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Delayed Gastric Emptying After Standard Pancreaticoduodenectomy Versus Pylorus-Preserving Pancreaticoduodenectomy: An Analysis of 200 Consecutive Patients

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- BACKGROUND:** It has been suggested that pylorus-preserving pancreaticoduodenectomy (PPPD) is associated with a high incidence of delayed gastric emptying and consequently with a prolonged hospital stay compared with standard Whipple's resection. The aim of this prospective study was to evaluate whether the incidence of delayed postoperative gastric emptying was different after both procedures.
- STUDY DESIGN:** From 1989 to 1996, 200 consecutive patients underwent pancreatic head resection (100 standard pancreaticoduodenectomy [PD]; 100 PPPD). The groups were compared with regard to patient characteristics, operative indices, postoperative morbidity, hospital stay, and mortality. Delayed gastric emptying was defined as nasogastric suction for ≥ 10 days or delay of regular diet until > 14 days postoperatively.
- RESULTS:** Operative time and blood loss were higher for PD: 6 versus 4.8 hours ($p < 0.0001$) and 1,580 versus 1,247 mL ($p < 0.001$), respectively. Postoperative morbidity was 48% after PD and 44% after PPPD (not significant [NS]). Hospital mortality was 6% and 1% after PD and PPPD, respectively (NS). Delayed gastric emptying occurred in 34 patients after PD and in 37 after PPPD (NS). Median days of gastric suction was 3 versus 6 days for PD and PPPD ($p < 0.0001$). A regular diet was tolerated after a median of 10 and 11 days for PD and PPPD, respectively (NS). Postoperative hospital stay was shorter for patients who underwent PPPD: 20 versus 18 days ($p < 0.03$). Patients with intraabdominal complications ($n = 52$) showed a higher incidence of delayed gastric emptying ($p < 0.0001$).
- CONCLUSIONS:** Our results show that PPPD is a safe procedure associated with less operative time and blood loss than PD. After PPPD, patients require longer postoperative nasogastric intubation than after PD, suggesting some form of early postoperative gastric stasis. There is, however, no difference in the incidence of delayed gastric emptying or the first postoperative day on which a regular diet is tolerated between these surgical procedures. Intraabdominal complications are major risk factors for delayed gastric emptying. (J Am Coll Surg 1997;185:388–395. © 1997 by the American College of Surgeons)
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The mortality rate after pancreaticoduodenectomy is declining and is currently reported to be $< 5\%$ in specialized centers.¹⁻⁷ Postoperative morbidity is still high after this procedure, up to 60%.^{1-6,8} The most serious and potentially lethal complications are pancreatic leakage,

gastrointestinal or intraabdominal hemorrhage, and intraabdominal abscess.^{3,4,9-11} A less serious complication is delayed gastric emptying, which is reported to occur at 25–70% after pancreaticoduodenectomy, with an average of 30%.^{4,12-19} Although delayed gastric emptying is not associated with mortality, it can be a troublesome complication and can jeopardize nutritional status when patients do not receive enteral or parenteral nutrition. It also increases the postoperative hospital stay.^{12,16,19} The variation in the incidence of partly delayed gastric emptying that is reported is probably due to the fact that no

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uniform definition exists. Some authors have defined delayed gastric emptying as the inability to tolerate a regular or normal diet by the fourteenth⁴ or the tenth postoperative day¹⁴⁻¹⁶ or the start of a liquid diet after ≥ 7 days.¹³ Others have described delayed gastric emptying as gastric stasis requiring gastric suction for 7 days,^{18,19} or ≥ 10 days.^{12,17}

Pylorus-preserving pancreaticoduodenectomy (PPPD) is considered a good alternative to standard pancreaticoduodenectomy, or Whipple's procedure (PD). Most reports have shown similar survival for the two techniques, and PPPD is now generally accepted as an equally effective procedure for pancreatic or periampullary tumors.^{6,17,19-21} A few studies have reported that PPPD leads to a shorter operative time, less blood loss, and a lower intraoperative need for transfusion.^{6,22} According to some authors, however, PPPD is associated with an increased incidence of delayed gastric emptying.^{13,16} This higher incidence of delayed gastric emptying after PPPD has not been confirmed in more recent reports.^{5,17,18,23}

After 1993, PPPD became the technique of choice for pancreatic head resection in our department, and PD was performed only when PPPD was not feasible. In this study, we evaluated prospectively the incidence of and risk factors for postoperative delayed gastric emptying after PD and PPPD, in combination with the overall postoperative morbidity, hospital stay, and mortality.

METHODS

Patients and data collection. Between September 1, 1989 and August 1, 1996, 200 consecutive patients underwent a subtotal pancreaticoduodenectomy. One hundred patients underwent PD and 100 underwent PPPD. All data concerning preoperative evaluation, intraoperative indices, postoperative complications, and mortality were collected prospectively. The collected data included days of nasogastric intubation, days of jejunal catheter feeding, days until regular diet was tolerated orally, and hospital stay.

Preoperative factors. The patients were divided into two groups, PD and PPPD. Patient characteristics (eg, age and gender) and preoperative laboratory values (eg, bilirubin, hemoglobin, and albumin) were assessed. Other preoperative factors that were assessed included biliary drainage, previous abdominal operation (excluding diagnostic laparoscopy), diabetes (requiring medical

Figure 1. Subtotal pancreaticoduodenectomy with gastrectomy (A) and pylorus-preserving pancreaticoduodenectomy (B). Both figures show the reconstruction as performed using a single jejunal loop.

treatment and present for > 12 months), and weight loss.

Procedure, intraoperative indices, and histopathologic diagnosis. From 1993, PD was performed only in patients who either had a previous gastric resection in their medical history or had tumor ingrowth extending into the proximal duodenum or into the pyloric area, or when vascularization of the antropylic area seemed insufficient during operation. From 1993, PPPD was the surgical procedure of choice. Figure 1 shows the two surgical procedures. For PPPD, reconstruction was performed with one jejunal loop for the pancreatic, biliary, and gastric anastomosis instead of a separate Roux-en-Y loop for the pancreatic and biliary anastomosis. In addition, the pancreaticojejunal anastomosis was performed in one layer instead of two. From 1993, pancreatic duct stenting was not performed, in contrast to the earlier

period. Truncal vagotomy was not performed in any of these operations.

All patients received a needle catheter jejunostomy at the end of the operation for early postoperative nutritional support. Enteral nutrition was started on the first postoperative day using Nutrison (Nutricia; Zoetermeer, The Netherlands; 4g fat, 4g protein, 12g carbohydrate, 100kCal [420kJ]/100mL), with a gradual increase during the following days to a maximum of 2,000mL/day.

Operative time (hours), estimated intraoperative blood loss (mL), and transfusions (units of packed red blood cells) were assessed, as were histopathologic diagnosis and tumor ingrowth into the resection margins in cases of malignancy. A radical resection was defined as microscopically free resection and dissection margins of the resection specimen on histopathologic diagnosis.

Postoperative course. Overall morbidity and mortality were evaluated, in addition to procedure-related complications such as pancreatic leakage, biliary leakage, hemorrhage, and intraabdominal abscess. General complications evaluated were pulmonary, cardiac, and renal complications. Overall postoperative morbidity was defined as procedure- or nonprocedure-related complications requiring medical or surgical intervention or readmission to the intensive care unit, and causing prolonged hospital stay or postoperative death. Mortality was defined as death during the hospital stay.

Delayed gastric emptying. Indices used to identify postoperative delayed gastric emptying included the number of days of nasogastric intubation, days of jejunal catheter feeding, days until a regular diet was tolerated, incidence of delayed gastric emptying, and hospital stay. The nasogastric tube was removed when production had decreased to <200–300mL/24 hours. Delayed gastric emptying was defined as gastric stasis requiring nasogastric intubation for ≥ 10 days or the inability to tolerate a regular (solid) diet on or before the fourteenth postoperative day.

Risk factors for delayed gastric emptying. The following preoperative and postoperative risk factors for delayed gastric emptying were evaluated: previous abdominal operation, diabetes, malnutrition, resection for malignancy, and postoperative intraabdominal complications. Malnutrition was defined as a preoperative albumin level <30g/L or a preoperative weight loss of >10% of pre-illness weight.

Table 1. Period of Resection, Patient Characteristics, Preoperative Laboratory Values, and Preoperative Factors

Characteristic	PD (n = 100)	PPPD (n = 100)	p value
Period of resection			
Sep. 1989-Feb. 1993 (3.5 y)	82	1	<0.0001
Mar. 1993-Aug. 1996 (3.5 y)	28	99	
Patient characteristics			
Age* (y)	59.8 $\pm$ 0.9	62.0 $\pm$ 1.0	NS
Gender (male/female)	55/45	45/55	NS
Preoperative laboratory values			
Bilirubin (μ mol/L)*	48.9 $\pm$ 6.2	30.3 $\pm$ 4.1	0.02
Hemoglobin (mmol/L)*	8.2 $\pm$ 0.1	8.2 $\pm$ 0.1	NS
Albumin (g/L)*	41.8 $\pm$ 0.6	41.9 $\pm$ 0.9	NS
Preoperative factors			
Biliary drainage	76	80	NS
Previous abdominal operation	28	21	NS
Diabetes	12	17	NS
Weight loss (kg)*	5.5 $\pm$ 0.5	6.7 $\pm$ 0.5	0.02

*Mean $\pm$ SEM.

NS, not significant; PD, standard pancreaticoduodenectomy; PPPD, pylorus-preserving pancreaticoduodenectomy.

Statistical analysis. All values were expressed as mean and standard error of the mean (SEM), except for days of nasogastric intubation, jejunal catheter feeding, days until regular diet, and hospital stay, which were expressed as median, mean, and range. Statistical analysis was performed using Mann-Whitney *U* test, chi-squared test, and two-sided Fisher's exact test, where applicable. A *p* value <0.05 was considered statistically significant.

RESULTS

Patients. Most PDs were performed in the first half of the study period; almost all PPPDs (99%) were performed in the second half of the study period. One patient underwent PPPD before March 1993 (Table 1).

Preoperative factors. Patient characteristics were comparable in both groups (Table 1). Preoperative bilirubin was lower for patients undergoing PPPD versus PD (*p* = 0.02). Hemoglobin and albumin levels were similar for both groups, as were the numbers of patients with preoperative biliary drainage, previous abdominal operations, and diabetes. The mean preoperative weight loss was higher for patients undergoing PPPD: 5.5 versus 6.7kg (*p* = 0.02) (Table 1).

Table 2. Intraoperative Parameters, Aspects of Reconstruction, Histopathology, and Tumor Status of the Resection Margins

Index	PD (n = 100)	PPPD (n = 100)	p value
Intraoperative indices			
Operative time (h)*	6.0 ± 0.1	4.8 ± 0.1	< 0.0001
Estimated blood loss (mL)*	1,580 ± 93	1,247 ± 115	< 0.001
Transfusions (units PRBC)*	2.5 ± 0.2	1.6 ± 0.2	< 0.001
Aspects of reconstruction			
Number of jejunal loops: 1/2†	15/85	97/3	< 0.0001
Pancreatic anastomosis: 1 layer/2 layers	27/73	100/0	< 0.0001
Stent pancreatic duct: no/yes	33/67	100/0	< 0.0001
Histopathologic diagnosis			
Pancreatic head carcinoma	40	42	NS
Ampullary carcinoma	30	29	
Distal common bile duct carcinoma	10	13	
Other malignancy	7	5	
Benign	13	11	
Resection margins in cases of malignancy			
Radical	52/87 (60%)	56/89 (63%)	NS
Nonradical	35/87 (40%)	33/89 (37%)	

*Mean ± SEM.

†Two loops indicates Roux-en-Y reconstruction.

NS, not significant; PD, pancreaticoduodenectomy; PPPD, pylorus-preserving pancreaticoduodenectomy; PRBC, packed red blood cells.

Procedure, intraoperative indices, and histopathologic diagnosis. In most cases, PD was performed in combination with reconstruction using a separate Roux-en-Y loop (85%), a two-layer pancreaticojejunal anastomosis (73%), and a pancreatic duct stent (67%). Most of the PPPDs were performed using one jejunal loop (97%) and a single-layer anastomosis (100%). In none of these patients was pancreatic duct drainage performed ($p < 0.0001$ for all three items) (Table 2).

The duration of the surgical procedure was significantly longer for PD than for PPPD: 6 versus 4.8 hours ($p < 0.0001$). Estimated blood loss and need for transfusion were also greater for PD: 1,580 versus 1,247 mL ($p < 0.001$) and mean of 2.5 versus 1.6 units ($p < 0.001$), respectively. Histopathologic diagnosis and tumor status of the resection margins were similar for both groups (Table 2).

Postoperative course. Overall morbidity was 46%: 48 patients after PD and 44 patients after PPPD (not significant [NS]). There were no differences in specific procedure-related or general complications (Table 3). Similar numbers of patients in both groups underwent relaparotomy or were admitted to the intensive care unit. Overall mortality was 3.5%: 6 patients after PD and 1 patient after PPPD (NS) (Table 3).

Delayed gastric emptying. Nasogastric intubation was prolonged after PPPD: 3 days versus 6 days after PD and PPPD, respectively ($p < 0.0001$). Days of jejunal catheter feeding and days until a regular diet was resumed were not different between the groups (Table 4). In total, eight patients (four in each group) were not fed through the jejunal catheter jejunostomy, because of either tech-

Table 3. Postoperative Complications, Relaparotomy, Readmission to Intensive Care Unit, and Mortality

Complication	PD* (n = 100)	PPPD* (n = 100)
Overall morbidity†	48	44
Pancreatic leakage	12	12
Biliary leakage	5	2
Hemorrhage	11	9
Intraabdominal abscess	26	19
Medical complications		
Pulmonary	12	15
Cardiac	11	5
Nephrologic	7	7
Relaparotomy	22	16
Readmission to ICU	23	18
Mortality‡	6	1

*There were no significant differences between the groups.

†Overall morbidity in the entire study group (n = 200) was 46%.

‡Overall mortality in the entire study group (n = 200) was 3.5%.

PD, pancreaticoduodenectomy; PPPD, pylorus-preserving pancreaticoduodenectomy; ICU, intensive care unit.

Table 4. Postoperative Days of Nasogastric Intubation, Jejunal Catheter Feeding, Days Until Normal Diet, Incidence of Delayed Gastric Emptying, and Postoperative Hospital Stay

Outcome	PD (n = 100)			PPPD (n = 100)			p value
	Median	Mean	Range	Median	Mean	Range	
Days of nasogastric intubation	3	6.3	1–31	6	9.0	1–40	<0.0001
Days of jejunal catheter feeding	9	10.6	0–38	9.5	11.6	0–57	NS
Days until regular diet tolerated orally	10	12.9	4–80	11	13.9	4–55	NS
Delayed gastric emptying,* n	34			37			NS
Hospital stay, d	20	30.6	8–219	18	21.9	10–68	0.02

*Overall incidence of delayed gastric emptying in the entire study group (n = 200) was 35.5%. Delayed gastric emptying was defined as nasogastric intubation $\geq$ 10 days or regular diet started $>$ 14th day postoperatively.

NS, not significant; PD, pancreaticoduodenectomy; PPPD, pylorus-preserving pancreaticoduodenectomy.

nical problems with the feeding catheter or direct postoperative complications prohibiting the start of feeding.

Delayed gastric emptying showed an overall incidence of 35.5%: 34 patients after PD and 37 after PPPD (NS). The median hospital stay was shorter for patients undergoing PPPD: 20 versus 18 days ($p = 0.02$) (Table 4).

Risk factors for delayed gastric emptying. There was a higher incidence of delayed gastric emptying in patients with previous abdominal operations. Forty-seven percent of the patients with previous abdominal operations had a delay in gastric emptying ($p = 0.054$). Diabetes, malnutrition, and resection for malignancy were not identified as risk factors for delayed gastric emptying in the present series. The incidence of delayed gastric emptying in patients with intraabdominal complications was 65% ($p < 0.0001$) (Table 5). Figure 2 shows a cholangiogram of a patient after PPPD with gastric stasis at 16 days postoperatively. After contrast injection into the T-tube, filling of the jejunal loop revealed a subclinical leakage of the pancreaticojejunal anastomosis.

DISCUSSION

Since the introduction of PPPD by Traverso and Longmire in the late 1970s,²⁴ many reports have been pub-

lished that assessed delayed gastric emptying after this procedure. The wide range in the incidence of delayed gastric emptying after PD and PPPD, varying at 25–70%, seems related to the different criteria for gastric function set by the authors of different reports.^{12–17,19,25}

In the present series, the patients required longer nasogastric intubation after PPPD than after PD. Although these results suggest some form of early gastric stasis after PPPD, it did not result in an overall increase in the incidence of delayed gastric emptying. In some reports, a similar number of days of postoperative nasogastric intubation was noted for both procedures.^{6,17,18} Others have reported a longer period of nasogastric intubation after the pylorus-preserving procedure,¹⁶ as in the present study. Days of jejunal catheter feeding and days until a regular diet was tolerated orally were not different between PD and PPPD. These results are in agreement with reports by others^{5,17,18,23} and lead to the conclusion that preservation of the pylorus is probably not an important factor in the occurrence of delayed gastric emptying.

Several factors are thought to play a role in the pathophysiology of delayed gastric emptying. In the present study, we found a high correlation between delayed gas-

Table 5. Number of Patients With Preoperative and Postoperative Risk Factors and Incidence of Delayed Gastric Emptying in These Patients

Risk factor	Total patients with risk factor	No DGE*		DGE		p value
		n	%	n	%	
Preoperative risk factor						
Previous abdominal operation	49	26	53	23	47	0.054
Diabetes	29	16	55	13	45	NS
Malnutrition	62	38	61	24	39	NS
Operation for malignancy	176	118	67	58	33	NS
Postoperative risk factor						
Intraabdominal complications	52	18	35	34	65	<0.0001

*DGE, delayed gastric emptying, defined as nasogastric intubation $\geq$ 10 days or regular diet started $>$ 14th day postoperatively. NS, not significant.

Figure 2. Cholangiogram in a patient after pylorus preserving pancreaticoduodenectomy with gastric stasis at 16 days postoperatively. The open arrows show the atonic gastric fundus. The solid arrows show the site of leakage of the pancreaticojejunal anastomosis, which was revealed by accident after filling of the jejunal loop. Note the proximity of the site of this subclinical pancreatic leakage with the stomach and pyloric region.

tric emptying and the development of intraabdominal complications. This relation was reported previously by others.^{14,26} Hocking and coworkers²⁷ reported gastric dysrhythmias in a patient with delayed gastric emptying, which were considered to be caused by a perihepatic abscess. Other factors that might be considered as causative for this complication are disruption of gastroduodenal neural connections^{28,29} and ischemia of the pyloric muscle.³⁰ Ligation of the right gastric artery is generally performed because it facilitates resection of the gastroduodenal artery, but some authors have advocated preserving the right gastric artery because of its arterial supply to the pylorus and antrum.³¹ In the present series, the right gastric artery was always ligated. Resection of the duodenum, the primary production site of most gastrointestinal hormones, might also play a role in the pathogenesis of this complication. Motilin, a gastrointestinal hormone, initiates interdigestive motility in the gastric antrum and small bowel and is produced primar-

ily in the duodenum.^{32,33} Yeo and associates¹² reported in a randomized trial that administration of erythromycin, a motilin agonist, decreased the incidence of delayed gastric emptying by 37% in patients who underwent PD. This difference, however, did not reach statistical significance.

In a study on delayed gastric emptying after different types of gastric operations, relations also were reported with resection for malignancy, preoperative malnutrition, and diabetes.¹⁴ In the present study, we did not find a higher incidence of delayed gastric emptying in patients with these risk factors.

In the present series, we found a decreased operative time, less blood loss, and consequently less transfusion need in patients who underwent PPPD. This difference might be explained by the difference in time period in which most of the resections were performed. Most PPPDs were performed in the later years, and other factors that might influence operative time and blood loss have

changed in this period, along with increased experience. Changes in the type of reconstruction (using a Roux-en-Y loop or not) and type of anastomosis (one or two layers) probably also played a role in decreasing operative time and blood loss. Others, however, have reported similar results favoring PPPD.^{6,22} It is obvious that performing partial gastric resection requires more operating time and blood loss, although a mean difference of 1.2 hours in operative time, as found in the present series, cannot be considered solely due to performing a gastric resection, but is also due to a higher number of Roux-en-Y reconstructions in patients who underwent PD.

There have been reports arguing against the use of PPPD for the resection of pancreatic tumors because of a potential increase in positive duodenal resection margins,³⁴ resulting in lower survival rates for pancreatic cancer after PPPD compared with PD.³⁵ Overall survival, however, does not seem to be compromised by PPPD in the majority of reports.^{6,17,19-21} Currently PPPD is accepted as an adequate surgical procedure for patients with pancreatic malignancies except in those patients with duodenal or distal bile duct tumors with ingrowth or with a location close to the duodenal resection margins.^{19,20,36}

In conclusion, the incidence of delayed gastric emptying in this series of 200 consecutive patients was similar after PD and PPPD. Patients who underwent PPPD did require longer postoperative nasogastric drainage than patients having PD, but time until a regular diet was tolerated orally was not significantly different between the surgical procedures, and hospital stay was even shorter after PPPD. The most important risk factor for delayed gastric emptying was the presence of intraabdominal complications, such as leakage of the pancreatic anastomosis or abscess. We have demonstrated that PPPD is a safe procedure that can be performed with less operative time, less blood loss, and less transfusion need than PD.

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