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ORIGINAL ARTICLE

Prevention of Delayed Gastric Emptying After Pylorus-Preserving Pancreatoduodenectomy with Antecolic Reconstruction, a Long Jejunal Loop, and a Jejuno-Jejunostomy

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Abstract
Background Delayed gastric emptying (DGE) is one of the major complications following pylorus-preserving pancreatoduodenectomy (PPPD). It leads to significant patient distress and prolonged hospitalization and therefore increased treatment costs. DGE etiology remains unclear but seems to be multifactorial. In order to decrease DGE rates, reconstruction methods have been modified. The presented retrospective study was to evaluate outcomes of different surgical techniques at our institution with special emphasis on retrocolic and antecolic reconstruction types.
Material and Methods One hundred thirteen consecutive patients underwent PPPD between September 2004 and December 2011 for periampullary and bile duct lesions of the pancreatic head and the papilla of Vater. These patients were reviewed for DGE occurrence and other factors. Four different types of reconstruction were applied: the classic retrocolic reconstruction using a short jejunal loop (short loop, n=40) and three types of reconstructions using a long loop: one with a long loop and retrocolic duodenojejunostomy (n=22), another with a long loop and an additional latero-lateral enterostomy (Braun's anastomosis, n=23), and finally, an antecolic group with Braun's anastomosis (n=28). Patients were reviewed for DGE incidence and severity following the International Study Group of Pancreatic Surgery definition of DGE.
Results The highest DGE occurrence was noted in the retrocolic group using a short jejunal loop (15 of 32 patients, 46.9 %), whereas the reconstruction types using long loops showed a notable decrease: DGE occurred in 4 of 16 patients (25 %) in the retrocolic group, in 6 of 21 patients (28.6 %) in the retrocolic group with an additional latero-lateral enterostomy (Braun's anastomosis), and finally, only 1 of 22 patients (4.5 %, p=0.009) in the antecolic group with Braun's anastomosis presenting with DGE, grade A. However, neither hospitalization time nor days in the intensive care unit were significantly different. There was no difference in DGE rates between the retrocolic long-loop groups with and without Braun's anastomosis.
Conclusion The results of this retrospective study suggest that the antecolic route with a long jejunal loop and Braun's anastomosis minimizes DGE rates.

Keywords Delayed gastric emptying · DGE · Pancreatoduodenectomy · Pancreaticoduodenectomy · PPPD · Whipple procedure · Longmire Traverso · Antecolic reconstruction · Gastrojejunostomy · Long loop reconstruction · Jejuno-jejunostomy · Entero-enterostomy · Braun´s anastomosis

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Introduction

Pylorus-preserving pancreatoduodenectomy (PPPD) is the gold standard for resection of tumors of the pancreatic head

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and the periampullary region as well as selected cases of chronic pancreatitis. Advances in both surgical technique and perioperative management have contributed to decrease mortality to <5 % in high-volume centers.[1–3] However, morbidity rates remain within a high range of 30–50 %[4,5] due to pancreatic fistula, intraabdominal abscesses, postoperative hemorrhage, or delayed gastric emptying (DGE). Besides pancreatic fistula (PF), DGE is the most common postoperative complication, leading to significant patient distress, prolonged hospitalization, and increased treatment costs.[6] First described by Warshaw in 1985,[7] DGE rates vary widely from 19 to 61 %.[4,8–10] Comparison of different trials, however, was hampered by the lack of definition of criteria used to classify DGE. In order to increase homogeneity in definitions for future studies, the International Study Group of Pancreatic Surgery (ISGPS) proposed a consensus definition based on the clinical impact in 2007.[11] Application of these consensus criteria demonstrated a DGE incidence of 33.3 to 44.5 % in large volume hospitals.[12–14]

Many attempts have been made in order to reduce DGE incidence after PPPD. In many early studies, a higher incidence of DGE was associated with PPPD in comparison to the conventional Kausch-Whipple pancreatoduodenectomy.[10,15–17] More recent studies failed to confirm this, however.[18,19] Consequently, various therapeutic approaches including pyloric dilatation[20,21], administration of prokinetic drugs like erythromycin,[22] preservation of the right gastric artery,[23] or the left gastric vein[24] have been utilized. Moreover, modifications of the reconstruction method have been instituted, focusing on the reconstruction of the gastric passage. Recent reports suggested that an antecolic duodenojejunostomy instead of the classical retrocolic reconstruction might lead to a decrease in DGE incidence.[25–27] Nonetheless, the few randomized controlled trials comparing those two reconstruction methods[28–30] showed either no difference or a beneficial effect of the antecolic route.

At our institution, the unsatisfactory DGE rates observed with the original reconstruction method lead to modifications of this technique over the last years. The purpose of this retrospective study was to evaluate the different surgical techniques regarding DGE rates as defined and graded following the ISGPS definition.

Materials and Methods

Patients

Data on 153 consecutive patients undergoing pancreatic surgery between September 2004 and December 2011 were reviewed retrospectively. After excluding procedures such as the classical Kausch-Whipple Pancreatico-duodenectomy (KWPD), bypass surgery, left pancreatectomies, or duodenum-preserving resections (performed according to Frey, Beger, or the Bern modification) in order to increase homogeneity in the study groups, 113 consecutive patients with PPPD performed for lesions of the pancreatic head or periampullary region were left for further analysis. Until January 2007, a short-loop reconstruction with a retrocolic duodenojejunostomy (short loop (n=40)) was the preferred surgical approach at our institution. Long-loop reconstructions using a retrocolic duodenojejunostomy (with Braun's anastomosis (n=23) or without Braun's anastomosis (n=22)) were performed during the following years as well as an antecolic duodenojejunostomy route and Braun's anastomosis (n=28) in most recent times. The latter has been the standard procedure since January 2009.

Surgical Procedures

After epidural catheter placement for postoperative pain management, the surgical procedure was performed as follows: after cholecystectomy, the common hepatic duct was transected, followed by transection of the duodenum 3 cm distal to the pylorus. The right gastroepiploic vessels, the right gastric artery, and the left gastric vein were routinely divided during the procedure. In turn, the pancreatic head and about 10 cm of the proximal jejunum were removed. In cases of malignancy or assumed tumors, lymphadenectomy was performed according to the consensus criteria,[31] including dissection of the hepatoduodenal ligament, the common hepatic artery, portal vein, superior mesenteric vein, the celiac trunc, and the superior mesenteric artery.

Reconstruction started by transferring the jejunum to the supra-mesocolic compartment through an incision in the right transverse mesocolon. An end-to-side pancreatojejunostomy with interrupted sutures was formed in a single-layer fashion, ensuring a tension-free anastomosis with adequate perfusion and excluding obstruction of the pancreatic duct. Five to ten centimeters distal to the pancreatoduodenectomy, a single-layer end-to-side hepaticojejunostomy was performed, using continuous sutures. The duodenojejunostomy was always performed in a single-layer end-to-side fashion with continuous sutures.

Reconstruction of the end-to-side duodenojejunostomy was performed in three different manners:

(1) a retrocolic anastomosis was performed about 15–20 cm distal to the hepaticojejunostomy (short loop). This group will be referred to as "Longmire-Traverso (LT) short retro," Fig. 1.
(2) a retrocolic anastomosis was performed about 40–50 cm distal to the hepaticojejunostomy (long loop). This group will be referred to as "LT long retro," Fig. 2.

(3) a retrocolic anastomosis was performed about 40–50 cm distal to the hepaticojejunostomy (long loop) with an additional latero-lateral enterostomy (Braun's anastomosis) 10–15 cm distal to the duodenojejunostomy. This group will be referred to as "LT long retro + Braun's," Fig. 3.
(4) an antecolic anastomosis was performed in the same distance as above (long loop) after positioning the stomach antecolically. Once more, Braun's anastomosis was performed 10–15 cm distal to the duodenojejunostomy. This group will be referred to as "LT long ante + Braun's," Fig. 4.

Routinely, two silicone drains were positioned at the side of the pancreatojejunostomy and the choledochojejunostomy. In addition, a 16 French nasogastric tube was inserted. All patients received intravenous antibiotics (tazobactam + piperacillin) at least 30 min preoperatively and another dose every 120 min during surgery.

Postoperative Management

All patients were transferred to the ICU for at least the first night following surgery. Intravenous antibiotics were not continued on a regular basis. All patients received an intravenous proton pump inhibitor which was converted to oral administration as soon as oral intake was possible. Postoperative oral intake was started after discontinuation of the nasogastric tube, usually on day 1 or 2 after the operation. Surgical drains were removed approximately on days 3–5 if no signs of fistula were present. When criteria of DGE were met (as defined by the ISGPS criteria, Table 1), patients were treated by nasogastric tube insertion and additional administration of prokinetic agents (erythromycin, neostigmine). No patient received somatostatin analogs during the perioperative period.

Postoperative Complications

DGE was defined according to the ISGPS criteria which grade DGE into three groups (Table 1).

DGE grades A–C required the presence of prolonged nasogastric tube (NGT) placement or reinsertion as well as inability to tolerate food. Presence of vomiting and administration of prokinetics was essential for DGE grades B and C, but not necessarily for DGE grade A. In selected patients with DGE, upper gastrointestinal radiography or endoscopy was performed to rule out mechanical obstruction of the duodenojejunostomy. Since no systematic evaluation was performed, these results are not presented in this study.

In their position statement in 2007, the ISGPS suggested that the proposed definition on DGE should be validated by high-volume centers regarding its clinical relevance. In 2009 and 2010, four study groups published their evaluations on DGE according to the ISGPS criteria. All of them stated a good correlation between the classification and the clinical course, revealing feasibility for patient management. However, the German study group (Welsch et al.) indicated limitations in case of major postoperative complications.[12] The authors proved that in patients requiring long-term intubation, relaparotomy, and those with fatal casualties, no differentiation between primary and secondary DGE was possible. Therefore, these patients were excluded from further analysis.

The patients left for analysis (n=91) were evaluated retrospectively for complications due to surgery, including anastomotic leaks leading to pancreatic, biliary, or enteric fistula. Lymphatic fistula was also recorded as well as postoperative hemorrhage or blood transfusions, stenosis, or intestinal perforation. In addition, postoperative infections, sepsis, acute pancreatitis, or wound infections were registered.

Pancreatic fistula was defined as drainage of lipase-rich fluid >3fold higher than the ULN for serum lipase and graded according to the International Study Group on Pancreatic Fistula Definition (ISGPF) criteria (types A–C).[32] Intra abdominal abscess was defined as any liquid retention detected by ultrasound or computed tomography that required drainage. Complications not associated with surgery like cardiac or pulmonary affections were also recorded.

Duration of hospitalization as well as days in the intensive care unit were calculated by considering the next day following surgery as day 1.

Statistical Analysis

Statistical evaluation was carried out using "GraphPad Prism 5" (GraphPad Software, Inc., La Jolla, CA, USA). Results

Table 1 ISGPS consensus definition of DGE after pancreatic surgery

DGE grade	NGT required	Inability 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	12	+	+
C	>14 days or reinsertion >POD 14	21	+	+

DGE delayed gastric emptying, *NGT* nasogastric tube, *POD* postoperative day

were expressed as mean ± standard deviation (SD). Non-normally distributed variables were calculated as medians and were compared by the Kruskal-Wallis test or ANOVA. Comparisons between categorical variables were determined by the X^2 and Fisher's exact test. All values were expressed in absolute numbers with percentages or the median in brackets. Since we had to compare four different groups (LT short retro, LT long retro, LT long retro + Braun's, and LT long ante + Braun's), significance had to be defined as $p<0.0125$ ($p<0.05$ divided by four) for α-adjustment, using the Bonferroni method.

Results

Patient Demographics and Perioperative Data

Our patient cohort consisted of 113 patients who underwent PPPD between September 2004 and December 2011. There was no significant difference in gender, age, BMI, or operation time between the groups (Table 2). Intraoperative blood transfusions differed significantly between the retrocolic group (short loop) and the antecolic group ($p=0.0063$), indicating lower transfusion rates in the antecolic group. The amount of blood supplied per patient was also in favor of the antecolic group compared to the other reconstruction techniques ($p=0.0048$). In contrast, the postoperative blood transfusions showed no statistical difference between the four groups. Major complications requiring relaparotomy did not occur in the LT long retro + Braun's group, revealing a significant difference in comparison to the LT long retro group ($p=0.0038$). No statistical significance was seen concerning mortality rates, duration of hospital stay, or days in the intensive care unit.

Comparison of DGE Incidence

Patients requiring long-term intubation or relaparotomy (mainly due to leakage of either the pancreatic or biliary anastomosis, Table 3) were excluded as well as cases of death due to the aforementioned. To evaluate DGE incidence in our cohort, 91 of the initial 113 patients (80.5 %) were left for analysis. Exclusion rates in the different groups were as follows: 20 % (8 of 40), 27.3 % (6 of 22), 8.7 % (2 of 23), and 21.4 % (6 of 28). According to the ISGPS criteria, DGE occurred in 26 of those patients (28.6 %) with significant differences among the study groups (Table 4).

DGE rates differed significantly between the short-loop group (46.9 %) and the antecolic group (4.5 %, $p=0.0007$). In terms of severity, all patients in the short retro group presented with grade A as well as the one patient in the antecolic group. Grade C did not occur in any of the groups. There was no difference regarding DGE in the retrocolic long-loop groups.

Comparison of Clinical Measures of DGE

Of the total number of 91 patients, 26 developed DGE. Six of these also presented with other abdominal complications (anastomotic leakage (duodenojejunostomy, $n=1$; lymphatic fistula, $n=2$; sepsis, $n=3$) which could be treated conservatively (Table 5)—three of them in the LT short retro group (20 % in this group) and another three in the long retro + Braun's group (50 % in this group). The majority of patients presenting with DGE suffered from nausea or vomiting, requiring prokinetics, with no significant difference between the four groups. Regarding NGT insertion, the longest duration (7 days ± 3 days) was seen in the short-loop group which was significantly increased compared to 1 day (1 day ± 0 day) in the antecolic group ($p=0.0004$). Once more, there was no statistical difference between the four groups. In terms of the duration of NGT reinsertion, the antecolic group presented the best results once more (1 day) compared to 8.5 days in the long-loop retro + Braun's group. Regarding the duration of the additional parenteral nutrition, the short retro group compared favorably (7 (5–14) days) whereas it was 14 (8–38) days in the long retro + Braun's group.

Due to small numbers, p value could not be determined, but a strong trend toward the antecolic reconstruction was noticed.

Of all reconstruction methods mentioned, retrocolic short-loop reconstruction showed more disadvantages compared to the long loops. Since significant differences could not be established between the LT long retro groups with or without Braun's anastomosis, we established a new cohort (LT long retro plus LT long retro + Braun's), comparing this retrocolic group with the antecolic one (Tables 6 and 7).

There was no statistical difference in demographic parameters between the retrocolic and antecolic reconstruction groups (Table 6). The antecolic group compared favorably regarding operation time ($p=0.0277$), whereas intra- or postoperative blood transfusions did not differ significantly. As mentioned before, only 1 of 22 patients (4.5 %) suffered from mild DGE (grade A) in the antecolic group in comparison to 27 % (10 of 37 patients, grade A in four patients, grade B in 6) in the retrocolic group which was significant ($p=0.0406$, Table 7). As a result, NGT insertion and reinsertion also differed significantly ($p=0.0055$ and $p=0.0151$). Relaparotomy (15.6 vs. 17.9 %, retro vs. ante) and mortality rates (2.2 vs. 7.1 %, retro vs. ante) did not

show statistical difference between the groups nor did the duration of hospital stay or days in the intensive care unit.

Discussion

Pylorus-preserving pancreatoduodenectomy (PPPD) is the standard procedure for tumors of the pancreatic head and the periampullary region. Standardization of surgical technique, perioperative patient management, and management of complications resulted in a significant reduction in mortality rates. Morbidity rates, however, remain high at 30–50 %.[4,5] Delayed gastric emptying (DGE) is one of the most common complications after PPPD, leading to considerable patient distress and prolonged hospitalization and therefore increased treatment costs.

DGE etiology remains unclear but is most likely multifactorial. Thus, various theories regarding the pathophysiological mechanisms have been proposed. Those include ischemia of the antropyloric region due to transection of the right gastric artery[33] or transient gastroparesis after damaging the pyloric branches of the vagal nerve (nerve of Laterjet) during extended lymph node dissection along the common hepatic artery.[34] Decreased motilin levels due to resection of the duodenum and the proximal jejunum, the hormone's primary localization, also seems to contribute to prolonged gastric atony resulting in DGE.[22] Some authors note an association between DGE and septic complications due to anastomotic leakage, intraabdominal abscess, or local inflammation,[35,36] whereas other trials revealed DGE as an isolated event.[15,20] In addition, torsion or transient angulation of the duodenojejunostomy, caused by gastroparesis leading to gastric distension, might create a mechanical outflow obstruction and therefore contribute to DGE.[37]

It may be speculated that fixation of the duodenojejunostomy using a short jejunal loop decreases the motility of the pyloric region, leading to angulation of the body of the stomach once the stomach is filled, thus causing functional outlet obstruction. Different therapeutical approaches have been employed to decrease DGE rates. Those include administration of prokinetic drugs such as the motilin-receptor agonist erythromycin[22] or the somatostatin analog octreotide. Others focus on the resection methods. There has been a long-standing controversy regarding higher DGE incidence in pylorus-preserving PD in comparison to the classic Kausch-Whipple PD. Recent studies emphasized that DGE is not attributable to pylorus preservation.[38] Nevertheless, in Japan, subtotal stomach-preserving PD which includes removal of the pylorus ring and 2 cm of the distal stomach has been performed since the 1990s as an alternative to PPPD and is still popular.[27,39] Intraoperative pylorus dilatation has also been reported to have benefits.[20,21] Moreover, various trials focusing on the reconstruction method and DGE incidence have been performed, whereas Billroth-II-type reconstructions seem to be superior to Billroth I,[40,41] controversy concerning a retrocolic or antecolic fashioned duodenojejunostomy still exists.[11,25,27–30,38,42,43]

At our institution, PPPD was introduced as the standard technique after several studies revealed equal long-term survival in patients undergoing this procedure. In particular, better postoperative quality of life due to a lower incidence of dumping syndromes was observed. PPPD with a short jejunal loop was initially the predominant reconstruction method, but high DGE incidence and ulcer of the duodenojejunostomy with the risk of malignant transformation was reported and led to a modification in the reconstruction technique. Starting in 2007, modifications of the surgical technique using long-loop reconstructions were established for three reasons—to improve gastric emptying by increasing gastric motility, to prevent reflux of gastric contents into the afferent loop and into the biliary system, and thirdly, to prevent the so-called "afferent loop syndrome" by stasis of enteric contents in the jejunal loop.

Our working hypothesis for the high incidence of DGE with the classical PPPD reconstruction technique was that fixation of the duodenojejunal anastomosis would cause gastric outlet obstruction. We assumed that gastric atony would happen to some degree in a large proportion of patients after PPPD. In turn, the stomach would be filled with gastric contents, causing distension of the stomach. Due to the fixation of the stomach close to the transverse mesocolon, the body of the stomach would descend to the middle or even lower abdomen, thereby causing angulation of the pyloric region and the development of gastric outlet obstruction. With utilization of a long jejunal loop as well as the antecolic reconstruction technique, the entire stomach including the pylorus and the duodenojejunal anastomosis would be able to move downward, preventing gastric angulation as discussed above.

The second rationale for using a long jejunal loop was the observation that in some patients with the short-loop reflux of gastric contents into the afferent loop as well as reflux into the biliary system and clinical evidence of cholangitis were observed. In analogy to the conventional technique of using a 50-cm long jejunal loop for Roux-en-Y reconstruction of the bilio-enteric anastomosis, we assumed that the use of a longer jejunal loop would prevent biliary reflux with potentially beneficial effects on the rate of cholangitis.

One disadvantage of the use of a long jejunal loop has previously been reported for Billroth II reconstruction

following gastrectomy as well as following pancreatic head resections. Reflux of gastric contents into the afferent loop was demonstrated to cause stasis of fluid in this loop and reflux into the biliary system, causing cholangitis.[44] In order to avoid the aforementioned "afferent loop syndrome," we established an additional latero-lateral enterostomy (Braun's anastomosis). This improved emptying of the afferent loop in the distal jejunal loop. One additional beneficial factor would be that pancreatic and bile duct fluid from the afferent jejunal loop would bypass the duodenojejunal anastomosis. Since it has previously been shown that this anastomosis is prone to developing ulcers, the bypass of the fluids through the enteroenterostomy would potentially decrease damage and ulceration at this point.

Several studies suggest that the antecolic reconstruction technique has distinct advantages as compared to the retrocolic route.[25–29] At our institution, the surgical approach has been standardized since 2009/2010; PPPD is carried out preserving the pyloric branches of the vagal nerve but transecting the right gastric artery in order to improve the motility of the pylorogastric region. Regarding reconstruction methods, an antecolic route with a latero-lateral enterostomy (Braun's anastomosis) is now the standard procedure. In support of our hypothesis, Tani et al. demonstrated in one of the few randomized controlled trials[29] a significant difference favoring the antecolic reconstruction technique, whereas the most recent trial by Gangavatiker et al.[30] could not establish a statistical difference nor could the retrospective study by Masui et al.[43] Furthermore, antecolic reconstruction in the present study resulted in decreased operation time as well as a significantly decreased requirement for intraoperative blood transfusions. These improvements may be explained by the technically easier reconstruction by an antecolic rather than a retrocolic route. In addition, increased surgical experience with these techniques might contribute.

Reconstruction methods are still discussed controversially in the current literature. Unfortunately, most of the investigations were conducted prior to the introduction of the ISGPS consensus definition[20,26,28,29] which makes comparison of different trials impossible. Nonetheless, there is a noticeable trend toward improved results with the antecolic route. Possible explanations include creating a longer distance between the duodenojejunostomy and the pancreatic anastomosis, a potential septic focus in cases of leakage since some studies have shown an association between DGE incidence and intraabdominal complications.[35,36] In addition, our hypothesis is that the antecolic route increases the motility of the stomach, reducing the risk of transient angulation of the anastomosis with consecutive outflow obstruction.

As mentioned before, we used the ISGPS consensus criteria which have only recently been validated for their clinical relevance in several high-volume centers,[12–14,45] revealing feasibility for patient management. However, Welsch et al. indicated limitations of the classification in case of major postoperative complications and ICU treatment.[12] Thus, we excluded patients with prolonged intubation, relaparotomy, or fatal casualties to enable differentiation of primary DGE and DGE as a secondary complication. This obviously distorts results, indicating less overall DGE rates.

Taking this into consideration, our overall DGE incidence was 28.6 % (26 of 91 patients) with significant difference between the study groups. Comparing the four groups for DGE incidence, the data indicated a very low incidence in the antecolic group with only 1 patient of 22 patients (4.5 %) presenting with DGE, grade A. From the six patients formerly excluded from the antecolic cohort (initially, $n=28$), two cases of death had to be recorded: one patient died from a cerebral stroke and subsequent intraabdominal bleeding due to hemodilution and the other patient due to either myocardial infarction or pulmonary embolism without intraabdominal pathology. Four patients required relaparotomy for either leakage of the hepaticojejunostomy ($n=1$), the pancreatojejunostomy ($n=1$), or both ($n=1$); one patient presented with an intraabdominal abscess ($n=1$) that could not be treated interventionally.

We recognize that there are many limitations of the current study, and several factors need to be taken into account to judge the implications of these findings in this rather limited number of patients. Due to the retrospective character of this study, the different types of reconstruction were not used concurrently or in a randomized fashion. Therefore, the implications of the findings need to be interpreted with some caution. Factors possibly influencing these favorable results might result from the antecolic reconstruction technique, in addition to improved surgical experience and implementation of a fast track rehabilitation concept.

From an evidence-based scientific view, a randomized controlled clinical trial would be helpful to clarify which surgical reconstruction would be best. However, the favorable clinical results of the presented technique have to be critically weighed against the justification to randomize patients to a potentially inferior and complication-prone surgical procedure.

In summary, we present retrospective data on modifications of the surgical reconstruction following pylorus-preserving pancreatoduodenectomy. We demonstrate that delayed gastric emptying was nearly eliminated, applying a simple modification of the reconstruction technique, using a long jejunal loop, an enteroenterostomy (Braun's anastomosis) and an antecolic route of the gastrojejunostomy. Further studies to support these findings in a larger cohort of patients are needed in order to make general recommendations for the use of this surgical technique in the future.

Conflict of Interest All authors have no conflicts of interest to declare.

Appendix

Table 2 Patient demographics and peri-/postoperative data in the different groups

	LT short retro (n=40)	LT long retro (n=22)	LT long retro + Braun's (n=23)	LT long ante + Braun's (n=28)	P value
Gender					0.9082
Male	22 (55 %)	10 (45.5 %)	12 (52.2 %)	15 (53.6 %)	
Female	18 (45 %)	12 (54.5 %)	11 (47.8 %)	13 (46.4 %)	
Age (years)	65 (42–86)	70 (32–81)	69 (29–82)	63,5 (34–83)	0.6074
BMI (kg/m^2)	24.39 (19.83–35.27)	24.26 (19.10–35.93)	23.81 (18.35–37.88)	25.04 (19.88–32.41)	0.9437
Operation time (min)	232.5 (155–450)	265 (130–360)	255 (140–370)	217.5 (170–395)	0.1331
Intraoperative blood transfusion					0.0327[a]
Yes	17 (42.5 %)	5 (22.7 %)	6 (26.1 %)	3 (10.7 %)	
No	23 (57.5 %)	17(77.3 %)	17 (73.9 %)	25 (89.3 %)	
Blood supply (units) per patient	0 (0–4)	0 (0–7)	0 (0–3)	0 (0–2)	0.0394[b]
Postoperative blood transfusion					0.2319
Yes	22 (55 %)	14 (63.6 %)	12 (52.2 %)	10 (35.7 %)	
No	18 (45 %)	8 (36.4 %)	11 (47.8 %)	18 (64.3 %)	
Blood supply(units) per patient	2 (0–39)	2 (0–37)	2 (0–8)	0 (0–21)	0.3642
Relaparotomy					0.0416[c]
Yes	7 (17.5 %)	7 (31.8 %)	0 (0 %)	5 (17.9 %)	
No	33 (82.5 %)	15 (68.2 %)	23 (100 %)	23 (82.1 %)	
Mortality					0.5968
Yes	3 (7.5 %)	1 (4.5 %)	0 (0 %)	2 (7.1 %)	
No	37 (92.5 %)	21 (95.5 %)	23 (100 %)	26 (92.9 %)	
Hospital stay (days)	17 (2–56)	19 (2–92)	16 (10–61)	15 (5–57)	0.5510
Intensive care unit (days)	3 (1–56)	4 (1–56)	3 (1–39)	4 (1–32)	0.4560

Units=500 ml each

BMI body mass index

[a] Significant difference: LT short retro/LT long ante + Braun's (p=0.0063)

[b] Significant difference: LT short retro/LT long ante + Braun's (p=0.0048)

[c] Significant difference: LT long retro/LT long retro + Braun's (p=0.0038)

Table 3 Pancreatic and biliary fistula rates in the different groups

	LT short retro (n=40)	LT long retro (n=22)	LT long retro + Braun's (n=23)	LT long ante + Braun's (n=28)	P value
Pancreatic fistula	4 (10 %)	2 (9 %)	1 (4.3 %)	1 (3.6 %)	0.6965
Type A	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	
Type B	2 (5 %)	0 (0 %)	1 (4.3 %)	0 (0 %)	
Type C	2 (5 %)	2 (9 %)	0 (0 %)	1 (3.6 %)	
Biliary fistula	5 (12.5 %)	1 (4.5 %)	0 (0 %)	2 (7.1 %)	0.2893
Pancreatic plus biliary fistula	1 (2.5 %)	1 (4.5 %)	0 (0 %)	1 (3.6 %)	–[a]

[a] Numbers too small for statistical analysis

Table 4 DGE incidence and grading in the different groups

	LT short retro (n=32, ex=8)	LT long retro (n=16, ex=6)	LT long retro + Braun's (n=21, ex=2)	LT long ante + Braun's (n=22, ex=6)	P value
DGE					0.009[a]
Yes	15 (46.8 %)	4 (25 %)	6 (28.6 %)	1 (4.5 %)	
No	17 (53.1 %)	12 (75 %)	15 (71.4 %)	21 (95.5 %)	
DGE grades					0.0025[b]
A	15 (46.8 %)	2 (12.5 %)	2 (9.5 %)	1 (4.5 %)	
B	0 (0 %)	2 (12.5 %)	4 (19 %)	0 (0 %)	
C	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	

DGE delayed gastric emptying, *Ex* number of patients excluded for DGE evaluation

[a] Significant difference: LT short retro/LT long ante + Braun's (p=0.0007)

[b] Significant difference: LT short retro/LT long retro + Braun's (p=0.0025)

Table 5 Clinical measures of DGE

	LT short retro (n=32, ex=8)	LT long retro (n=16, ex=6)	LT long retro + Braun's (n=21, ex=2)	LT long ante + Braun's (n=22, ex=6)	P value
DGE without other complications	12 (37.5 %)	4 (25 %)	3 (14.3 %)	1 (4.5 %)	–[a]
DGE in combination with other abdominal complications	3 (9.4 %)	0 (0 %)	3 (14.3 %)	0 (0 %)	–[a]
Nausea/vomiting (number of patients)	13 (40.6 %)	4 (25 %)	5 (23.8 %)	1 (4.5 %)	0.029[b]
NGT insertion (in days)	7 (4–10)	1 (1–2)	1.5 (1–4)	1 (1–1)	0.0004[c]
NGT reinsertion (in days)	7 (6–8)	5 (3–8)	8.5 (3–18)	1 (1–1)	0.3212
Administration of prokinetics (number of patients)	12 (37.5 %)	4 (25 %)	6 (28.6 %)	1 (4.5 %)	0.0536
Duration of additional parenteral nutrition (in days)	7 (5–14)	13 (7–20)	14 (8–38)	11 (11)	0.0372[d, e]

DGE delayed gastric emptying, *Ex* number of patients excluded for DGE evaluation, *NGT* nasogastric tube

[a] Numbers too small for statistical analysis

[b] Significant difference: LT short retro/LT long ante + Braun's (p=0.0037)

[c] Significant difference: LT short retro/LT long ante + Braun's (p=0.0081); LT short retro/LT long retro + Braun's (p=0.001); LT short retro/LT long retro (p=0.0028)

[d] No significant difference applying Bonferroni method (short retro/long retro + Braun's (p=0.0203)

[e] Numbers too small in the long ante + Braun's group for statistical analysis

Table 6 Comparison of demographic and peri-/postoperative factors in the long-loop groups (retrocolic and antecolic route)

	LT long retro ± Braun's (n=45)	LT long ante + Braun's (n=28)	P value
Gender			0.8376
Male	22 (48.9 %)	15 (53.6 %)	
Female	23 (51.1 %)	13 (46.4 %)	
Age (years)	70 (29–82)	63,5 (34–83)	0.2288
BMI (kg/m^2)	24.22 (18.35–37.88)	25.04 (19.88–32.41)	0.9367
Operation time (min)	260 (130–370)	217.5 (170–395)	0.0277
Intraoperative blood transfusion			0.2228
Yes	11	3	
No	34	25	
Blood supply (units) per patient (n=73)	0 (0–7)	0 (0–2)	0.1277
Postoperative blood transfusion			0.0926
Yes	26	10	
No	19	18	
Blood supply (units) per patient (n=73)	2 (0–37)	0 (0–21)	0.1442
Relaparotomy			1.0000
Yes	7 (15.6 %)	5 (17.9 %)	
No	38 (84.4 %)	23 (82.1 %)	
Mortality			0.5543
Yes	1 (2.2 %)	2 (7.1 %)	
No	44 (97.8 %)	26 (92.9 %)	
Hospital stay (days)	19 (7–92)	15 (5–57)	0.3041
Intensive care unit (days)	3 (1–56)	4 (1–32)	0.4588

Units=500 ml each

BMI body mass index

Table 7 Clinical measures of DGE in the long-loop groups (retrocolic and antecolic route)

	LT long retro ± Braun's (n=37, ex=8)	LT long ante + Braun's (n=22, ex=6)	P value
DGE			0.0406
Yes	10 (27 %)	1 (4.5 %)	
No	27 (73 %)	21 (95.5 %)	
DGE grade			0.4545
A	4 (10.8 %)	1 (4.5 %)	
B	6 (16.2 %)	0 (0 %)	
C	0 (0 %)	0 (0 %)	
DGE without other complications	7 (18.9 %)	1 (4.5 %)	
DGE in combination with other abdominal complications	3 (8.1 %)	0 (0 %)	
Nausea/vomiting (number of patients)	9 (24.3 %)	1 (4.5 %)	0.0739
NGT insertion (days)	1 (1–4)	1 (1–1)	–[a]
NGT reinsertion (days)	5 (3–18)	1 (1–1)	–[a]
Administration of prokinetics (number of patients)	10 (27 %)	1 (4.5 %)	0.0406
Duration of additional parenteral nutrition (days)	13 (7–38)	11 (11–11)	–[a]

DGE delayed gastric emptying, *Ex* number of patients excluded for DGE evaluation, *NGT* nasogastric tube

[a] Numbers too small for statistical analysis

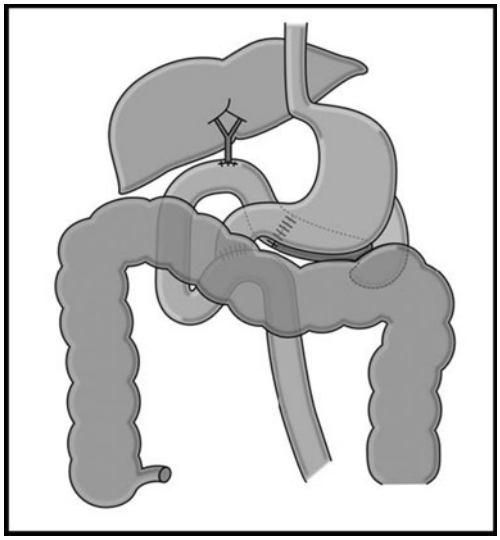

Fig. 1 Retrocolic route with a short-loop reconstruction ("Longmire-Traverso (LT) short retro"). The jejunal limb is brought up through a single rent in the right mesocolon

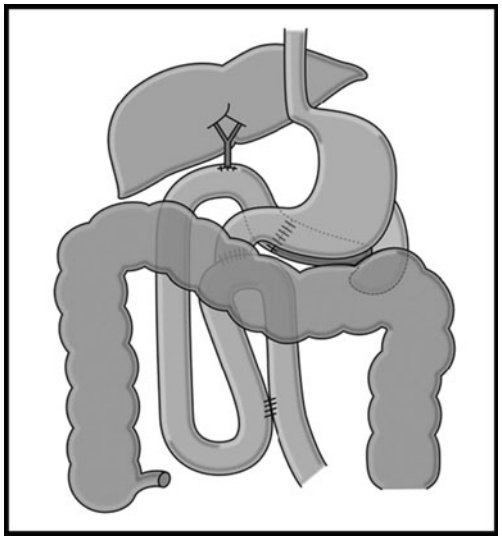

Fig. 3 Retrocolic route with a long-loop reconstruction and an additional latero-lateral enterostomy (Braun's anastomosis, "LT long retro + Braun's"). The jejunal limb is brought up through two separate rents (right and left of the middle colic artery) in the mesocolon

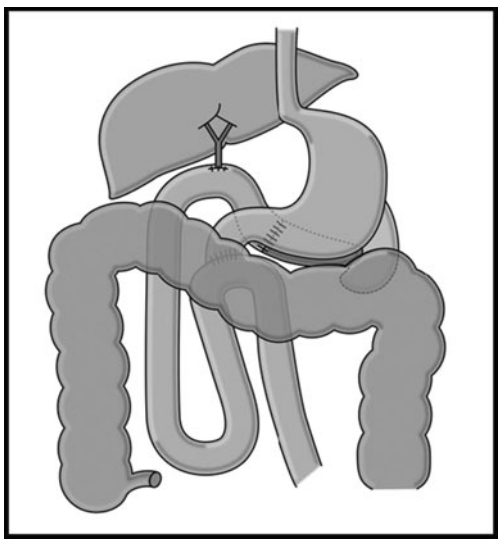

Fig. 2 Retrocolic route with a long-loop reconstruction ("LT long retro"). The jejunal limb is brought up through two separate rents (right and left of the middle colic artery) in the mesocolon

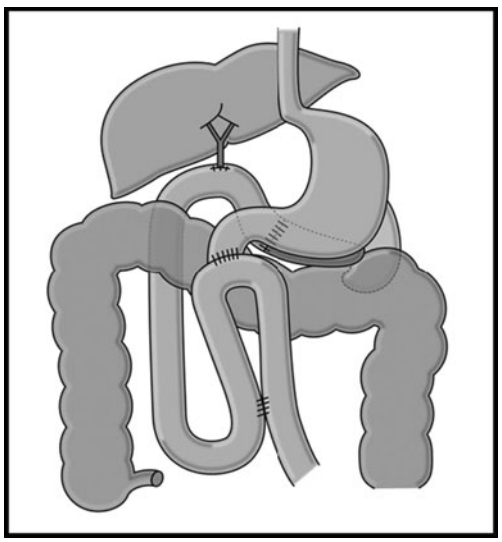

Fig. 4 Antecolic route with a long-loop reconstruction and an additional latero-lateral enterostomy ("LT long ante + Braun's"). The jejunal limb is brought up through a single rent in the right mesocolon distal to the hepaticojejunostomy

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