	
Total				
Count	15	7	22	
% within POPF	100.0%	100.0%	100.0%	

Table 5 Incidence of POPF in different pancreatic textures in both groups

	m-Bulmgert group	m-Heidelberg group	*P* value
POPF in firm pancreas	3/14 cases (21.4%)	2/12 cases (16.7%)	0.759
POPF in soft pancreas	1/10 cases (10%)	5/10 cases 50%	0.051

of PJ, there is still no agreement on a single technique to be the gold standard to improve the POPF [4,33,34].

In addition to suggesting various technical hints and steps, there were also many mitigation strategies suggested to improve the outcome of the pancreatic anastomosis, for example usage of sealants and omental roll-up to decrease the CR-POPF, which is still debatable [35–37]. As well as usage of Somatostatin analogs which still has conflicting results concerning POPF [3].

There were also trials to omit the step of pancreatic anastomosis by closing the pancreatic duct by ligating it, using stapler or glue, but unfortunately the resultant postoperative pancreatitis is equally fatal as the POPF, so no clinical benefit from it [38]. Another attempts to avoid the POPF by total pancreatectomy were done. The removal of the pancreatic stump is performed rarely [39].

On the same manner, studies targeting only various PJ techniques also present different results. These conflicting results strongly reflect different biases such as lack of statistical power, the mostly retrospective, single-center nature of the studies, and also the multiple modifications of the described anastomosis techniques, which hinder strict direct comparison. These results also go in line with those from the RECOPANC study [40], which is one of the largest RCTs performed on that issue [3].

To prevent CR-POPF, four essential features regarding PJ technique should be taken into consideration, evidence based; Pancreatic secretion should be totally drained, the pancreatic stump should have adequate blood flow, no laceration made in pancreatic parenchyma, and the jejunal serosa should be in close contiguity to the pancreatic cut surface [15].

Table 6 POPF in correlation to fistula risk score in both groups

Fistula risk score		Blumgert tech	Heidelberg tech	*P* value
High and intermediate risk group	Total n.	7	5	
	n. of leakage	4 (57%)	5 (100%)	0.1
Low risk group	Total n.	14	9	
	n. of leakage	0 (0%)	2 (22.2%)	0.07

Here in our study, we compare m-BA to modified Heidelberg duct-to-mucosa anastomosis both with long internal stent.

The theoretical privileges of BA include the following (i). Blood flow to the pancreatic remnant is not affected by interrupted transpancreatic mattress U-sutures holding the pancreas in close contiguity to the jejunum wall; (ii). Excellent visualization of the pancreatic duct permits performing the Duct-to-mucosal sutures easily, accurately and also the sutures can be meticulously done before securing the anterior and posterior seromuscular layer of the jejunum under a tension-free approximation; (iii). Leaks from minor pancreatic ducts and bleeding from the stump may be prevented due to the extra compression by the tension of the jejunal covering on the cut surface; (iv). Although they are tangential sutures, the transpancreatic mattress U-sutures could abolish tangential tension and shear force at the pancreatic remnant, especially during tying the knots which would cut through the fragile pancreas [41].

Moreover, the BA needs a less time to perform, and it is easy to replicate. That's why BA became one of the most common methods of performing the PJ since it had been issued in early 2000s [42].

In our study, there was no significant difference in all preoperative and demographic data. However in the operative data the highly significant difference was in the duration of the procedure in favor of m-BA (21.08 ±3.5 min with P value < 0.001) and as a result the duration of the operation was significantly less in m-BA relative to m-HA (366.63±83 to 407.27±32.4 min with P value 0.037), also the number of sutures showed highly significant difference between both groups as the median (IQR) in m-BA was 9 (9–9) sutures in comparison to 28 (26–30) sutures in m-HA. These together reflect that the operative financial cost will be less in m-BA.

As for the primary outcome, POPF, it was less in m-BA than m-HA (16.7–31% with P value 0.229) and also the CR-POPF (12.5–22.7% with P value 0.58) but both were statistically insignificant. However, it is noticed that the POPF in soft pancreas was much less in m-BA (10%) in comparison to (50%) in m-HA with P value 0.051 (although statistically insignificant but clinically significant). Also it is noticed that the m-BA technique showed much less POPF (57%) in high and intermediate risk zone patients than the other group in which 100% of the cases had POPF. But still it is statistically insignificant. However, these data together reflect the benefit of m-BA in PJ in soft pancreas.

As for the other postoperative complications, there was no statistically significant difference between both groups regarding the PPH, DGE, hospital admission, re-exploration and mortality. Severe complications according to Clavien-Dindo classification in m-BA were 4 cases (16.6%) versus 7 cases (31.8%) in m-HA.

Very similar to our study, the research of Hirono and colleagues comparing between interrupted sutures and m-BA regarding; duration of the procedure, intraoperative blood loss and transfusion. The incidence of POPF was similar in both groups. However, time required for pancreatic anastomosis was significantly less in the m-BA group than in the other group (26 vs. 28.5 min). Interestingly, as the number of sutures was less in m-BA group (2 vs. 4 sutures; $P < 0.001$), the cost of sutures used in the anastomosis was significantly less in that group. However, there was no significant difference between both groups in the incidence of CR-POPF, neither in the patients with soft pancreas nor in the overall incidence [15].

In one of the most recent studies in Jan 2023, m-BA had better perioperative outcomes than Dunking technique regarding complications related to the procedure like CR-POPF, PPH and overall major postoperative complications, as well as duration of hospital stay [4].

Also, some recent studies had emphasised the declined complication rate and POPF in the BA compared with dunking invagination PJ [2,4]. And also, Grobmyer *et al.* [11] suggested that BA can be practiced in all patients with identifiable pancreatic ducts, and is associated with significantly less complications. Others have stated no such privilege of the BA in decreasing POPF incidence [34].

The first RCT on m-BA was presented in 2019 in Wakayma Medical University. CR-POPF occurred in 7 (6.8%) cases in the interrupted suture group and 11 (10.3%) in BA group. They concluded that m-BA did not reduce CR-POPF in comparison with interrupted suture [15].

Comparable to our study, the study of Casadei and colleagues stated that the BA had no significant impact on decreasing CR-POPF in comparison to other techniques of PJ. However, this technique could

reduce severe complications significantly like; POPF grade C, re-exploration rate, ICU admission, and mortality within 90 days postoperative. In particular, POPF grade C, and 90-day mortality were 0% [2].

A study comparing it with PG in 2016, total of 206 patients underwent PD were included. BA group was associated with less postoperative hospital admission period. There was no surgical mortality in the BA group, but in the PG group it was 4.9%, $P = 0.030$. The CR-POPF in BA group was significantly less than that by PG for overall patients (7% vs. 20%, $P = 0.007$), particularly for those with intermediate fistula risk score (6% vs. 21%, $P = 0.048$) and high fistula risk score (14% vs. 47%, $P = 0.038$) [41].

As for using pancreatic stent, many published articles have documented decreased rates of POPF with external drainage of pancreatic juice using pancreatic duct stent [43]. Some studies showed that the occurrence of POPF was not statistically different between using either external or internal stents, but the internal stent might decrease the postoperative hospital admission period [27,44]. In addition, the internal stents preserve the pancreatic juice in the GIT so its role in the digestive function is not lost, as well as it declines the catheter-related complications associated with using the external stents. However, using short pancreatic stents still have the issue of exposing the PJ to the pancreatic juice, and its proteolytic enzymes may be activated by the bile flowing from the nearby bilioenteric anastomosis [41]. Nevertheless, to solve that matter, one study has documented the results of using long internal stents for pancreatic drainage and concluded that unfortunately it did not reduce POPF after PD in patients with small diameter of the main pancreatic duct [45].

However, in a study by Wongta and colleagues, 12 patients underwent PD using combined m-BA with long internal pancreatic duct stent, which is very similar to our technique. The rate of CR-POPF was 33.3%, two patients had the intraabdominal drain kept in place for long period, and one patient with intraabdominal collection was managed by percutaneous drainage. The only patient with Grade C-POPF died after reoperation due to septic shock. The median postoperative admission period was 12 days. The overall mortality rate was 8.3%.They concluded that combination of m-BA with the long internal pancreatic duct stent is an alternative technique that may hamper the postoperative PF [41], which go in similar line with our results.

Most of the constraints of our study are innate in studies that are retrospective in nature and performed at a single center. Specifically, the sample size in our study was small (number = 46) and the interventions were practiced at different times, so we strongly recommend that further studies on that topic should be RCTs on larger scale of cases.

Conclusion

Although the constraints in that study mentioned above, the statistically and/or clinically significant differences between groups in some items may underscore the importance of the m-BA over m-HA in improving the results and therefore can be recommended as a fast, simple and safe alternative for pancreatic reconstruction after PD especially in soft pancreas with high-risk score.

However, as no technique has proven to be superior to others regarding the POPF rate, it seems that the technique of the anastomosis should be individually designed with regard both the patient's characteristics and the surgeon's preference.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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