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A new technique of duodenojejunostomy may reduce the rate of delayed gastric emptying after pylorus-preserving pancreatoduodenectomy: The growth factor technique (with video)

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ABSTRACT

Background: Despite various technical modifications, delayed gastric emptying (DGE) is one of the most common complications after pancreatoduodenectomy. DGE results in longer hospital stay, higher cost, lower quality of life, and delay of adjuvant therapy. We have developed a modified duodenojejunostomy technique to reduce the incidence of DGE. Here we evaluate our 4-year experience with this technique.

Methods: This study evaluated consecutive patients who underwent pylorus-preserving pancreatoduodenectomy using the growth factor technique. It consists of performing a posterior seromuscular running suture with a zigzag stitch that stretches the jejunum and allows future growth of the anastomosis. This results in a longer jejunal opening. The angles at the edge of the duodenum are cut to accommodate the duodenal opening to the longer jejunum (the growth factor). The anterior seromuscular layer is then performed with interrupted sutures to accommodate the larger anastomosis. These patients were compared with a cohort of patients (n = 103) before the introduction of this new technique using propensity score matching.

Results: 134 patients underwent pylorus-preserving pancreatoduodenectomy. Delayed gastric emptying occurred in only three patients (2.2%), one grade B and two grade C. Compared with the 103 patients in the control group with standard technique, the incidence of DGE was significantly higher (11.6%; P = 0.00318). The median hospital stay was also statistically longer in the control group (P = 0.048704). A similar trend was observed in the matched cohort; the proportion of patients who developed DGE was significantly (P = 0.005) lower in the growth factor technique group (2.1% vs. 12.9%). Hospital stay was significantly longer in the standard group (P = 0.008), and patients operated on with the standard technique resumed feeding later than those with the growth factor technique.

Conclusions: This study demonstrated that the new technique of duodenojejunostomy can reduce the incidence and severity of DGE and allow earlier hospital discharge. Comparative studies are still needed to confirm these preliminary results.

1. Introduction

Pancreatoduodenectomy is the gold standard technique for the treatment of tumors in the periampullary area [1]. Although the original description (classic Whipple) involved an antrectomy, in recent years surgeons have increasingly resorted to pyloric preservation, arguing that this technique results in less blood loss and a better quality of life [2,3]. However, subsequent studies indicated that pyloric preservation could be associated with an increase in delayed gastric emptying (DGE) [4,5]. Conversely, meta-analyzes [6,7] showed no differences between the incidence of DGE in pylorus-preserving pancreatoduodenectomy (PPPD) and classic Whipple. Other operative factors may also affect the rate of DGE, such as the method of gastric drainage reconstruction (antecolic versus retrocolic) [8].

DGE after pylorus-preserving pancreatoduodenectomy has been attributed in part to devascularization and denervation of the pylorus with subsequent pylorospasm [9,10]. Recent reports comparing standard pylorus-preserving pancreatoduodenectomy with additional pyloric dilatation or pyloromyotomy support this concept and suggest a decrease in the incidence of DGE after these modified techniques [11,

Abbreviations: DGE, Delayed gastric emptying; PPPD, Pylorus-preserving pancreatoduodenectomy; POD, Postoperative day; PD, Pancreatoduodenectomy.

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12]. Other factors have also been considered as independent risk factors for DGE, such as a preoperative biliary stent, diabetes, and pyloric resection [13].

Current data suggest that despite various technical modifications, delayed gastric emptying is one of the most common complications after pancreatic head resection, occurring in up to 80% of cases [14]. Delayed gastric emptying results in longer hospital stay, high cost to health care systems, decreased quality of life, and delay in adjuvant cancer therapy [14]. We have developed a modified technique of duodenojejunostomy to reduce the incidence of delayed gastric emptying. Here, we evaluate our 4-year experience with this technique using a prospective database.

2. Methods

2.1. Study design and setting

This observational study includes a cohort of patients treated in an urban reference center for pancreatic diseases in São Paulo, Brazil. All patients undergoing pancreatic resection at our institution are included in a database prospectively maintained by our hepato-pancreato-biliary (HPB) fellows and clinical study nurses and submitted to a multidisciplinary tumor board. This study retrospectively examined consecutive patients who underwent pylorus-preserving pancreatoduodenectomy for benign or malignant disease by open or minimally invasive procedures by this team between May 2018 and September 2022, and the occurrence of DGE is recorded and classified. All patients were followed up in our surgical clinic with data collection forms. Patients with pyloric resection were excluded from the analysis. This cohort of patients was later compared with historical cases before the introduction of the new technique.

2.2. Delayed gastric emptying (DGE) definition

Delayed gastric emptying (DGE) was defined according to the International Study Group of Pancreatic Surgery [15].

According to this classification, mild, moderate, and severe forms of DGE after pancreatic resection can be divided into grades A, B, and C based on their clinical impact. Grade A DGE should be considered if the nasogastric tube (NGT) is required between POD 4 and 7, or if the NGT had to be reinserted due to nausea and vomiting after removal by POD 3 and the patient cannot tolerate solid food at POD 7 but resumes solid food before POD 14. A Grade B DGE is present if NGT is required from POD 8–14, if the NGT had to be reintroduced after POD 7, or if the patient cannot tolerate unlimited oral intake by POD 14 but can resume solid oral foods before POD 21. Grade C DGE is present if nasogastric intubation cannot be discontinued or must be reintroduced after POD 14 or if the patient is unable to maintain unlimited oral intake until POD 21.

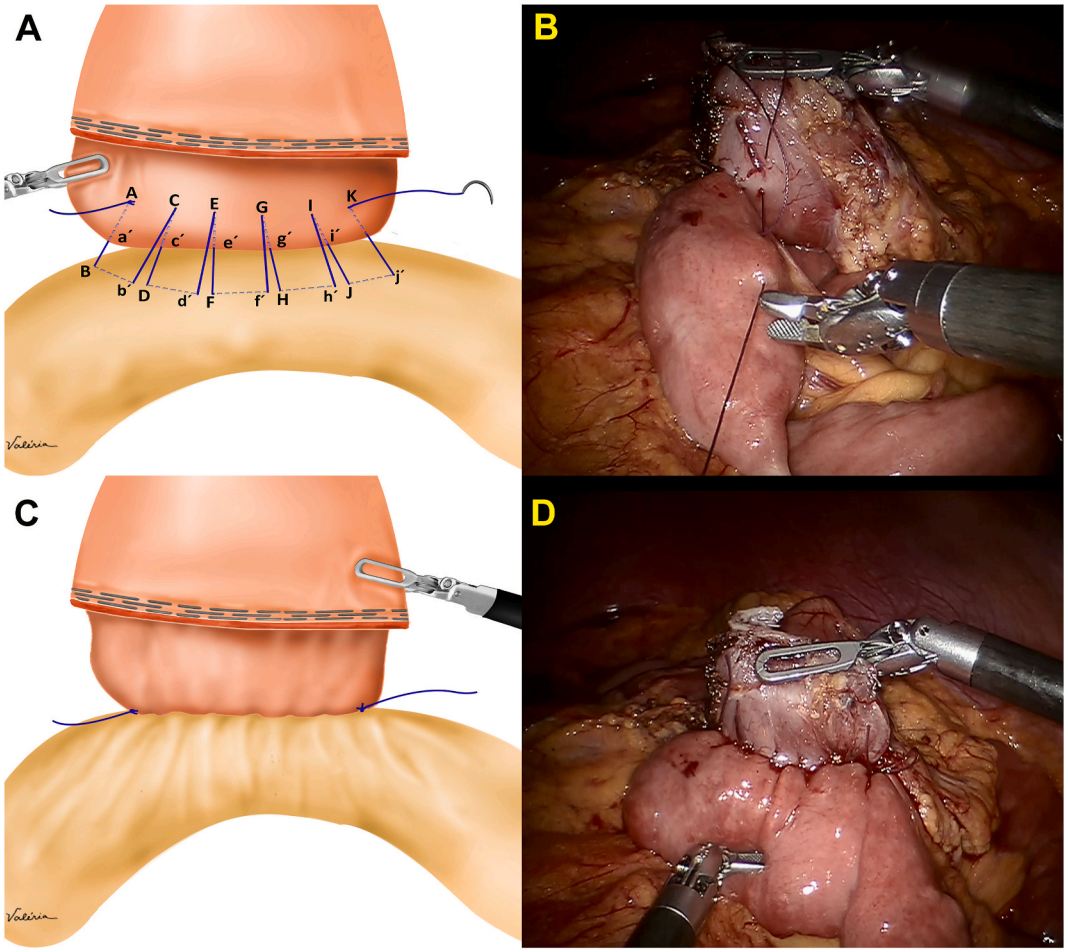

Fig. 1. The growth factor technique of duodenojejunostomy
A. Schematic drawing. Posterior seromuscular running suture with zigzag stretch stitch. The suture is performed by placing a longitudinal suture through the seromuscular layer of the duodenum (A to a'), 1 cm below the pylorus, and another suture along the jejunal axis (B to b').
B. Intraoperative photograph of the posterior seromuscular stretch suture.
C. Schematic drawing of the stretched jejunum.
D. Intraoperative image of the stretched jejunum.

2.3. The growth factor technique

After pylorus-preserving pancreatoduodenectomy, pancreaticojejunostomy was performed with the duct-to-mucosa technique without stenting. Hepaticojejunostomy was performed with a single layer of absorbable running suture. Reconstruction of the digestive tract was performed with an antecolic duodenojejunostomy.

The new technique of duodenojejunostomy consists of performing a seromuscular running suture with a zigzag stretch stitch (Fig. 1). The suture is performed by placing a longitudinal suture through the seromuscular layer of the duodenum, 1 cm below the pylorus, and another suture along the jejunal axis. This type of suture stretches the jejunum (Fig. 1) and allows for a future growth of the anastomosis. The second step is to open the duodenum and jejunum. The jejunal opening is longer than the duodenal opening. Therefore, some adjustments are necessary. The angles at the edge of the duodenum are cut according to the size of the jejunal opening so that the posterior suture fits (Fig. 2). The third step is to perform a full-length posterior layer with a running suture (Fig. 3A). Next, the anterior layer of the duodenum is removed to approximate the length of the jejunum, as shown in Fig. 3B. The next step is to perform a full-length anterior layer with running suture (Fig. 3C) to match the opening of the duodenum to the longer jejunum (growth factor). The anterior seromuscular layer is then performed with interrupted sutures to accommodate the larger opening, and the duodenojejunostomy is completed (Fig. 3D). Fig. 4 shows the endoscopic view of duodenojejunostomy in the immediate postoperative period in a patient with the new technique (Fig. 4A and B) and a patient with the standard technique (Fig. 4C and D).

2.4. Control group

The cohort of patients who underwent the new technique was compared with patients operated on by the same team before the introduction of this technique. 103 patients who underwent pylorus-preserving pancreatoduodenectomy were identified in our prospective database between January 2014 and April 2018.

2.5. Statistical analysis

Propensity score matching (PSM) was performed to increase comparability between the two groups (i.e., growth factor vs. standard technique). The propensity score was estimated using key baseline characteristics related to group assignment, including age, sex, BMI (body mass index), ASA (American Society of Anesthesiologists classification), diagnosis, technique (open or minimally invasive), and tumor size. PSM was performed with a 1:1 matching ratio after the difference was less than 0.1, which considered PSM balanced. Results are presented as mean and standard deviation for numeric variables (after checking for normal distribution) and as number and percentage for categorical data. Comparison between groups was performed using Student's t-test for paired data with equal variance for numerical data (after checking for normal distribution) and chi-square test for categorical data. A value of $p < 0.05$ was considered significant. Data were analyzed using the program R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

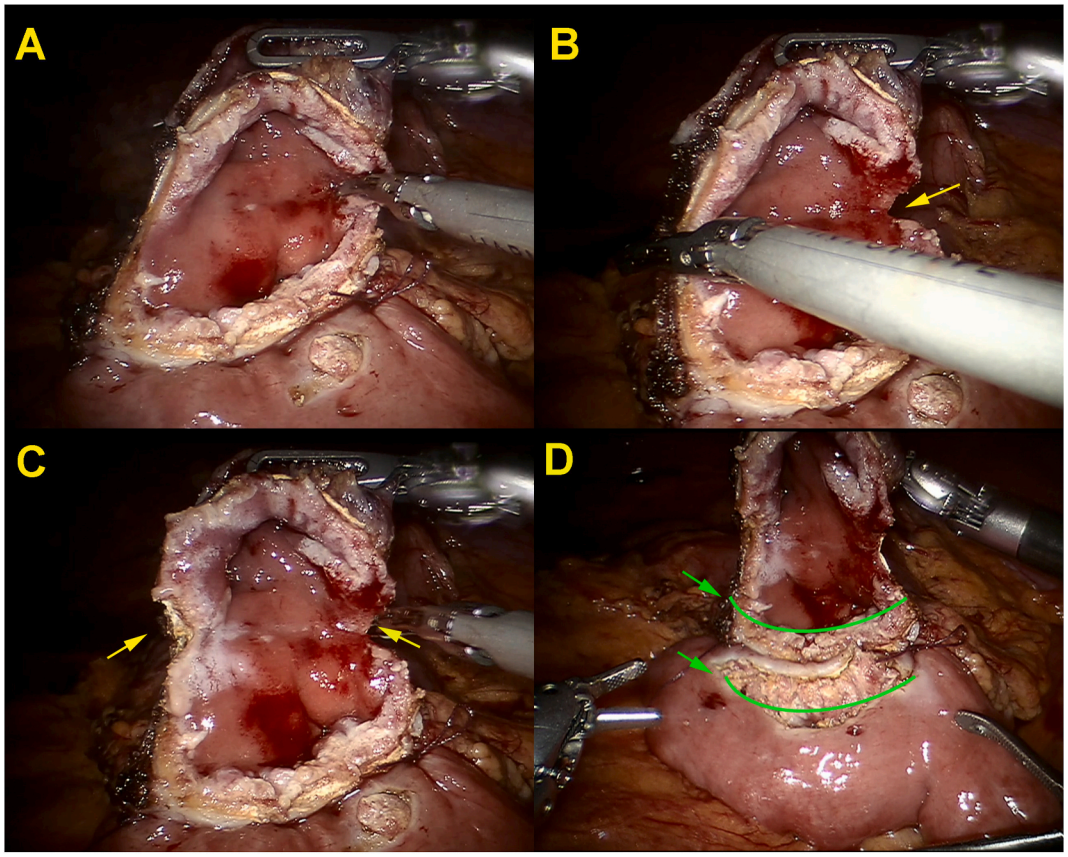

Fig. 2. The growth factor technique of duodenojejunostomy
A. Intraoperative photograph showing the cut of the angle at the edge of the duodenum with a harmonic scalpel.
B. Intraoperative photograph showing the incision of the other angle at the edge of the duodenum. The first incision can be seen (arrow).
C. Intraoperative image showing the aspect of the duodenal opening after cutting the angles at the edge of the duodenum (arrows).
D. Intraoperative image showing the adjustment of the openings of the duodenum and jejunum (lines and arrows).

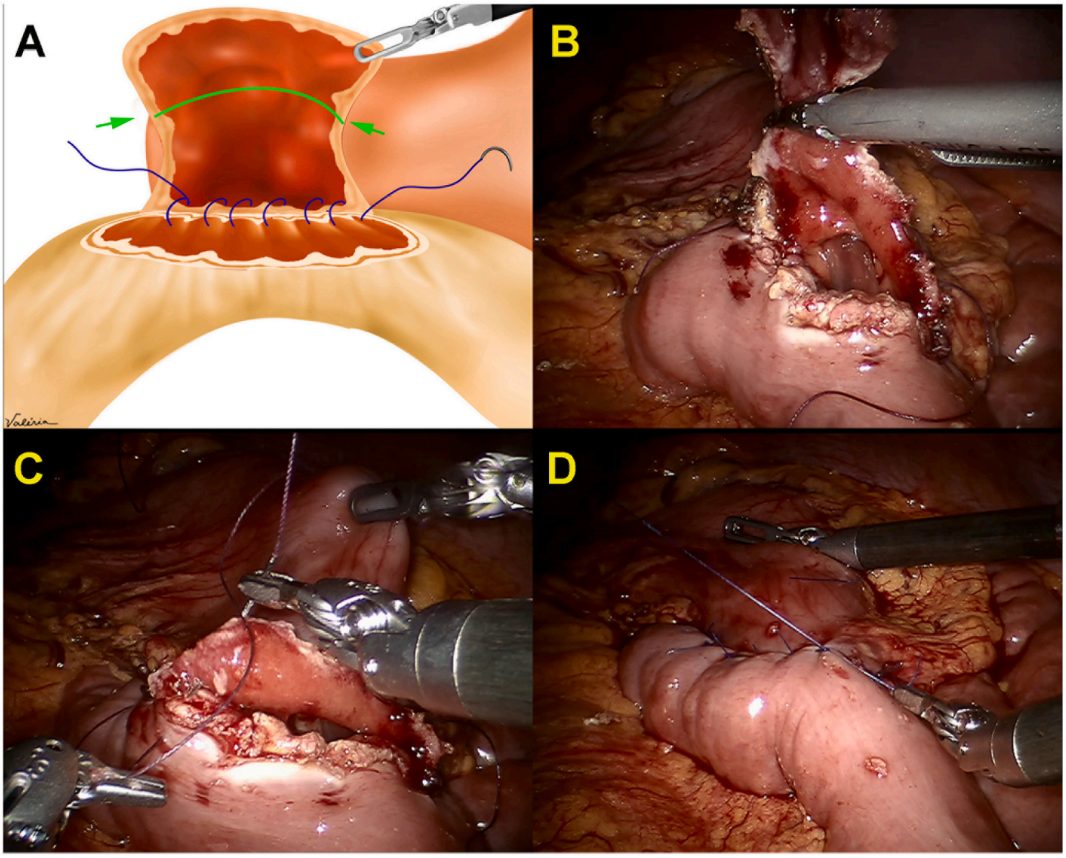

Fig. 3. The growth factor technique of duodenojejunostomy
A. Schematic drawing. After a full-length posterior layer with a running suture, the anterior layer of the duodenum is removed (curve line) to approximate the length of the jejunum (arrow).
B. Intraoperative photograph showing removal of excess duodenal tissue with a harmonic scalpel.
C. Intraoperative photograph showing the full-length anterior layer with a running suture.
D. Intraoperative image showing completion of the anterior seromuscular layer with interrupted sutures to allow for the larger opening.

3. Results

During the study period, 161 patients underwent pancreatoduodenectomy. Of these, 14 patients who underwent total pancreatectomy and 13 who underwent pyloric resection were excluded from the analysis. A total of 134 patients underwent pylorus-preserving pancreatoduodenectomy, of whom 121 underwent a minimally invasive (MI) approach and 13 underwent conventional open surgery. Four patients were converted to open surgery. There were 72 men and 62 women with a mean age of 63.7 years (range: 19–88 years). The main indication for surgery was ductal adenocarcinoma (PDAC) in 67 patients (50%), followed by intraductal papillary mucinous neoplasm [IPMN; N = 18 (13.4%)], neuroendocrine tumor [NET; N = 15 (11.2%)], papilla of Vater adenocarcinoma (15 patients, 11.2%), distal bile duct cancer (6 patients, 6.7%), chronic pancreatitis (5 patients, 1.5%), and other indications (8 patients, 6%).

The median size of the pancreatic tumor was 3 cm (range: 0.7–8.1 cm), and 19 (range: 5–77) lymph nodes were removed. The median hospital stay was 7 days (range: 6–71 days). Nine patients required blood transfusion. Mortality was 0.7% (one patient died of acute portal vein thrombosis after surgical resection and reconstruction). Morbidity was 15.7% (21 patients, but some with more than one complication). Five of them had postoperative complications unrelated to pancreatic surgery. Two patients had mild pulmonary symptoms, one patient had cardiac arrhythmia, one patient had a transient cerebrovascular accident, and one patient had anaphylactic shock due to latex. According to the revised 2016 ISGPS [16] classification of postoperative pancreatic fistula (POPF), 96 patients (71.6%) had no POPF, 29 (21.6%) had biochemical leak, and 7 patients (5.2%) had grade B POPF. Grade C POPF was observed in two patients. Biochemical leak was not considered a surgical complication.

Infectious complications occurred in eight patients (6%). Hemorrhagic complications occurred in five patients, two with bleeding from duodenojejunostomy successfully controlled with upper endoscopy and 3 with pseudoaneurysms of the gastroduodenal artery treated with interventional radiology.

Delayed gastric emptying occurred in only three patients (2.2%), one grade B and two grade C. These patients had a prolonged hospital stay (18, 34, and 71 days, respectively). The patient with grade B was discharged on postoperative day 18. One patient underwent reoperation for gastric torsion, with gastric fixation in the abdominal wall, and was discharged on postoperative day 71.

The cohort of patients with the new technique of duodenojejunostomy was compared with another cohort of patients who had undergone the same surgical procedure before the introduction of this new technique, as a control group for comparison.

After propensity score 1:1 matching, 93 patients were allocated to each group, resulting in a total of 186 patients. The baseline characteristics of the matched cohort included a mean age of 63 years, male predominance (63%), mean BMI of 24, ASA 1 or 2, pancreatic cancer predominance (57.5%), minimally invasive technique preference (82.8%) and tumor size of 30 mm. The baseline characteristics of the main and matched cohorts are summarized in Table 1.

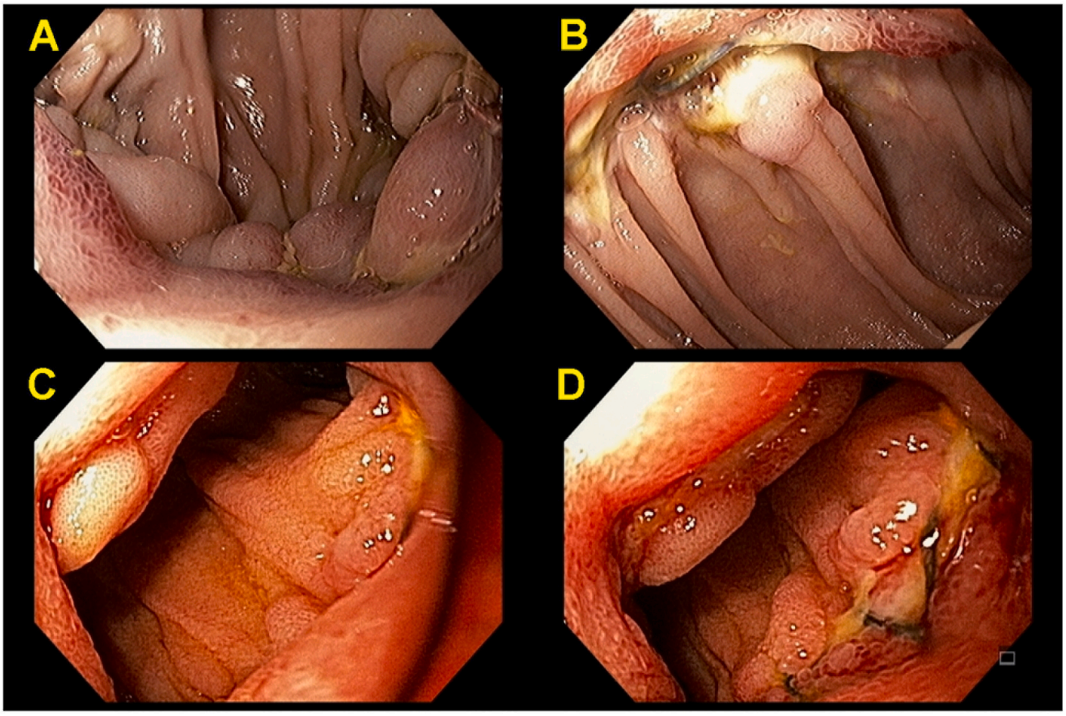

Fig. 4. Early postoperative endoscopic view of duodenojejunostomy techniques
A. Endoscopic view (PO day 7) of duodenojejunostomy using the growth factor technique. We can see the transition between duodenum and jejunum and a large opening.
B. Endoscopic view (PO day 7) of duodenojejunostomy using the growth factor technique. We can see the transition between duodenum and jejunum and a large opening.
C. Endoscopic view (PO day 7) of duodenojejunostomy using the standard technique. We can see the transition between duodenum and jejunum with small opening. This patient presented a grade C DGE.
D. Endoscopic view (PO day 7) of duodenojejunostomy using the standard technique. We can see the transition between duodenum and jejunum with small opening. This patient presented a grade C DGE.

Table 1
Baseline characteristics of main and matched cohorts.

	Main Cohort			Matched cohort		
	Growth (n = 134)	Standard (n = 103)	*P* value	Growth (n = 93)	Standard (n = 93)	*P* value
Age, years, mean (SD)	63.7 (12)	62.9 (11.7)	0.692445	63.1 (10.5)	63.1 (10.4)	0.955401
Male sex, n (%)	72 (53.7)	58 (56.3)		59 (63.4)	58 (62.4)	0.879354
BMI, mean (SD)	24.8 (3.2)	24.2 (3.6)	0.106807	24.3 (2.7)	24.2 (2.8)	0.748769
ASA, n			0.362409			
1 or 2	122 (91)	90 (87.4)		81 (87.1)	80 (86)	0.829792
>2	12 (9)	13 (12.6)		12 (12.9)	13 (14)	
Diagnosis, n (%)			0.859471			0.988764
PDAC	67 (50)	55 (53.4)		53 (57)	54 (58)	
Periampullary cancer	21 (15.7)	16 (15.5)		14 (15.1)	15 (16.1)	
IPMN	18 (13.4)	11 (10.7)		12 (12.9)	11 (11.8)	
NET	15 (11.2)	14 (13.6)		14 (15.1)	13 (14)	
Technique, n (%)			0.396953			
Open	13 (9.7)	16 (15.5)		13 (14)	13 (14)	1
MI	117 (87.3)	84 (81.6)		77 (82.8)	77 (82.8)	
MI, converted	4 (3)	3 (2.9)		3 (3.2)	3 (3.2)	
Tumor Size, mm (SD)	31 (14)	33 (9.7)	0.13399	30 (12)	30 (13)	0.843149

SD, Standard deviation, PDAC, pancreatic ductal adenocarcinoma, IPMN, intraductal papillary mucinous neoplasm.
NET, neuroendocrine tumor, MI, minimally invasive surgery.

3.1. Outcomes

In the main cohort, mean tumor size, number of lymph nodes removed, blood loss, and transfusion requirements were not statistically different in the two groups (Tables 1 and 2). Delayed gastric emptying was lower in the growth factor technique than in the control group (p = 0.00318). Therefore, the onset of diet was significantly delayed in the control group. This resulted in a longer median hospital stay in the control group (p = 0.048704). When we compare the two groups according to the degree of DGE, it shows a higher severity of DGE in the control group (p = 0.022765). Overall morbidity, clinically relevant postoperative pancreatic fistula and mortality were similar in both groups (Table 2).

A similar trend was observed in the matched cohort; the proportion of patients who developed delayed gastric emptying was significantly (P = 0.005) lower in the growth factor technique group (2.1% vs. 12.9%).

Table 2
Outcomes of main and matched cohorts.

	Main Cohort			Matched cohort		
	Growth (n = 134)	Standard (n = 103)	*P* value	Growth (n = 93)	Standard (n = 93)	*P* value
Lymphnodes, mean (SD)	21.6 (12)	19.8 (10.6)	0.119881	21.7 (12)	21.1 (11.6)	0.744879
Hospital stay, mean (SD)	9.7 (7.3)	11.4 (12.4)	0.048704	8.8 (7)	11.5 (8.4)	**0.008765**
Blood loss, mean (SD)	297 (135)	324 (147)	0.072508	311 (152)	329 (149)	0.435007
Blood transfusion, n	9	8	0.756032	7	7	1
Start of diet, d (SD)	4 (3)	5.4 (4.3)	0.003913	3.7 (2.1)	5.7 (4.4)	**0.000182**
DGE, n	3	12	0.003180	2	12	**0.005448**
Grade DGE			0.022765			**0.046997**
A, n	0	2		0	2	
B, n	1	6		1	6	
C, n	2	4		1	4	
Morbidity, n	21	23	0.191276	11	18	0.157117
Mortality, n	1	2	0.414470	1	2	0.560524

SD, Standard deviation, DGE, delayed gastric emptying.

Hospital stay was significantly longer in the standard group (P = 0.008), and patients operated on with the standard technique resumed feeding later than those with the growth factor technique. The details of the results in each group are summarized in Table 2.

4. Discussion

Delayed gastric emptying (DGE) is a common complication after pancreatoduodenectomy and can occur in up to 80% of patients [14]. Although DGE is not life-threatening, it worsens patients' quality of life and prolongs hospital stay after surgery [17]. Several studies have reported that pylorus-preserving PD (PPPD) [4,5], ischemic anastomotic sites during digestive tract reconstruction, and vagus nerve injury [9,15] may be risk factors for the development of DGE after PD. Even the ligation of the left gastric vein has been implicated in the genesis of DGE [18]. During resection, care must be taken not to injure the vagus nerve and to preserve the irrigation of the pylorus. Despite the myriad hypotheses, we believe that most cases of DGE after pylorus-preserving PD are related to duodenojejunostomy.

A recent randomized clinical trial comparing classic Whipple surgery with PPPD showed no difference in the incidence and severity of DGE, but the incidence was 50% and 62%, respectively [6]. Surgeons have been concerned about how to prevent the development of DGE after PD. Therefore, any attempt to reduce the incidence of DGE is welcome. An interesting idea was the addition of pyloric dilatation or pyloromyotomy, which, according to initial results, significantly reduced the incidence of DGE after these modified techniques (26% versus 7% and 25% versus 2%, respectively) [10,11,19]. We have used pyloric dilatation in some patients during open PPPD without a significant reduction in the incidence of DGE. In addition, since 2012, we have performed most of our cases with minimally invasive techniques, laparoscopic or robotic procedures. Dilatation of the pylorus is not easy to perform with minimally invasive techniques, but we did not observe any significant change in the incidence of DGE.

In 2018, after two consecutive cases of grade C DGE after MI PPPD, we reviewed the cases and postoperative radiological studies and devised a way to improve duodenojejunostomy. The main idea was that the anastomosis is performed with a running suture, which can usually result in a smaller opening of the anastomosis (Fig. 4C and D), which can be aggravated by the edema that is usually present. Therefore, a larger resulting opening would be desirable. In studying the many suture types, we came across the zigzag stretch stitch (Fig. 1), which could be used to stretch a larger portion of the jejunum, resulting in a larger opening once divided. However, the duodenal layer would be the same size and thus smaller. We then decided to cut the edges to fit the opening. Next, oval removal of the excess duodenal tissue would give the anastomosis the extra length it needed. We then call it growth factor anastomosis because of its similarity to the Starzl technique for portal anastomosis [20], stretch to grow. Finally, the anterior seromuscular layer is performed with interrupted sutures to accommodate the grown anastomosis.

This report demonstrates in detail the new technique with schematic drawings, and the addition of a short video of a robotic growth factor duodenojejunostomy illustrates step by step the procedure.

In our historical series of PPPD with standard duodenojejunostomy, several cases of DGE were observed, which increased the average hospital stay (Table 2). Since the introduction of this new technique, we observed a rapid decrease in the incidence and severity of DGE. This new technique also significantly shortened the mean hospital stay after PPPD. To reduce potential bias from historical controls, we perform propensity score matching to increase comparability between the new technique and the standard one. The propensity score was estimated using the main baseline characteristics related to group assignment and confirmed a lower incidence of DGE using this new technique.

In conclusion, the results of this study show that the new technique of duodenojejunostomy can reduce the incidence and severity of DGE, allowing earlier discharge from the hospital and avoiding further interventions. Comparative randomized trials are still needed to confirm the results of this preliminary study.

Disclosure

Drs. Machado, Mattos, Lobo Filho and Makdissi have no conflicts of interest or financial ties to disclose.

Authorship contributions

Conception and design of study: MA Machado, B Matos, M Lobo Filho, F Makdissi, acquisition of data: MA Machado, analysis and/or interpretation of data: MA Machado, F Makdissi, Drafting the manuscript: MA Machado; revising the manuscript critically for important intellectual content: MA Machado, B Matos, M Lobo Filho, F Makdissi, Approval of the version of the manuscript to be published (the names of all authors must be listed): MA Machado, B Matos, M Lobo Filho, F Makdissi.

Declaration of competing interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.suronc.2023.101902.

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