Pylorus-preserving Pancreatoduodenectomy

A Clinical and Physiologic Appraisal

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Since 1978, 252 patients from different centers in the world have undergone pylorus-preserving pancreatoduodenectomy. Fifty-five per cent of the patients had malignant tumors in the region of the head of the pancreas. The overall operative mortality rate was 2.8%. Anastomotic leakage and fistulae occurred in 19% of the patients. Pancreatic, biliary, and enteric fistulae represented 11%, 4%, and 4%, respectively. Peptic ulcers were subsequently diagnosed in seven patients (3%), two of whom required vagotomy and antrectomy. Delayed recovery of gastric function was the most common complication of this operation, with an overall incidence of 30%. Although the cause of this gastric dysfunction is unknown, its transient nature in most patients makes expectant therapy with gastric tube drainage the best remedy when the problem is encountered. Pylorus-preserving pancreatoduodenectomy decreased the incidence of postgastric surgery syndromes that are commonly associated with the standard Whipple operation. The existing data support the continued use of the operation and the need for future laboratory and clinical investigation of its physiologic impact.

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THE ANTRUM AND PYLORUS were structurally preserved in the first successful radical pancreatoduodenectomies performed by Kausch in 1912[1] and Whipple in 1935.[2] However, in both of these operations, the duodenum was interrupted and the antropyloric mechanism bypassed with a gastroenterostomy. In 1942, Watson[3] reported pancreatoduodenectomy for carcinoma of the ampulla of Vater, in which he preserved the antrum, pylorus, and 1 inch of duodenum. He performed an end-to-end duodenojejunostomy, thus preserving in *functional continuity* the distal stomach, pylorus, and proximal duodenal segment. Watson believed that preservation of an intact stomach would facilitate digestion and thus improve the patient's nutritional status.

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Submitted for publication: April 10, 1986.

In 1942, Whipple,[4] applying the principle of wide *en bloc* resection of cancer surgery, reported one-stage radical pancreatoduodenectomy including resection of the distal third of the stomach, the entire duodenum, and the head of the pancreas. Gastrointestinal continuity was reestablished by antecolic gastrojejunostomy. The technique was subsequently modified and less extensive gastric resections were advocated,[5] resulting in a high incidence of marginal ulceration. High gastric resection with or without truncal vagotomy therefore became the norm,[6] despite the high morbidity rate of a reduced gastric reservoir. This standard Whipple operation continues to be the most commonly performed procedure for resectable tumors in the head of the pancreas.

In 1978, pancreatoduodenectomy entered the current era of pylorus preservation. Traverso and Longmire,[7] like Watson, reasoned that preservation of an intact stomach would eliminate the complications of a reduced gastric reservoir and improve the nutritional status of patients. Furthermore, they believed that this modification of the Whipple operation would decrease the postoperative incidence of jejunal ulceration, perforation, and bile reflux.

This review reports our initial experience with pylorus-preserving pancreatoduodenectomy at Duke University Medical Center and assesses the clinical and physiologic results of this operation based on a series of patients reported from other centers around the world.

Clinical Series and Indications for Operation

Duke Medical Center Series

Between 1983 and 1985, seven patients underwent pancreatoduodenectomy with preservation of the pylorus and gastric antrum. There were four women and three

TABLE 1. *Pancreatoduodenectomy with Pylorus Preservation: Clinicopathologic Features—Duke Medical Center, 1983–85*

Patient #	Age/Sex	Clinical Presentation	Histologic Diagnosis
1	57/M	Lethargy, anemia, melena	Primary leiomyosarcoma of the 2nd portion of the duodenum
2	56/M	Jaundice, anemia, guaiac-positive stools	Moderately differentiated adenocarcinoma of the pancreas
3	74/M	Weight loss, jaundice, anemia	Moderately differentiated adenocarcinoma of the ampulla
4	58/F	Weight loss, jaundice	Poorly differentiated adenocarcinoma of the pancreas
5	17/F	Epigastric pain, nausea, vomiting	Islet cell tumor of the head of the pancreas
6*	50/F	Weight loss, jaundice, anemia	Well differentiated adenocarcinoma of the pancreas
7	60/F	Weight loss, jaundice, anemia	Well differentiated adenocarcinoma of the ampulla with invasion into the pancreatic bed

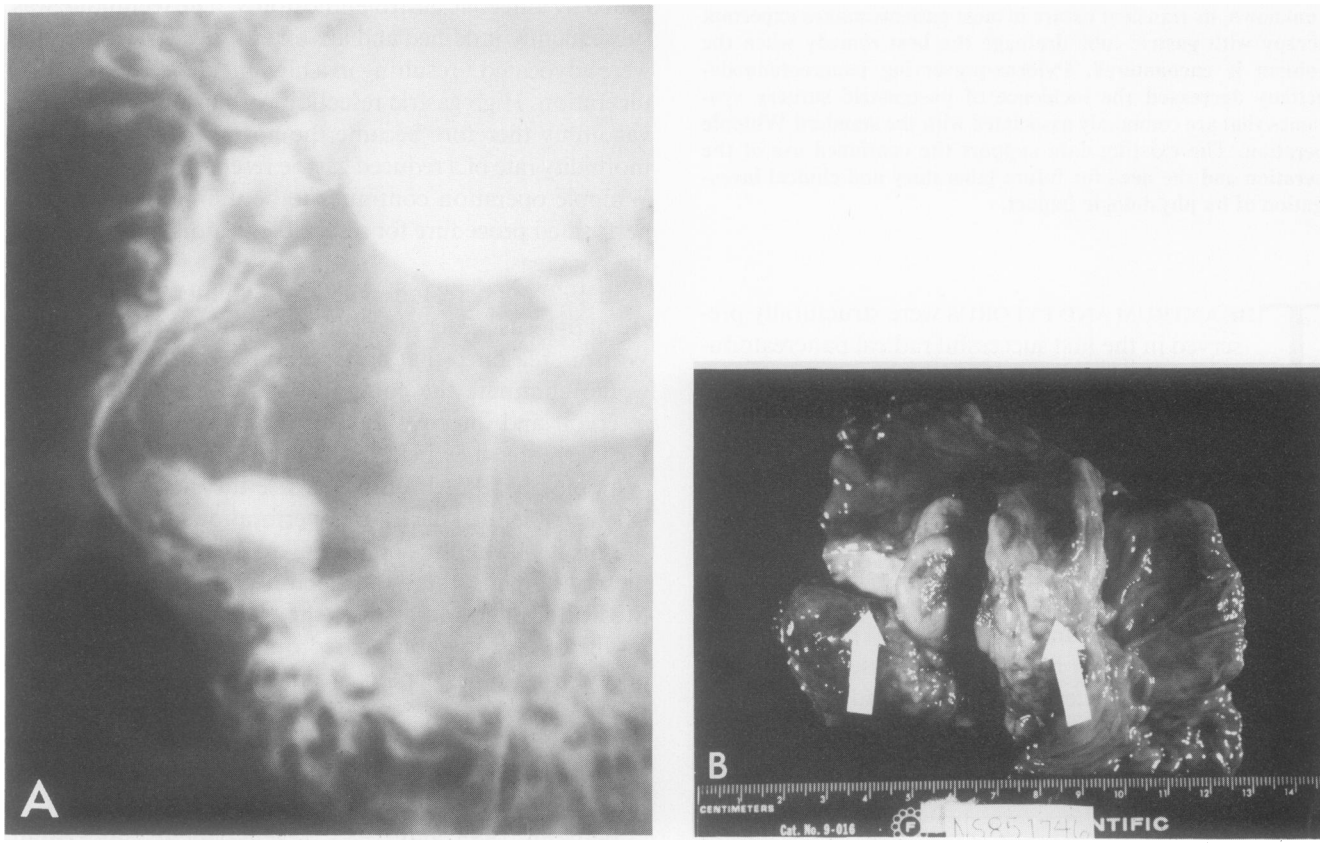
* Patient died 2.5 years after operation.

men with a median age of 54 years (range: 17–74, Table 1). Five patients had painless jaundice and weight loss and another patient had lethargy, anemia, melena, and weight loss. The remaining patient suffered from severe abdominal pain.

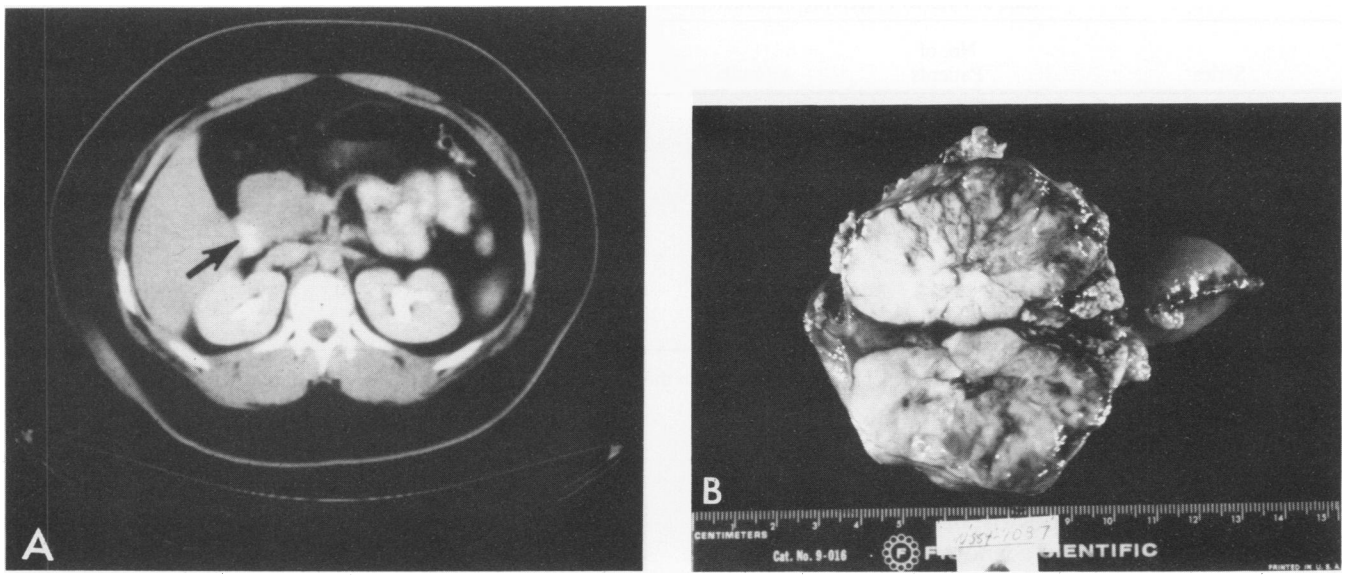
The patient with melena and anemia had a leiomyosarcoma of the second portion of the duodenum (Fig. 1). Two of the five patients with jaundice had adenocarcinoma of the ampulla of Vater. The other three patients had adenocarcinoma of the head of the pancreas. The patient with abdominal pain had an endocrinologically silent islet cell tumor of the head of the pancreas in proximity to the duodenum (Fig. 2). At exploration, all patients had resectable tumors. No patients died during operation, and six of the patients are still alive. The first patient to be operated on with this procedure died of a recurrence of pancreatic carcinoma 2.5 years after operation.

Collected Cases

A total of 188 patients who underwent pylorus-preserving pancreatoduodenectomy have been reported in



FIGS. 1A and B. Leiomyosarcoma of the second portion of the duodenum. (*A*) Upper GI series showing large mass arising from the medial aspect of the second portion of the duodenum. Endoscopy revealed ulceration overlying a mostly submucosal mass. (*B*) Gross pathology showing the ulcerating tumor with extension into the pancreas head (arrows).



FIGS. 2A and B. Islet cell tumor. (*A*) CT scan in the region of the head of the pancreas showing a 6-cm mass proximal to the duodenal wall. (*B*) Gross pathology.

the literature.[3,8–15] This makes a total of 252 patients, including the Duke patients and the additional patients reported through written personal communications from other centers.[16–20] The overall operative mortality rate was 2.8% (7 patients). Ninety-seven patients underwent this operation for chronic pancreatitis, three for biliary stricture, and three for benign pancreatic tumors. Thus, 45% (113 patients) had benign conditions (Table 2) and 55% (139 patients) underwent resection of malignant tumors of the ampulla and periampullary region. Pancreatic malignancies accounted for 45% (53 of 119 patients), ampullary tumors 33% (39 of 119 patients), bile duct tumors 15% (18 of 119 patients), and duodenal malignancies 7% (8 of 119 patients). There were five cases of islet cell carcinoma of the pancreas, two cases of duodenal leiomyosarcoma, one common bile duct sarcoma, one metastatic hypernephroma, and one patient with a periampullary carcinoid tumor (Table 3).

Indications for Operation

In their initial report, Traverso and Longmire[7] limited the application of pylorus-preserving pancreatoduodenectomy to patients with benign diseases of the pancreas and carefully selected localized tumors of the duodenum. According to Moossa,[21] this procedure is not applicable to cancer of the head of the pancreas or cancer of the lower end of the common bile duct since it may compromise the only chance of cure. That 55% of the patients who have undergone this procedure have had carcinomas, including carcinoma of the head of the pancreas and of the distal common bile duct (Table 3), represents a significant change in thinking among surgeons.

Two factors have contributed to the growing popularity of pylorus preservation: simpler reconstruction than after gastrectomy, and the concept that an intact stomach and pylorus would protect against postgastrectomy syndromes and allow more normal digestion of food. Moreover, the presence of the pylorus with its possible role as an antireflux mechanism may prevent reflux alkaline gastritis and the development of gastric ulceration.

Although quantitative data are not yet available, historic data suggest that the use of the less radical procedure may not compromise the prognosis of patients. Cubilla et al.,[22] in a series of 33 pancreatoduodenectomies, found that pancreatic duct adenocarcinoma tended to metastasize early to multiple lymph nodes (88% of patients) as well

TABLE 2. *Pylorus-Preserving Pancreatoduodenectomy Pathologic Diagnoses—Benign Conditions*

Series	No. of Patients	Pancreatitis (with Biliary Stricture)	Neoplasms
Gall and Gebhardt[8]	3	3	0
Mosca et al.[10]	8	8	0
Flautner et al.[14]	37	37	0
Braasch et al.[16]	30	30 (2)	0
Warshaw[17]	10	NA	NA
Williamson and Cooper[18]	11	10 (1)	1*
Baltasar et al.[19]	1	1	0
Grace and Pitt[20]	12	11	1†
Present report	1	0	1‡
Total	113	100 (3)	3

* Insulinoma; †pancreatic cystadenoma; ‡islet cell adenoma.
NA = not available.

TABLE 3. *Pylorus-Preserving Pancreatoduodenectomy Pathology—Malignant Tumors*

Series	No. of Patients	Ampulla	Pancreas (Islet Cell)	Common Bile Duct	Duodenum (Leiomyosarcoma)
Watson[3]	1	1	0	0	0
Mosca et al.[10]	22	7	13	2	0
Braasch et al.[16]	57	18	22 (4)	13*	3 (1)
Warshaw[17]	20	NA	NA	NA	NA
Williamson and Cooper[18]	5	3	1	0	1
Baltasar et al.[19]	3†	1	0	1	0
Grace and Pitt[20]	25	8‡	13 (1)	2	2
Present report	6	1	4	0	0 (1)
Total	139	39	53 (5)	18	6 (2)

* One common bile duct sarcoma; †one hypernephroma metastatic to the head of the pancreas; ‡one periampullary carcinoid.
NA = not available.

as to groups of lymph nodes distant from the head of the pancreas (33%). Ampullary adenocarcinoma metastasized to fewer nodes and to one adjacent periampullary lymph node group in 33% of patients. The authors concluded that a standard Whipple operation is at best only palliative when used for adenocarcinoma of the head of the pancreas since in 33% of patients nodal metastases were probably already present in groups of lymph nodes not usually removed in this operation. The lymph nodes situated along the lesser and greater curvature of the stomach did not reveal evidence of metastases in any of the 33 pancreatoduodenectomies. Moreover, in a series of 124 patients who underwent Whipple operation for ductal carcinoma of the head of the pancreas, Edis et al.[23] found approximately half of the patients to have metastatically involved lymph nodes. Prognosis in these patients was similar to that of those with no lymph node involvement by tumor. These findings would make pylorus preservation a reasonable option, especially if it decreased postoperative morbidity rates[15] and resulted in comparable long-term survival. Initial data from UCLA suggest that survival is as good after pylorus preservation as after standard pancreatoduodenectomy or total pancreatectomy without pylorus preservation.[15]

Two patients, one from Duke University and the second from the Lahey Clinic, underwent pylorus-preserving pancreatoduodenectomy for duodenal leiomyosarcoma. This condition has been associated with a low incidence of lymph node metastases (7%) even in the face of very extensive disease.[24] Pancreatoduodenectomy with pylorus preservation in cases of resectable duodenal leiomyosarcoma, especially if the tumor is of low Broders' grade, should result in cure rates similar to those of a classic Whipple procedure, without the associated postgastrectomy morbidity rates. Patients with islet cell tumors in proximity to or involving the duodenal wall are similarly good candidates for the Longmire–Watson procedure.

Resectability and Techniques of Reconstruction

Assessment of Resectability

Although computerized tomography, visceral arteriography, and endoscopy, including cholangiopancreatography, have greatly aided preoperative evaluation of patients who are potential candidates for pancreatoduodenectomy, intraoperative assessment remains the crucial final diagnostic step. Clinical staging is falsely negative in up to 20% of patients.[25] Although laparoscopy improves the accuracy of clinical staging of pancreatic cancer, gross disease is still overlooked in up to 10% of patients.[26] Careful intraoperative evaluation must therefore be performed before radical resection is performed. Intraoperative assessment of patients undergoing pylorus preservation is similar to that described for the standard Whipple operation. First, gross distant metastases to the liver, omentum, peritoneal surfaces, and periaortic lymph nodes must be excluded. Three groups of lymph nodes are then examined carefully: (1) nodes along the celiac and gastric arteries; (2) nodes in the hepatoduodenal ligament and surrounding the hepatic artery, bile duct, and portal vein; and (3) nodes associated with the inferior pancreatoduodenal artery, the superior mesenteric vessels, and vessels in the region of the ligament of Treitz.[27,28] Involvement of the celiac axis, the superior mesenteric vessels, or lymph nodes in the region of the ligament of Treitz indicates that the tumor has spread beyond the limits of resection. Tumor-bearing nodes in the hepatoduodenal ligament and distally along the gastroduodenal artery may be included in an *en bloc* dissection so that the lesion may still be resectable. Wide kocherization and mobilization of the hepatic flexure of the colon are necessary for evaluation.

Finally, it is important to ensure that the superior mesenteric and portal veins are free of tumor. The neck of the pancreas is carefully elevated off the portal vein to demonstrate its freedom from invasion.[28] If the lesion is

judged resectable, operation may then proceed. The limits of resection are identical to those described by Longmire[27] and Waugh and Giberson[29] for the standard Whipple operation except for division of the proximal duodenum, which is preserved in continuity with the intact pylorus (Fig. 3).

Transection of the duodenum in pylorus-preserving pancreatoduodenectomy was done at a site 3–4 cm distal to the pylorus by Traverso and Longmire.[7] Others have transected the duodenum at distances ranging from 1 cm[12] to 6 cm.[13] The site of duodenal transection in our patients varied from 1–3 cm distal to the pylorus.

The Longmire Reconstruction and its Variations

Two techniques for duodenojejunostomy have been used. The first, reported by Traverso and Longmire,[7] consists of an end-to-side anastomosis of the duodenal segment to a loop of jejunum passed dorsal to the mesenteric vessels, in the bed of the resected duodenum (Fig. 4). In this operation, Traverso and Longmire performed a side-to-side lateral pancreatojejunostomy. Other methods of managing the pancreatic remnant include anastomosis of the pancreatic duct over a stent that is inserted through the side wall of the jejunum[30]; two-layer, end-to-side pancreatojejunostomy[31]; the dunking or intussuscepting pancreatojejunostomy; pancreatogastrostomy[14]; occlusion of the pancreatic duct with solidifying agents[8,32]; and ligation of the duct.[3] Most surgeons reestablish biliary-intestinal continuity by end-to-side choledochojejunostomy. Side-to-side anastomosis may be preferred in patients in whom the common bile duct is of normal caliber, as is often the case in the absence of obstructive jaundice.

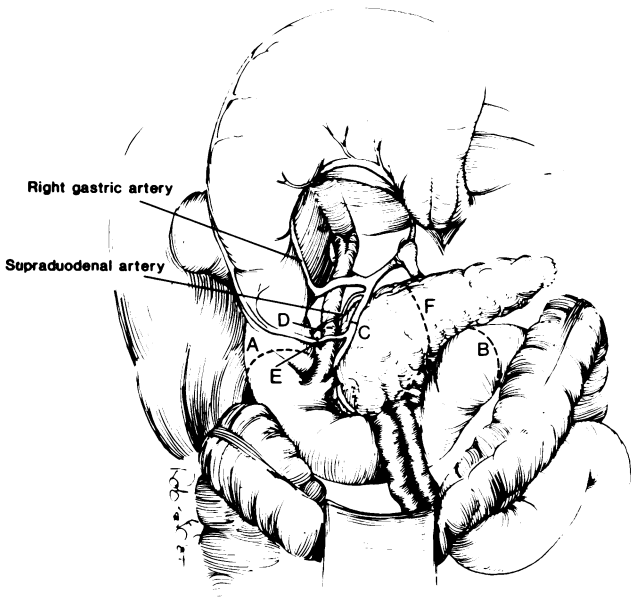


FIG. 3. Perimeters of resection in pylorus-preserving pancreatoduodenectomy. A—Transection of the proximal duodenum at 1–2 cm distal to the pylorus. B—Transection of the jejunum in the region of the ligament of Treitz. C—Division of the gastroduodenal artery after it gives its first branch. D—Transection of the common bile duct. E—Division of the right gastroepiploic artery close to its origin. F—Division of the neck of the pancreas.

FIG. 4. Watson's pylorus-preserving pancreatoduodenectomy. Note end-to-end technique of duodenojejunostomy. Watson performed the procedure in two stages: Stage 1: Cholecystojejunostomy; Stage 2: Pancreatoduodenectomy with pylorus preservation, antecolic duodenojejunostomy, and ligation of the pancreatic duct.

The second type of duodenojejunostomy, first performed by Watson,[3] consists of an end-to-end anastomosis (Fig. 5). Watson ligated the pancreatic duct and performed a cholecystojejunostomy, distal to the duodenojejunostomy. End-to-end duodenojejunostomy has been performed in combination with pancreatic duct occlusion,[32] pancreatogastrostomy,[14] and pancreatogastrostomy with Roux-en-Y choledochojejunostomy.[9]

The end-to-side duodenojejunostomy may be fashioned with an antecolic loop of jejunum after the pancreatic remnant and common bile duct have been anastomosed in sequence to the proximal jejunal limb passed through the bed of the resected duodenum (Fig. 6). The "dunking" type of pancreatojejunostomy, in which the end of the pancreas is inserted into the open end of the jejunum, is

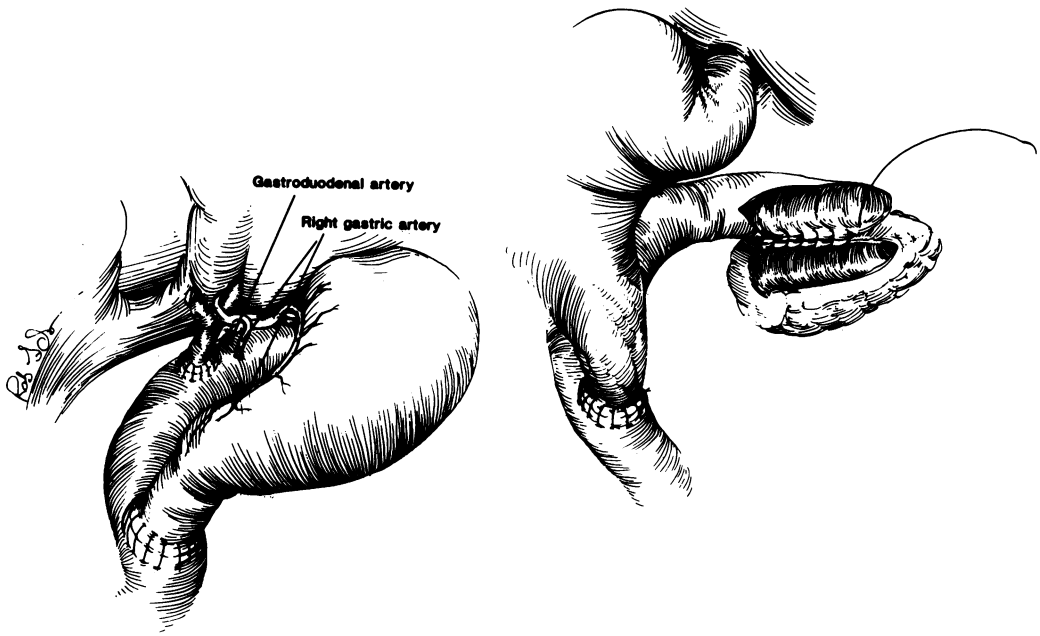


FIG. 5. Longmire pancreatoduodenectomy. Reconstruction with end-to-side duodenojejunostomy, end-to-side choledochojejunostomy, and side-to-side lateral pancreatojejunostomy.

perhaps the easiest option when the gland is soft and the duct normal in size. However, care must be exercised not to compromise the duct during placement of the pancreatic sutures.

Complications

Among the 252 patients, delayed gastric emptying was the most common complication seen after pylorus-preserving pancreatoduodenectomy. Seventy-six patients experienced persistent postprandial discomfort with nausea and vomiting, requiring prolonged gastric tube drainage. Warshaw and Torchiana[11] found that the mean length of gastric tube drainage and the average time to tolerance of a general diet after pylorus-preserving pancreatoduodenectomy were almost double those of patients who underwent a classic Whipple pancreatoduodenectomy. The mean duration of hospitalization was increased by 8 days. This observation was confirmed in our patients who did not tolerate oral fluid until the 12th postoperative day and did not accept a regular diet until the 15th day after operation (Table 4). One of our patients experienced prolonged problems with nausea, vomiting, and early satiety. Watson's patient[3] had severe nausea, vomiting, intolerance of food, and required a feeding jejunostomy on the 15th day after operation. It is of interest to note that both our patient and Watson's had intra-abdominal abscesses that required drainage. In both patients, gastric function improved after reoperation. One patient in the Lahey Clinic series[12] required reoperation due to poor gastric emptying. The patient did well after partial gastrectomy.

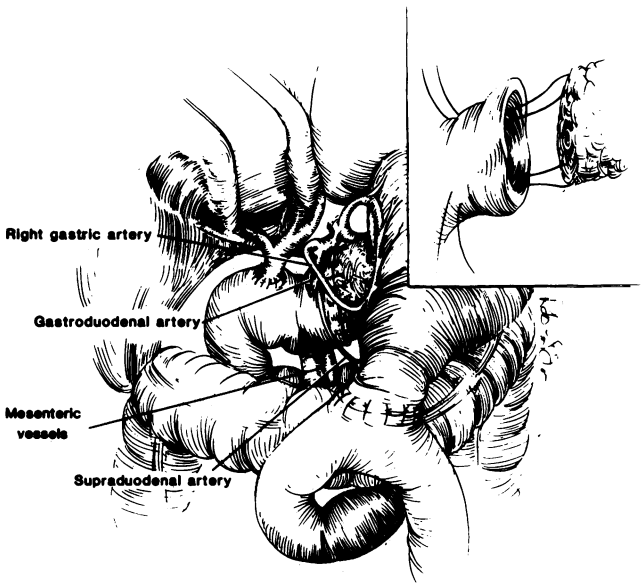


FIG. 6. Pylorus-preserving pancreatoduodenectomy with antecolic end-to-side duodenojejunostomy and dunking type pancreatojejunostomy. The choledochojejunostomy and the pancreatojejunostomy are performed to the proximal jejunal limb which is brought through the bed of the resected duodenum. Note that the right gastric artery is preserved. The supraduodenal artery should be preserved when technically feasible.

Jejunal ulceration at the site of anastomosis was reported in six patients,[11,15,33] two of whom required vagotomy and antrectomy.[11,15] The remaining four patients were treated successfully with H_2 receptor-blocking agents and antacids. All of the patients in the series by Mosca et al.[10] underwent upper gastrointestinal endoscopy. None of these patients showed marginal or jejunal ulceration. However, five patients (24%) had moderate inflammation of the antral mucosa.

Mosca et al.[10] reported duodenogastric reflux in four of 14 patients who had scintigraphic scanning using tech-

TABLE 4. *Gastric Function after Pylorus-Preserving Pancreatoduodenectomy—Duke University Medical Center 1983–85*

Patient No.	No. of Days after Operation: Gastric Drainage Terminated	Oral Fluids	Solid Diet	Discharge Time	Presence of Gastric Emptying Disorder (Clinical)	Presence of Gastric Emptying Disorder (Radiological)
1	11	11	14	15	P	P
2	9	11	14	22	A	A
3	7	8	9	15	A	A
4*	8	9	11	15	P	P
5	8	8	10	16	P	P
6	5	25	32	41	P	P
7	10	11	17	18	P	P
Mean (days)	8.3	11.9	15.3	20.3		

A = Absent, P = Present.

* Patient still showing gastric emptying disturbance at 1 year after operation.

netium-99m diethyl HIDA. Duodenogastric reflux was severe and persisted in two of these patients. Enterogastric reflux was also measured by this technique in five patients and five normal subjects at the Lahey Clinic.[33] Moderate enterogastric reflux was found after ingestion of a liquid meal in the group that underwent resection. Reflux indices in this group were significantly lower than those reported in asymptomatic patients after Billroth II gastrectomy.

Other major complications, probably related to operative technique, included anastomotic leaks and fistulae that occurred in 19% of 193 patients reported,[3,8,10,14,15,17–19,32,34,35] including one patient from the current series. Pancreatic fistulae developed in 22 patients (11%), biliary fistulae in 7 patients (4%), and enteric fistulae in 8 patients (4%).

Gall and Gebhardt[8] reported two instances of jejunal herniation and strangulation through the transverse mesocolon.

Discussion

None of the patients who experienced delay in gastric emptying had gastric outlet obstruction as evidenced by barium studies and endoscopy. In addition, the single patient who underwent antrectomy for this problem did not have a mechanical cause of gastric outlet obstruction.[12] Anastomotic edema, developing in most patients within the first 24 hours after operation,[36] usually resolves by the fifth day after operation, and could not account for the prolonged delay in the recovery of gastric function. Warshaw et al.[11] reported that gastric motility was abnormally reduced in their patients. They suggested that the stomach with its antrum and pylorus intact apparently could not empty effectively because muscular tone and peristalsis were decreased as a result of the operation.

What is known about the regulation of gastric motility and emptying? The proximal stomach (fundus and orad corpus) acts as a reservoir, regulates intragastric pressure, and controls gastric emptying of liquids. On the other hand, distal gastric motility and function are regulated by a myogenic electrical pacemaker located along the greater curvature in the proximal corpus.[37] The electrical activity controls the rate, strength, and direction of gastric peristalsis.[38] The electrical pattern of the small bowel is controlled by a separate pacemaker located within the first centimeter of the duodenum.[39] As pacesetter potentials (slow waves) spread from these natural pacemaking sites to the distal small bowel, they phase the onset and direction of contractions in the bowel.[40] Contractions are present when bursts of action potentials are associated with the pacesetter potentials.

The effect of laparotomy and anesthesia on gastric myoelectric activity was studied by Sarna et al.,[41] who showed that the pacesetter potentials were highly irregular, had an orad direction, and were not associated with action potential activity. The pacesetter potentials remained abnormal for the first 7–25 hours after laparotomy,[41] and motor activity did not resume until at least 24–72 hours after operation.[42] These changes did not bear any relationship to the particular anesthetic agents used.[43] Since sequential aboral contractions are responsible, at least in part, for gastric emptying, the rate of gastric emptying would be seriously affected during the period of irregular frequencies and absence of contractions. Moreover, Dahlgren and Selking[44] have shown that postoperative motility was altered in patients who underwent pancreatoduodenectomy. Using endoradiosondes, they showed that the resting motility of the small intestine was only moderately reduced by laparotomy and that enterotomy did not inhibit the resting peristalsis of the small intestine. However, pancreatoduodenectomy resulted in clear inhibition of peristaltic waves, with some activity returning 16 hours after operation. These data are consistent with the hypothesis that abnormal motility may underlie the alterations of gastric function seen after pancreatoduodenectomy in the early postoperative period.

Mosca et al.[10] speculated that a duodenal segment 1–

2 cm beyond the pylorus would ensure functioning of the pylorus, and that it was not necessary to preserve 3–4 cm of duodenum as originally suggested by Traverso and Longmire.[7] The wide range of duodenal segment lengths (1–6 cm) reported did not seem to have an impact on gastroduodenal motility and gastric emptying. It is important to note that this procedure preserves the natural duodenal pacemaker that is located in the proximal 0.5–0.6 cm of the duodenum.[39] Although it has been documented that duodenal transection alters the pattern of the small intestinal pacesetter potentials, reducing their frequency and periodicity distal to the site of transection,[45] it is unknown whether there is any associated alteration in gastric emptying. We have recently performed preliminary studies of the effects of duodenojejunostomy on gastric emptying using dogs.[46]

In six dogs that underwent transection of the duodenum 2 cm distal to the pylorus and anastomosis to an antecolic jejunal loop, gastric emptying of both liquids and solids was sluggish until the third postoperative day. Thereafter duodenojejunostomy had no significant effect on gastric emptying during 3 months of follow-up. These observations excluded anesthesia, bowel handling, and duodenojejunostomy as causes of prolonged delay in gastric emptying and suggested a role for other physiologic or complicating factors.

One such factor is the endocrinologic milieu created by duodenectomy and pancreatectomy, whether partial or total. Hormones that are primarily found in the duodenum and pancreas with actions on the antrum and pylorus include motilin, which is important in the control of motor activity in the stomach[47] and is localized in a specific cell mainly found in the duodenum.[48] Cholecystokinin (CCK), which is also released from the duodenum, increases the frequency of pacesetter potential in the distal stomach,[49] thus enhancing gastric peristalsis. CCK also increases pyloric pressure and may thereby retard gastric emptying.[50] In contrast, both secretin and gastric inhibitory polypeptide (GIP), which are also found in the duodenum, inhibit distal gastric action potentials and contractions and likely impair antral trituration and emptying of solids.[51] Secretin has the same action on the pylorus as CCK.[50] Glucagon and pancreatic polypeptide are both released by pancreatic endocrine cells. Glucagon, like secretin, inhibits antral motor activity while augmenting pyloric pressure.[50] Pancreatic polypeptide does not alter the gastric emptying rate of a meal.[52] In humans, enkephalins, in addition to being localized in gastric antral mucosa, are found in high concentration in the duodenal mucosa,[53] and endorphins have been reported in the human pancreas.[54] Opiates may play an important role in the regulation of normal gut motility, mainly by increasing the resting muscular tone of the gastric antrum and small intestine. The physiology of regulation of gastrointestinal motility and emptying after pylorus-preserving pancreatoduodenectomy and other operations will remain an important field of study for some time.

Another factor that might lead to disordered gastrointestinal function after pylorus-preserving pancreatoduodenectomy is insufficiency or damage of the blood supply and nerves to the preserved gastroduodenal segments. The gastroepiploic artery, with its large ascending pyloric branch, should probably be taken close to its origin from the gastroduodenal artery. The right gastric artery was severed in the Longmire operation but was left intact in our patients because of its rich supply to the antrum and pylorus (Fig. 6). The first portion of the duodenum is supplied by the supraduodenal artery which arises in 50% of the cases from the retroduodenal branch, in 25% of the cases from the gastroduodenal artery, and is a branch of the proper hepatic artery in the remaining cases.[55] The gastroduodenal artery should probably be severed distal to its first branch and should be preserved in cases of chronic pancreatitis where dissection could proceed by taking the pancreaticoduodenal artery at its origin from the gastroduodenal artery. Equal attention must also be given during the procedure to preserve the innervation to the antrum and pylorus. The antropyloric branches of the nerves of Latarjet must be preserved, as should the branches from the hepatic division of the vagus nerve. Compromise of these structures will result in functional gastric outlet obstruction and gastric retention.[56]

Not surprisingly, there is as yet no consensus on how the gastric emptying disturbances occurring in these patients should be treated. Watson[3] resorted to a feeding jejunostomy, whereas Braasch et al.[34] advocated the placement of a gastrostomy tube for decompression. Mosca et al.,[10] in addition to nasogastric tube drainage, administered somatostatin intravenously for the first 72 hours after operation as an antisecretory drug to allow prolonged endoluminal decompression. Warshaw and Torchiana[11] administered metoclopramide intramuscularly to several of their patients as an adjunct to nasogastric drainage. Questionable benefit seems to result from the adjunctive modalities, but gastric decompression appears to be the mainstay of therapy for this group of patients.

The occurrence and severity of duodenogastric reflux seem to bear no direct relationship to the length of the duodenal segment distal to the pylorus. Indeed, the role of the pylorus in preventing reflux remains controversial. Fisher and Cohen[57] postulated that duodenogastric reflux is a physiologic event in humans. Muller-Lissner et al. found that surgical destruction of the pylorus in dogs by pyloroplasty[58] or pylorectomy[59] increases reflux, confirming a role for the pylorus in preventing reflux of duodenal contents into the stomach. Furthermore, some authors who believe that increased duodenogastric reflux causes gastric ulcer postulate that chronic gastritis is the

intermediate step in ulcer production.[60,61] Braasch[62] has suggested that the loss of the pylorus by allowing alkaline reflux would result in antral stimulation, which would in turn cause parietal cell stimulation and, ultimately, increased gastric secretion of acid. Braasch concluded that pyloric preservation may prevent jejunal ulcer formation by preventing this possible chain of events. The three patients with scintigraphic reflux and gastric inflammation on biopsy in the series reported by Mosca et al.[10] demonstrate the need for carefully controlled studies since reflux occurs in physiologically normal individuals.

Of the remaining problems relating to surgical technique, the most important are pancreatic fistulae, biliary fistulae, and enterocutaneous fistulae, which were reported in 11%, 4%, and 4% of the patients, respectively. Some patients in whom the pancreatic duct was occluded at operation had developed pancreatic fistulae subsequently. Although the operative management of the pancreatic duct is a major factor in the development of pancreatic fistulae after pancreatoduodenectomy, Grace et al.[15] showed that, provided the pancreatic duct was drained into the gastrointestinal tract, the type of anastomosis was not the major determinant of the risk of fistula formation. In fact, the incidence of pancreatic fistula in their series was similar in patients who had mucosa-to-mucosa anastomosis and those in whom the cut end of the pancreas was invaginated into the jejunum. Invagination of the pancreatic remnant into the jejunum with a small plastic catheter inserted into the pancreatic duct to act as a stent seems to be technically less demanding.

In 1934, Tripodi and Sherwin[63] sutured the pancreas to the stomach in an attempt to prevent the activation of trypsinogen induced by the alkaline intestinal milieu and thus prevent secondary pancreatitis. Flautner et al.[14] combined pylorus preservation and pancreatogastrostomy in 25 patients, only one of whom had a pancreatic fistula. However, an additional patient hemorrhaged from the pancreatic remnant.

Internal herniation of the jejunal loop through the mesocolon after retrocolic duodenojejunostomy[8] makes antecolic reconstruction more attractive.

Conclusion

Preserving the antrum and pylorus in radical pancreatoduodenectomy maintains gastric volume as well as the mixing function of the stomach, which resides in its antral region. The nutritional problems that follow standard pancreatoduodenectomy are ameliorated as are postgastric surgery problems, including dumping. Survival is not adversely affected in patients with malignancy. However, operative mortality and morbidity rates may be improved because reconstruction is easier than after the standard Whipple operation. Pancreatojejunal leakage and fistula formation remain the most common problems contributing to long-term morbidity after operation. Delay in gastric emptying is transient in most patients, and peptic ulceration and duodenogastric reflux occur in only a small number of patients. These observations have opened a new and interesting physiologic debate on the role of the preserved antrum and pylorus in these patients. Pylorus preservation appears to be the technique of choice at this time for gastrointestinal reconstruction after pancreatoduodenectomy.

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