A comparative study between Roux-en-Y reconstruction with isolated biliary limb and single loop after pancreaticoduodenectomy: a solution for delayed gastric emptying

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Background
Whipple's operation is the primary treatment for periampullary and pancreatic tumors. The rates of morbidity and mortality have gone down to approach 50 and 1%, respectively. The incidence of delayed gastric emptying (DGE) is reported in 25–70% of patients, making it a significant morbidity. In this study, we described the use of an isolated biliary limb in Roux-en-Y hepaticojejunostomy (HJ) for biliary reconstruction and analyzed its effect on the incidence and severity of the DGE as a primary end point as well as postoperative morbidity and mortality and length of hospital stay as secondary end points.

Patients and methods
A before-and-after prospective study was conducted between January 2019 and December 2021 in the hepatopancreaticobiliary and liver transplantation unit of Air Force Specialized Hospital. We included 39 patients who underwent pancreaticoduodenectomy with resectable or borderline resectable preampullary tumors and were divided into two groups: group A included 17 patients who underwent standard pancreaticoduodenectomy, and group B included 22 patients with Roux-en-Y HJ with an isolated biliary limb.

Results
The overall incidence of DGE in the study group was 33% (13/39 patients). It was lower in group B and showed significant statistical values in all grades A, B, and C, with *P* values of 0.015, 0.000, and 0.023, respectively. After the use of isolated biliary limb in group B, the incidence had decreased significantly to 13% (3/22 patients), with significant prolongation of the mean hospital stay by a mean of 6.34 days longer in group A (*P*=0.016). The prolonged need for nasogastric tube was recorded in three (17.64%) of 17 cases in group A, two-thirds of which were grade A and one-third were grade B, with *P* values of 0.022 and 0.041, respectively, when compared with only 4.55% of patients in group B. The mean time needed until the removal of the nasogastric tube was significantly lower in group B (2.1±0.43 vs. 3.9 ±1.65 days), with *P* value of 0.037, with no incidence of reinsertion on both groups. When considering the solid oral intake tolerance, group B patients developed at a faster rate, with a mean of 3.33±2.88 days, whereas group A needed 8.46±2.81 days to reach tolerance (*P*=0.055).

Conclusion
The technique of reconstruction with isolated biliary loop away from both HJ and gastrojejunostomy in pancreaticoduodenal resection markedly reduced the postoperative incidence and severity of DGE reflected in a lesser duration of hospital stay.

Keywords:
delayed gastric empting, isolated biliary limb, pancreaticoduodenectomy, Roux-en-Y

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Introduction

Pancreaticoduodenectomy (PD) know as Whipple's operation is the primary treatment for periampullary and pancreatic tumors either benign or malignant; owing to the progress in surgical practice and the experience buildup, the rates of morbidity and mortality have gone down to approach 50 and 1%, respectively [1], which has helped to shift the focus from the operation itself to fast tracking it to lower the hospital costs [2–4].

As the incidence of delayed gastric emptying (DGE) [5] after PD is reported in 25–70% of patients [6], it is a significant postoperative morbidity. Such a morbidity presents with frequent nausea and vomiting, but in another way, it may affect the postoperative weight

gain, hospital stay, and its related morbidity, which may advance to dangerous and potentially life-threatening complications, for example, fatal aspiration and pneumonia.

Theoretically, the pathogenesis of DGE following PD has involved multiple factors such as gastric dysrhythmias, and/or atony, biliary reflux gastritis, and ischemic injury to the antropyloric muscle mechanism [7].

Several techniques of reconstruction have been tried to minimize DGE. The first described reconstruction using a Roux loop was in 1976 [8], as a trial to reduce the pancreatic enzyme activation aiming to develop what is called a benign fistula if anastomotic reconstruction fails and leakage happened [9,10], and since, then several trials have been reported aiming to minimize the morbidities associated with such a complex operation.

In this study, we described the use of an isolated biliary limb in Roux-en-Y hepaticojejunostomy (HJ) for biliary reconstruction, which isolated the biliary anastomosis from both the pancreatic and the gastric anastomosis, and analyzed its effect on the incidence and severity of the DGE as a primary end point as well as postoperative morbidity and mortality and length of hospital stay as secondary end points.

Patients and methods

Study design

A before-and-after prospective study was conducted between January 2019 and December 2021. The study was done in Air Force Specialized Hospital, hepatopancreaticobiliary and liver transplantation unit. We recruited 76 patients indicated for PD with resectable or borderline resectable preampullary tumors according to the definition put by the International Study Group of Pancreatic Surgery (ISGPS) [11], irrespective of tumor origin or pathology.

During the progress of the study, 37 patients (Fig. 1) were excluded owing to different reasons as follows: either patients who underwent extended PD according to the definition put by the ISGPS [12] or patients who had chronic pancreatitis (confirmed by pathology) without suspected malignancy, pancreatic trauma, or complications following endoscopic retrograde cholangiopancreatography (ERCP), in addition to patients who had pylorus preserved PD (PPPD), liver cirrhosis, previous gastrectomy, or neoadjuvant treatment. Moreover, patients suffering from clinically relevant postoperative pancreatic fistula (POPF) [13], that is, grades B and C, postpancreatectomy hemorrhage (PPH) [14] both grades B and C or chylous leakage [15] grades B or C were excluded, as these complications may causes or affect the severity of GDE and markedly affect the hospital stay and also

Figure 1

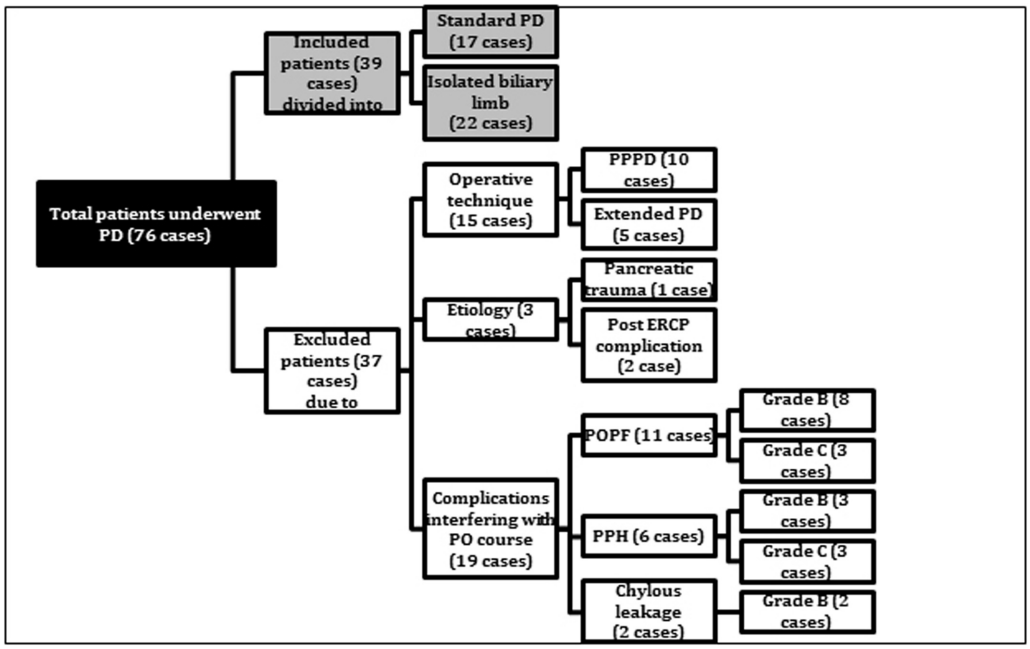

Chart showing all patients underwent PD (black boxes). The included patients (gray boxes) were divided into two groups, and exclusion of patients (white boxes) was based on exclusion criteria. PD, pancreaticoduodenectomy.

may lead to conflict during interpretation of the outcomes.

In this study, we included 39 patients who underwent PD with curative intention (Fig. 1) whose data were analyzed. These patients were divided into two group: group A between the period from the start of the study till the end of June 2020, during which 17 patients underwent standard PD, where the stomach was transected 2 cm above the pyloric ring, preserving nearly 90% of the stomach and all the three anastomosis were done by the standard method on a single jejunal loop. However, group B included 22 patients between the periods from the beginning of July 2020 till the end of the study; during this period, the technique of the operation was changed to Roux-en-Y HJ with an isolated biliary limb as described later.

Figure 2

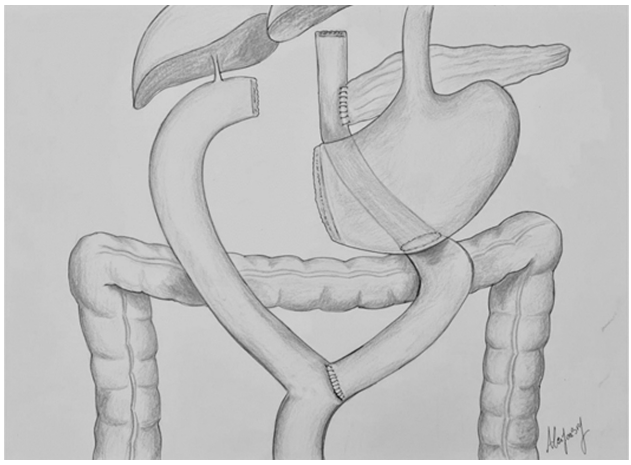

Illustration diagram showing the technique of the isolated jejunal loop (biliary limb) reconstruction.

All patients underwent evaluation and preparation for the surgery according to the defined center protocol, and resectability was assessed by multiphasic computed tomography pancreatic protocol. Preoperative biliary drainage by either percutaneous transhepatic cholangiography or ERCP with plastic stenting was accepted if the serum bilirubin was more than 12 mg/dl or if the patient experienced recurrent attacks of cholangitis. The study protocol was approved by the ethical committee of the hospital, and all patients provided an informed consent.

DGE5, resectable 11 or borderline resectable 11 tumor, standard 12 and extended 12 PD POPF [13], PPH [14], and chylous leakage [15] were defined according to the ISGPS criteria.

Technique of isolated jejunal loop (biliary limb) reconstruction (Fig. 2).

After finishing the resection phase of the PD operation by the standard way, the specimen was removed en bloc. The sequence of anastomoses were started with an end-to-side antecolic two-layer pancreaticojejunostomy (PJ) mucosa-to-mucosa stentless anastomosis between the jejunum and the pancreatic stump using 4/0 polydioxanone sutures for the inner layer and 4/0 polypropylene sutures for the outer layer. Then, the side-to-side gastrojejunal (GJ) anastomosis was done 10–15 cm distal to the pancreatic anastomosis between the same limb and posterior wall of the distal stomach, using a linear GIA-75 stapler (Ethicon, Cornelia, Georgia, USA) over which a second hemostatic layer was taken by 4/0 polydioxanone suture. The ostia, through which the stapler was introduced, was closed extramucusally by 4/0 polydioxanone suture in two layers.

After that, an isolated jejunal limb was created by dividing jejunum 40 cm from the GJ preserving the vascular arcade. The proximal end of this limb was taken antecolic and anastomosed with the common hepatic duct in an end-to-side single-layer stentless duct-to-mucosa HJ using interrupted 4/0 polydioxanone suture.

Approximately 20–30 cm distal to the HJ anastomosis, a Roux-en-Y reconstruction of the jejunum was performed by anastomosing the two jejunal segments following similar steps used in the GJ.

Two silicone drains were placed: one near the PJ anastomosis and the other drain near the HJ anastomosis. The drainage tubes were kept in place for at least 7 days after surgery and were removed when less than 50 ml of clear fluid was drained per day. Patients may be discharged with abdominal drain if there was a well-controlled grade A pancreatic leakage.

Postoperatively, a third-generation cephalosporin combined with metronidazole was administrated. Proton pump inhibitor such as omeprazole 40 mg was given once daily. If the diagnosis of POPF was established, sandostatin ampule subcutaneously 50 μg/1 ml every 8 h was given. Prokinetic such as trimebutine maleate 50 mg every 8 h was used only if the patient was diagnosed with DGE.

Total parenteral nutrition was started on the first day after surgery and replaced gradually by oral intake

which begun immediately after removal of the nasogastric tube (NGT) by the third day on condition that less than 100 ml of gastric juice was drained daily. Patients were discharged when they were able to tolerate solid food approximately half of their daily-recommended calorie intake calculated by the hospital nutritionist.

All interventions were done by a team of surgeons with experience in hepatobiliary and pancreatic surgery. All authors are surgeons, and all contributed to the study. The two senior authors are staff surgeons with special dedication to HBP surgery and liver transplantation and have more than 10 years of experience. At least one of them was always present during the procedures.

The same team of surgeons carried out clinical follow-up of all patients. All patients were followed up for at least 2 months. During the hospital stay, daily laboratory and radiological assessments were done during the first week and then twice weekly until discharge. Biliary reflux was diagnosed either on clinical parameters in the form of epigastric pain, bilious emesis, or if bile output through the NGT tube was more than 200 ml in 24 h.

After discharge, follow-up comprise scheduled outpatient visits to the operating surgeons in the perioperative period on a weekly base. Patients were asked in every visit for abdominal ultrasound and duplex together with routine laboratory data. Otherwise, no other diagnostic radiological or laboratory test was scheduled routinely during the postoperative period, and follow-up contrast-enhanced computed tomography with angiography was done only if necessary based on the patient's condition.

Postoperative morbidity encompassed the appearance of any complication during the hospital stay or within 30 days after surgery. Perioperative mortality was defined as death during the same hospital admission or within 30 days after surgery if the patient was discharged earlier. Readmissions during the first 30 days after surgery were also registered.

Statistical analysis

The patients' age, sex, etiology, comorbidity, preoperative drainage, and BMI were abstracted. Postoperative operation-related complications, for example, POPF, PPH, biliary reflux, biliary leakage, and chylous leakage, as well as length of hospital stay, the need for prokinetics or Total parenteral nutrition (TPN), and mortality were also recorded. The incidence of DGE, NGT requirement and reinsertion, and solid oral intake tolerance were collected and are classified in Table 1.

Recorded data were analyzed using the Statistical Package for the Social Sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). The quantitative data were presented as mean±SD and ranges. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk test. The confidence interval was set to 95%, and the margin of error accepted was set to 5%. Therefore, the *P* value was considered significant as follows: *P* value less than 0.05 was considered significant, *P* value less than 0.001 was considered as highly significant, and *P* value more than 0.05 was considered insignificant.

Results

Between January 2019 and December 2021, we performed 76 cases of PD in our unit. We excluded 37 cases that did not meet our inclusion criteria owing to different causes, as illustrated in Fig. 1. All patients completed at least 2 months of follow-up.

The study included 39 consecutive patients divided into two groups based on the technique used and were compared according to the operation timing. Demographic and preoperative data are presented in Table 2, and when compared, there was no significant difference between the two groups regarding age, sex, BMI, etiology, or comorbidities. In addition, preoperative drainage in the form of percutaneous transhepatic cholangiography or ERCP was adopted in 8/17 (40%) patients in group A versus 6/22 (30%) patients in group B but without any statistical significance ($P>0.05$).

Table 1 Consensus definition of delayed gastric emptying after pancreatic surgery [5]

DGE grade	NGT required				Unable to tolerate solid oral intake by POD	Vomiting/gastric distension	Use of prokinetics
A	4–7	Days or reinsertion	>	POD 3	7	+/–	+/–
B	8–14	Days or reinsertion	>	POD 7	14	+	+
C	14	Days or reinsertion	>	POD 14	21	+	+

DGE, delayed gastric emptying; NGT, nasogastric tube; POD, postoperative day. To exclude mechanical causes of abnormal gastric emptying, the patency of either the gastrojejunostomy or the duodenojejunostomy should be confirmed by endoscopy or upper gastrointestinal gastrografin series.

Table 2 Comparison between standard pancreaticoduodenectomy group and isolated limb group according to baseline characteristics

Baseline characteristics	Standard PD: group A *N*=17	Isolated limb: group B *N*=22	*P* value	Significance
Age				
Mean±SD	50.1±4.63	55.35±3.33	0.611	NS
Range	18–71	22–75		
Sex				
Male				
n (%)	11 (64.7)	13 (59)	0.234	NS
Female				
n (%)	6 (35.3)	9 (41)	0.313	NS
BMI				
Mean±SD	27.61±1.5	25.34±1.49	0.573	NS
Range	16.5–35.5	19.1–36.2		
Etiology				
Pancreatic				
n (%)	6 (35.29)	5 (22.73)	0.327	NS
Ampullary				
n (%)	7 (41.19)	13 (59.1)	0.102	NS
Duodenal				
n (%)	2 (11.76)	1 (4.54)	0.271	NS
Lower CBD				
n (%)	2 (11.76)	3 (13.63)	0.222	NS
Comorbidity				
DM				
n (%)	3 (15)	4 (20)	0.304	NS
Hypertension				
n (%)	2 (10)	1 (5)	0.277	NS
IHD				
n (%)	2 (10)	1 (5)	0.312	NS
Perioperative drainage				
PTC				
n (%)	3 (15)	2 (10)	0.512	NS
ERCP				
n (%)	5 (25)	4 (20)	0.538	NS

ERCP, endoscopic retrograde cholangiopancreatography; NS, nonsignificant; PD, pancreaticoduodenectomy; PTC, percutaneous transhepatic cholangiography.

Table 3 Comparison between standard pancreaticoduodenectomy group and isolated limb group according to general complications

	Standard PD: group A [*n* (%)]	Isolated limb: group B [*n* (%)]		
General complications	*N*=17	*N*=22	*P* value	Significance
Wound infection	2 (11.76)	1 (4.54)	0.277	NS
Pneumonia	0	1 (4.54)	0.134	NS
Pulmonary embolism	0	1 (4.54)	0.134	NS
UTI	2 (11.76)	0	0.031	S
Readmission	1 (5.89)	1 (4.54)	0.212	NS
Reoperation	0	0	NA	NA
Mortality	0	0	NA	NA

NA, not applicable; NS, nonsignificant; PD, pancreaticoduodenectomy; S, significant.

Regarding the general complications (Table 3), the only significant finding was the incidence of Urinary tract infection (UTI) in group A (two patients, 11.76%, *P*=0.031). These two patients required only modification on the antibiotic regimen that did not affect the general plan of management. As mentioned in Table 3, we had two cases of readmission: one patient in group A was readmitted owing to repeated vomiting and inability to tolerate solid oral intake and was managed conservatively without the

need of NGT reinsertion, whereas the other patient in group B was readmitted with wound infection for wound care and parenteral antibiotics.

Although the incidence of biochemical fistula (Table 4) was higher in group B (13.64 vs. 5.89%), it did not reach statistical significance (P=0.405). In contrast, grade A PPH and grade A chylous leakage showed statistically significant difference (P=0.031 and 0.021, respectively), but owing to the small number of patients, both were considered irrelevant (Table 4). The use of a single limb contributed to biliary reflux, which occurred in 29.41% of cases in group A, and this showed a high significance when compared with group B (P=0.000).

The overall incidence of DGE in the whole study group was 33% (13 out 39 patients). Upon comparing the two groups regarding the DGE, Table 5 summarizes and highlights that the overall as well as the stratified incidence according to grades was lower in group B and showed statistically significant values in all grades A, B, and C, with P value of 0.015, 0.000, and 0.023, respectively.

Overall, 77% of these patients (10 out of 13 cases) experiencing DGE were in group A, which represents 58.8% of patients in this group (Table 5). After the use of isolated biliary limb in group B, this incidence had decreased significantly to 13% (three of 22 patients) (Table 5). Moreover, the use of a single loop led to significant prolongation of hospital stay, with a mean of 6.34 days longer in group A (P=0.016) (Table 6) and was also reflected in the higher demand for prokinetics (50% vs. 15%) and TPN (25% vs. 5%) when compared with group B (P=0.021 and 0.11, respectively) (Table 6).

Table 4 Comparison between standard pancreaticoduodenectomy group and isolated limb group according to operation-related complications

	Standard PD: group A [*n* (%)]	Isolated limb: group B [*n* (%)]		
Operation-related complications	*N*=17	*N*=22	*P* value	Significance
POPF (BF)	1 (5.89)	3 (13.64)	0.405	NS
PPH (grade A)	0	1 (4.54)	0.031	S
Biliary reflux	5 (29.41)	0	0.000	HS
Chylous leak (grade A)	1 (5.89)	0	0.021	S
Biliary leak	0	0	NA	NA

BF, biochemical fistula; HS, highly significant; NA, not applicable; NS, nonsignificant; PD, pancreaticoduodenectomy; POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrhage; S, significant.

Table 5 Comparison between standard Pancreaticoduodenectomy group and isolated limb group according to incidence of delayed gastric emptying according International Study Group of Pancreatic Surgery grading

	Standard PD [*n* (%)]	Isolated limb [*n* (%)]		
Incidence of DGE	Group A	Group B	*P* value	Significance
Overall	10/17 (58.8)	3/22 (13.64)	0.000	HS
According ISGPS grading				
Grade A	6/10 (60)	3/3 (100)	0.015	S
Grade B	3/10 (30)	0	0.000	HS
Grade C	1/10 (10)	0	0.023	S

DGE, delayed gastric emptying; HS, highly significant; ISGPS, International Study Group of Pancreatic Surgery; PD, pancreaticoduodenectomy; S, significant.

Table 6 Comparison between standard pancreaticoduodenectomy group and isolated limb group according to hospital stay and postoperative medications needed

Postoperative course	Standard PD: group A *N*=17	Isolated limb: group B *N*=22	*P* value	Significance
Hospital stay				
Mean±SD	14.79±0.81	8.45±1.93	0.016	S
Range	10–22	6–12		
Postoperative medications [*n* (%)]				
Sandostatin	1 (5.9)	3 (13.6)	0.551	NS
Prokinetics	10 (50)	3 (15)	0.021	S
TPN	5 (25)	1 (5)	0.011	S

NS, nonsignificant; PD, pancreaticoduodenectomy; S, significant.

We had studied the two main pillars defining the DGE, that is, the NGT requirement (Table 7) and the solid oral intake tolerance (Table 8). First, the prolonged need for the NGT was recorded in three (17.64%) of 17 cases in group A, two-thirds of which were grade A and one-third were grade B, with *P* values of 0.022 and 0.041, respectively, when compared with only 4.55% of patients in group B (Table 7). The mean time needed until the removal of the NGT was significantly lower in group B (2.1±0.43 vs. 3.9±1.65 days), with *P* value of 0.037, with no incidence of reinsertion in both groups (Table 7).

Second, the solid oral intake tolerance (Table 8) development was faster in group B, with a mean of 3.33±2.88 days, whereas group A needed 8.46±2.81 days to reach tolerance (*P*=0.055). It is worth mentioning that all three patients diagnosed with DGE in group B were grade A, whereas intolerance to solid oral intake was diagnosed in 10 cases in group A; grades A, B, and C were 57.14, 28.57, and 14.29%, respectively (*P*=0.711, 0.031, and 0.025, respectively).

Discussion

DGE is a common complication after PD, and because of this, the ISGPS in 2007 developed a standard definition of DGE. Multiple studies have recorded that the incidence varies widely, from ~20–70% of cases [1].

As DGE is multifactorial, it may present alone or accompanied with other complications. Based on the study published by Horstmann *et al.* [7] and confirmed by Qu *et al.* [16], there was a significant increase in the incidence of DGE, reaching 28% if the patient had wound infection, or temporary cardiopulmonary complications, or transient occurrence of amylase/lipase-rich drainage fluid without signs of sepsis. This increases to 43% if the patient was complicated with anastomotic leakage, bleeding, septic complications, or re-explored. Therefore, in our study, we chose to minimize the interfering factors as much as possible, so we excluded patients with grades B or C for POPF, PPH, or chylous leakage.

In the standard PD, only a short segment of the bowel separates the biliary and pancreatic anastomoses. Therefore, if any leakage from any of these two anastomoses occurred, the secretion leaking through the formed fistula will delay healing and cause digestion of the surrounding tissue because of the active pancreatic enzymes [17].

Table 7 Comparison between standard pancreaticoduodenectomy group and isolated limb group regarding delayed gastric emptying according to nasogastric tube requirement or reinsertion and day of removal

DGE according to NGT requirement	Standard PD [*n* (%)] Group A	Isolated limb [*n* (%)] Group B	*P* value	Significance
Overall	3/17 (17.64)	1/22 (4.55)	0.000	HS
Grade A[1]	2/3 (66.7)	0	0.022	S
Grade B[2]	1/3 (33.3)	0	0.041	S
Grade C[3]	0	0	NA	NA
Reinsertion of NGT	0	0	NA	NA
Day till NGT removal				
Mean±SD	2.9±1.65	2.1±0.43	0.037	S
Range	2–12	1–3		

DGE, delayed gastric emptying; HS, highly significant; NA, not applicable; NGT, nasogastric tube; PD, pancreaticoduodenectomy; POD, postoperative day; S, significant. [1]NGT in place for 4–7 days or reinsertion more than POD 3. [2]NGT in place for 8–14 days or reinsertion more than POD 7. [3]NGT in place for more than 14 days or reinsertion more than POD 14.

Table 8 Comparison between standard pancreaticoduodenectomy group and isolated limb group regarding delayed gastric emptying according to day to tolerate solid oral intake and day to establish solid oral intake

DGE according to day to tolerate solid oral intake	Standard PD [*n* (%)] Group A	Isolated limb [*n* (%)] Group B	*P* value	Significance
Overall	7/17 (41.2)	3/22 (13.64)	0.055	S
Grade A[1]	4/7 (57.14)	3/3 (100)	0.711	NS
Grade B[2]	2/7 (28.57)	0	0.031	S
Grade C[3]	1/7 (14.29)	0	0.025	S
Day to establish solid oral intake				
Mean±SD	8.46±2.81	3.33±2.88	0.031	S
Range	6–25	2–7		

DGE, delayed gastric emptying; HS, highly significant; NA, not applicable; NS, nonsignificant, PD, pancreaticoduodenectomy; POD, postoperative day; S, significant. [1]Not tolerating solid oral intake till POD 7. [2]Not tolerating solid oral intake till POD 14. [3]Not tolerating solid oral intake till POD 21.

In the late 1800s, a modification had been suggested by Braun to improve DGE. He described Braun enteroenterostomy aiming to eliminate bile reflux [18]. The original technique was a side-to-side enteroenterostomy 25 cm away from the GJ.

In 2010, Hochwald *et al*. [19] in the University of Florida had reevaluated the Braun enteroenterostomy and revealed that the rate of DGE decreased from 60 to 36% in those who had performed a Braun enteroenterostomy. A more recent meta-analysis done by Zhou *et al*. [20] including 11 studies and more than 1600 patients who had a Braun enteroenterostomy reported that DGE was present in 11.5% compared with 26.6% in those without a Braun enteroenterostomy.

However, this modification did not completely prevent biliary reflux, as the GJ and the HJ were done on the same limb of jejunum, making it inevitable. It also sacrificed the initial part of the jejunum containing the maximum number of motilin receptors as they used the proximal limb as the afferent limb during reconstruction, beside the disadvantage of the retrocolic path of the jejunal limb.

To overcome this and to prevent the bile from entering the stomach, Wayne *et al*. [21] suggested to interrupt the afferent limb with a stapler just before it enters the stomach to prevent the possibility of bile reflux. However, this modification added more complexity to the operation. They recorded no cases of DGE with this technique. The mean time to tolerate regular diet was eight days, and the mean hospital stay was 8.4 days.

Machado *et al*. [8] from Hiroshima University first described the use of a separate Roux loop in 1976. It seemed to apply a physiological rationale of preventing the biliary reflux and activation of the enzyme precursors. Machado and Machado [22] used an antecolic Roux-en-Y limb of the jejunum after PPPD isolating the pancreaticogastrostomy and the GJ anastomosis from the biliary anastomosis and they were successful in reducing the incidence of DGE significantly.

Unfortunately, in the previous study, DGE diagnosis was based on different criteria than that of the ISGPS, as DGE was diagnosed if the NGT was kept in place for more than 10 days, or if there was an intolerance to solid diet on or before the 14th postoperative day rather than 4 and 7 days according to ISGPS correspondingly. Therefore, the data from this study could not be integrated in the analysis. Besides technically, they placed an external pancreatic tube and decompression gastrostomy tube in all patients, a technique we did not apply in our study.

Another study done by Murakami *et al*. [23] differs from our study in few steps, as they did PPPD for all patients and used PG for the pancreatic anastomosis. Murakami concluded that the only independent factor associated with DGE was the type of reconstruction and the antecolic Roux-en-Y reduced the incidence of DGE after PPPD.

In a similar study in 2015, Krishna *et al*. [6] succeeded to reduce the incidence of DGE by four folds from 21.6% down to 5.2% upon using the isolated loop technique. It worth mentioning that during their study the pancreatic remnant was anastomosed to the stomach. In spite of using a different technique than that used in our study, we also agreed that the Roux-en-Y reconstruction group performed significantly better than the standard group regarding DGE.

In contrast, the first meta-analysis done by Yang *et al*. [24] on the effect of Roux-en-Y reconstruction for the GJ after PD revealed that the incidence of DGE (grades B and C) after PD was higher using Roux-en-Y reconstruction rather than the Billroth II (3.9 vs. 12.9%, P=0.01), and there was no significant difference in overall incidence of DGE (grades A, B, and C) with the use of Roux-en-Y groups (16.4 vs. 19.9%, P=0.34). In this meta-analysis, they did not exclude grade B and C pancreatic fistula nor bile leak, which according to our belief may be the reason for these opposite results.

In our study, we modified Roux-en-Y reconstruction by isolating the biliary anastomosis from the pancreatic and the gastric anastomoses adding another advantage over the modification done by Machado. First, we separated the pancreatic anastomosis from the biliary one and completely diverted the bile away from the stomach. Second, anastomosing the proximal jejunum to the remnant of the pancreas and stomach maximizes the exposure of the motilin receptors aiming to improve gastric empting.

On analyzing the cause of the DGE in the studied group, we observed that the main cause of DGE in group B was intolerance to solid oral intake. The three recorded cases in group B were grade A, and all patients had removed the NGT before the fourth day. Group A showed a significant increase compared with group B,

with 10 cases of intolerance to solid oral intake. This may be explained by the theory adapted by Sanger *et al.* [25] based on the location of the motilin receptors being maximum at the proximal 30–40 cm of jejunum. In the Roux-en-Y reconstruction group in our study, the jejunal segment used for the PJ and GJ contained the maximum motilin receptors. Therefore, the propagation of motor complex activity was maintained from the proximal to the distal small intestine, leading to significant peristalsis and intestinal empting.

Barakat *et al.* [26] had published a study in 2016, using a different sequence of anastomosis than ours, where the GJ was done first and the jejunum was transected 35–40 cm distal to the GJ and the PJ then followed by the HJ, and both limbs were retrocolic. Similar to our study, they used the proximal jejunum for the GJ. They compared 118 patients who underwent standard PD with 90 patients with proximal Roux-en-Y GJ anastomosis. The overall and clinically relevant rates of DGE were significantly lower in the Roux-en-Y group than in the standard reconstruction (10 and 2.2% vs. 57 and 24%), which was reflected on the shorter hospital stay in the Roux-en-Y group.

Finally, the PAUDA trial, 2018, a randomized controlled trial by Busquets *et al.* [27], compared standard PD and Roux-en-Y reconstruction after PD. In this trail, in the Roux-en-Y group, the proximal jejunum was anastomosed first to the pancreas then to the bile duct then transected 60 cm distally. The trial concluded that the incidence and severity of DGE does not differ between the two techniques of reconstruction. Based on the theory of the motilin receptor-rich jejunum segment recommended by Sanger *et al.* [25], they lost a significant amount of receptors. In our study, we started with the PJ followed by GJ, thus retaining a significant amount of proximal jejunum. This specific difference could be the reason for the better results in the RY group in our study.

Limitations

Our study had several limitations. First, this is a single-center study; therefore, the results may not be generalizable to other centers; in addition, it is a nonrandomized study. Second, the small sample size limits the power of the study and hinders the statistical capacity to do multivariate analysis. Finally, we did not confirm information regarding biliary reflux as we did not do upper gastrointestinal endoscopy for patients and was based only on clinical parameters in the form of epigastric pain, bilious emesis, or bile output through a NGTs tube more than 200 ml in 24 h. Besides that, the hepatobiliary scintigraphy study is not available in Egypt.

Conclusion

The technique of reconstruction with isolated biliary loop away from both HJ and gastrojejunostomy in pancreaticoduodenal resection markedly reduces the postoperative incidence and severity of DGE reflected in the lesser duration of hospital stay. However, larger prospective randomized studies are warranted to validate this technique.

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Conflicts of interest

There are no conflicts of interest.

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