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HOW I DO IT

Reconstruction Following the Pylorus Preserving Whipple Resection: PJ, HJ, and DJ

Eugene P. Kennedy · Jennifer Brumbaugh · Charles J. Yeo

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Abstract
Introduction Pancreaticoduodenectomy is one of the most challenging procedures performed by general surgeons.
Discussion Many studies have been performed looking at the technical aspects of reconstruction after pancreaticoduodenal resection. Multiple randomized trials have failed to convincingly demonstrate the superiority of any single approach or technique. Here, we illustrate our approach to reconstruction, with an emphasis on technical aspects and details.
Conclusion The fine points can help avoid technical errors that result in anastomotic failure.

Keywords Pancreaticoduodenectomy · Pancreaticojejunostomy · Hepaticojejunostomy · Duodenojejunostomy

Introduction

The definitive surgical management of periampullary pathology has long been a challenging endeavor. The basic concepts of safe dissection and reconstruction around the head of the pancreas have been well described for greater than 70 years.[1] However, it was not until the last 20 to 30 years that the rates of perioperative morbidity and mortality declined to the point that pancreaticoduodenectomy (PD) became a standard and accepted treatment for periampullary tumors. Currently, at high-volume centers, the rates of perioperative mortality and morbidity are typically reported at 1–3%, and 30–40%, respectively.[2,3] Multiple factors have contributed to this decline in morbidity and mortality. These factors include advances in cross-sectional imaging that allow accurate preoperative staging and patient selection,[3,4] advances in perioperative patient management and ICU care including the development of critical pathways,[5] and the development of specialized expertise at high-volume pancreatic surgery centers.[6]

High-quality cross-sectional imaging and the development of specialized centers have done much to assure safe and careful dissection in experienced hands. This leaves anastomotic leakage, particularly at the pancreaticojejunostomy, as the primary cause of morbidity after PD. Contemporary series report varying rates of pancreatic fistula after PD. Published rates vary between 2% and greater than 20%, with several large series reporting fistula rates of approximately 10%. An international group has proposed a clear definition of pancreatic fistula.[7] Much effort has gone into attempts to identify technical or pharmacologic approaches that would reliably reduce the rate of pancreatic fistula after PD. These approaches include variations in anastomotic technique such as pancreaticogastrostomy vs. pancreaticojejunostomy,[8] pancreatic duct stenting,[9] the use of octreotide,[10] and the use of fibrin sealant.[11] None of these approaches were able to demonstrate a reproducible decrease in the pancreatic fistula rate in the setting of randomized clinical trials. Our recent prospective randomized dual-institution study suggested that

E. P. Kennedy · J. Brumbaugh · C. J. Yeo
Department of Surgery, Jefferson Pancreatic, Biliary and Related Cancer Center, Thomas Jefferson University, Philadelphia, PA, USA

C. J. Yeo (✉)
Department of Surgery, Thomas Jefferson University, 1015 Walnut Street, 620 Curtis, Philadelphia, PA 19107, USA
e-mail: charles.yeo@jefferson.edu

an invagination pancreaticojejunostomy may have benefits as compared to a duct-to-mucosa pancreaticojejunostomy.[12]

These studies as well as a large number of retrospective case series have reached essentially the same conclusion, that underlying pancreatic texture (i.e., soft gland) is the primary determinant of pancreatic fistula formation.[2,3,8–11] Multiple permutations of similar and dissimilar techniques failed to alter the fact that soft pancreatic texture predisposes to anastomotic leakage. Perhaps overlooked in all these studies is the important role of meticulous surgical technique. Surgical technique cannot change underlying pancreatic morphology or physiology, but technical precision and the avoidance of any technical errors maximizes the possibility of a good outcome. Additionally, the same concept applies to the performance of the other two anastomoses performed during reconstruction of the GI tract after pylorus-preserving PD (PPPD), namely, hepaticojejunostomy and the duodenojejunostomy. Here, we present our standard approach to reconstruction after PPPD with special emphasis on technical details that we believe are critical for achieving good outcomes. The senior author (C.J.Y.) has evolved to these techniques over 20 years, with input from various colleagues, mentors, and publications and personal experience (as surgeon or assistant) with over 1,000 pancreaticoduodenal resections.

Surgical Technique

Specimen Removal to Pancreaticojejunostomy

After the specimen has been removed, the reconstruction following PPPD begins. If the operative procedure has been performed for a malignant neoplasm, titanium clips may be placed to mark the tumor bed, allowing for targeted postoperative radiation therapy.

We commence the reconstruction by closing the rent at the level of the ligament of Treitz with interrupted 3–0 silk sutures. The retained jejunum is then brought up through a separate small rent in the right side of the transverse mesocolon. This can often be identified as a thin "bare" space to the right of the middle colic vessels. It is critical to ensure that the retained proximal jejunum is not twisted on its mesentery when it is brought through this mesocolic rent and that it reaches to the pancreatic remnant and bile duct without tension.

The pancreatic remnant is then mobilized out of the retroperitoneum for a distance of at least 2 cm posteriorly, by dividing the connective tissue located superiorly and inferiorly along the pancreatic body and elevating the remnant ventrally, away from the splenic vein. A lacrimal duct probe or Baake's dilator of appropriate caliber may be placed in the lumen of the remnant pancreatic duct and used as an atraumatic handle to help elevate the pancreatic remnant during this dissection. Superiorly, it is uncommon to encounter a substantial-sized blood vessel; however, there may be adjacent lymph nodes present. Our mobilization typically does not go leftward as far as the splenic artery. Inferiorly, one must be careful to avoid injury to small vessels, which may either drain into the inferior mesenteric, splenic, or superior mesenteric vein. Additionally, small arteries originating from the superior mesenteric artery may be found along the inferior border of the gland or posterior to the pancreatic remnant.

Invagination Pancreaticojejunostomy

Following mobilization of the pancreatic remnant, we commence our reconstruction with the pancreaticojejunostomy. This is typically performed in end-to-side fashion, to the proximal-most portion of the available jejunum just distal to the oversewn staple line. Suture placement begins at the superior aspect of the remnant pancreas (Fig. 1), placing an interrupted 3–0 silk corner suture first through the superior edge of the pancreatic remnant and subsequently as a seromuscular bite on the jejunum. This posterior outer row is then performed in horizontal mattress fashion, taking substantial bites of the posterior pancreatic capsule and parenchyma and seromuscular bites of the jejunum. The previously placed lacrimal duct probe or Baake's dilator can be maintained in the lumen of the remnant pancreatic duct, to minimize the chance that any of these posterior stitches will catch and occlude the pancreatic duct. On the average, five to seven of these posterior outer 3–0 silk sutures are first placed and then tied without tension. The tied sutures are then placed on tension retracting leftwards, and a jejunotomy is created with the electrocautery 2–3 mm from the suture line, typically

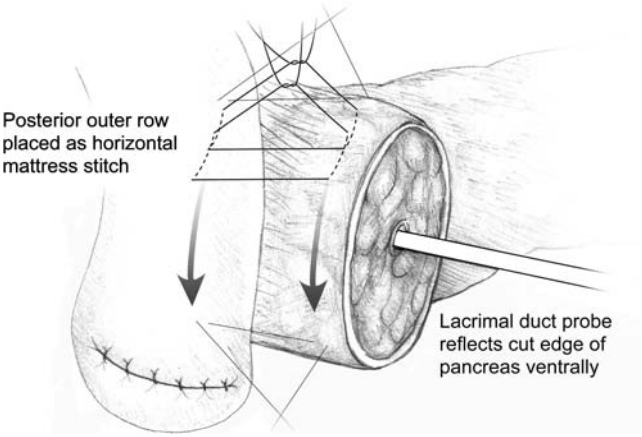

Figure 1 End to side pancreaticojejunostomy: The posterior outer row is performed with 3–0 silk, in horizontal mattress fashion. The *arrows* indicate the direction of consecutive suture placement, starting superiorly and moving inferiorly. A lacrimal duct probe is used to reflect the cut edge of the pancreas ventrally.

extending from the penultimate superior silk suture to the penultimate inferior silk suture, opening the jejunum full thickness (Fig. 2). All but the most superior and inferior silk sutures are then cut, and a vein retractor is placed to hold the jejunal lumen open. In performing the invagination type of pancreaticojejunostomy, the inner posterior layer is performed using 3–0 polysorb suture in continuous fashion. Two sutures are placed at essentially the same spot at the inferior most aspect of the jejunal opening. A running, locking posterior row is placed, taking good bites of the pancreatic parenchyma and capsule on the pancreas side and full thickness bites of the bowel wall on the jejunal side (Fig. 3). The posterior suture is continued up and around the superior corner of the inner layer of the anastomosis. At the completion of the inner posterior row, the vein retractor and probe or dilator in the pancreas duct are removed, and the anterior inner row is completed by running the 3–0 polysorb suture from superior to inferior along the anterior aspect of the pancreas. These bites typically contain an ample amount of pancreatic capsule and parenchyma as well as full thickness jejunum. The goal is to invaginate or "dunk" all of the cut edge of the pancreas into the jejunal lumen, allowing apposition of the pancreatic capsule to the jejunal serosa (Fig. 4).

The anterior outer layer is then performed using interrupted 3–0 silk sutures, taking ample bites of the pancreatic capsule and parenchyma, and then seromuscular bites of jejunum well away from the anastomosis, allowing the jejunum to roll up over the anterior inner layer, to complete the two-layer invagination end-to-side pancreaticojejunostomy (Fig. 5 and inset). The anterior outer layer sutures are all first placed and then tied down sequentially. When dealing with a gland of soft texture, the first assistant

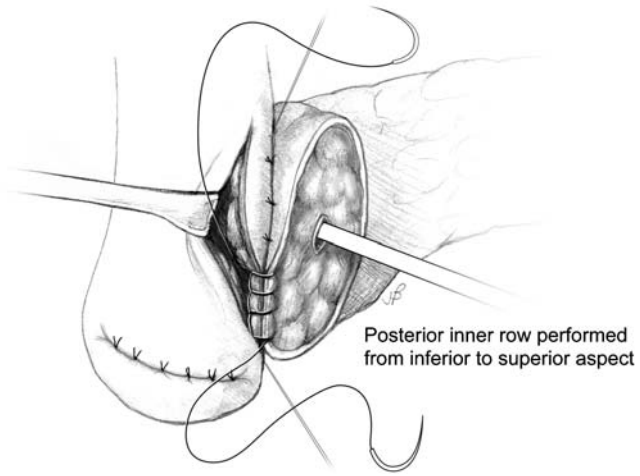

Figure 3 Invagination pancreaticojejunostomy: A vein retractor holds the jejunum open. The posterior inner layer is performed from inferior to superior with running locking 3–0 polysorb, taking good bites of the pancreas (parenchyma and capsule) and full thickness bites of the jejunum.

crosses the next untied suture adjacent to the one being tied by the operating surgeon, to reduce tension and minimize the chance of the suture cutting through the pancreatic parenchyma.

Duct-to-Mucosa Pancreaticojejunostomy

The posterior outer row of 3–0 silk suture is placed as described above (see "Invagination Pancreaticojejunostomy", Fig. 1). The tied silk sutures are then held on tension, and the pancreatic duct is identified and probed. A small, full-thickness jejunotomy is then created in the jejunum, using electrocautery, in line with the pancreatic duct (Fig. 6). The

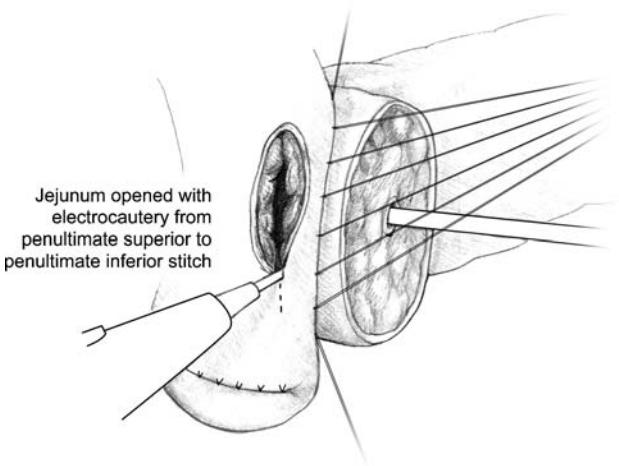

Figure 2 Invagination pancreaticojejunostomy: The jejunum is opened with the electrocautery from the penultimate (next to last) superior silk stitch, to the penultimate inferior silk stitch.

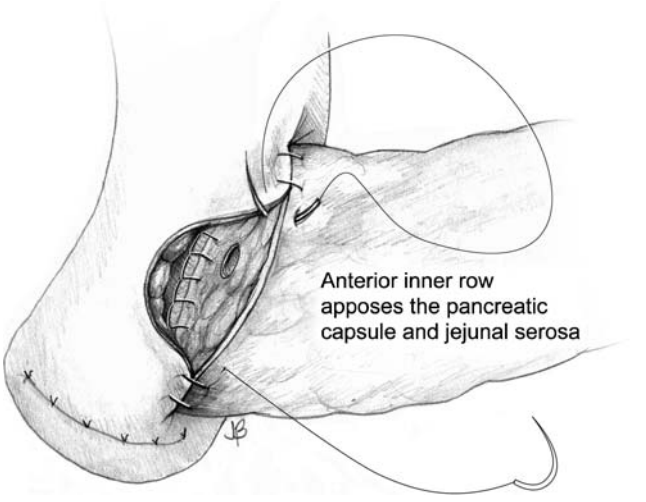

Figure 4 Invagination pancreaticojejunostomy: The vein retractor and lacrimal duct probe have been removed. The anterior inner layer is performed with running 3–0 polysorb, achieving apposition of the pancreatic capsule and the jejunal serosa.

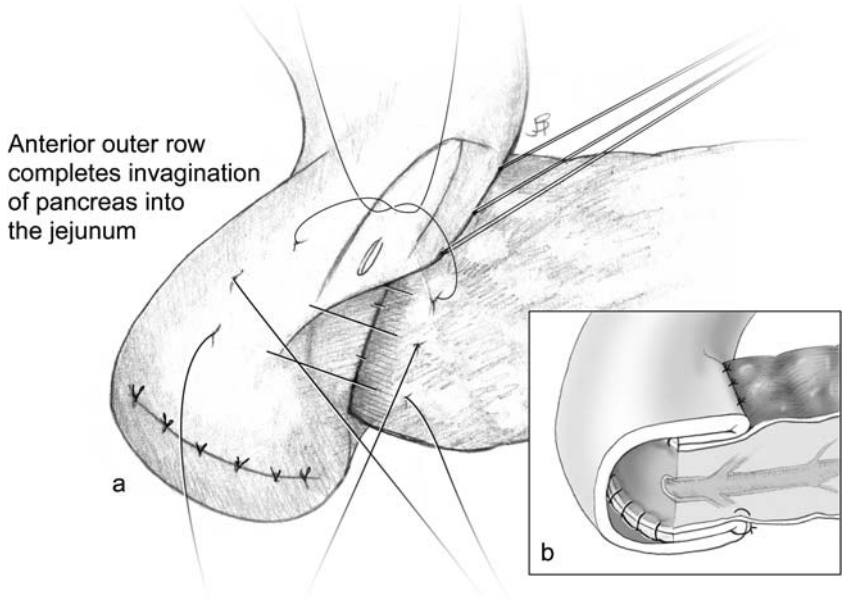

Figure 5 Invagination pancreaticojejunostomy: The anterior outer layer is performed with interrupted 3–0 silk, pulling the mobile jejunum over the immobile anterior inner suture line, allowing apposition of the jejunal serosa to the pancreatic capsule. The *insert* shows how the completed anastomosis invaginates the pancreas into the jejunum.

posterior inner layer is then performed using 5–0 PDS suture and loupe magnification if necessary, taking ample bites of the pancreatic parenchyma and pancreatic duct and full thickness bites of the jejunum. If a small pancreas duct is encountered (1–2 mm in diameter), a total of three to four 5–0 PDS sutures may be used on the posterior row. For a larger pancreatic duct, the sutures are spaced no more than 1.5 mm apart, and up to ten 5–0 PDS sutures may be required (Fig. 7).

A nice maneuver at this point is to use a sterile pediatric feeding tube (3.5, 5.0, or 8.0 Fr and sized appropriately to fit into the pancreas duct) and place one end up into the pancreatic duct extending 5 cm into the pancreatic body and the other end through the jejunotomy and downstream into the jejunum. We typically cut the pediatric feeding tube to a length of 20 cm, allowing there to be approximately 5 cm within the pancreatic parenchyma and roughly 15 cm in the downstream jejunum (Fig. 8). The pediatric feeding tube is not intended as a permanent anastomotic stent but rather as a temporary guide for the placement of the anterior inner and outer rows of sutures. Its presence in the lumen of the pancreas duct minimizes the chance that any of the anterior inner row sutures will catch the back wall of the

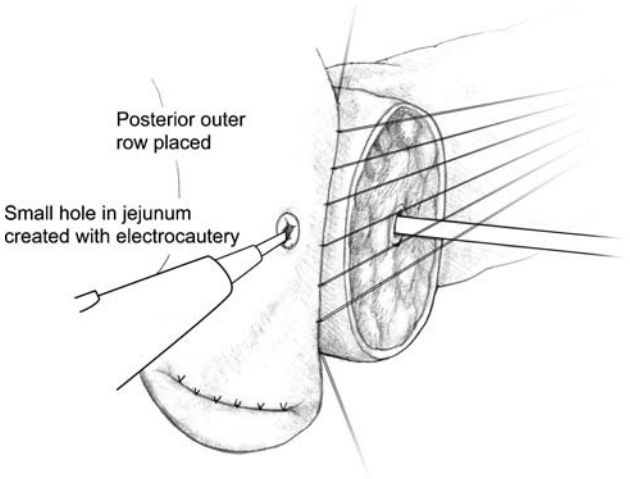

Figure 6 Duct-to-mucosa pancreaticojejunostomy: After the posterior outer row of 3–0 silk sutures is placed (as per Fig. 1), a small hole is created in the jejunum using the electrocautery, at the level of the pancreatic duct.

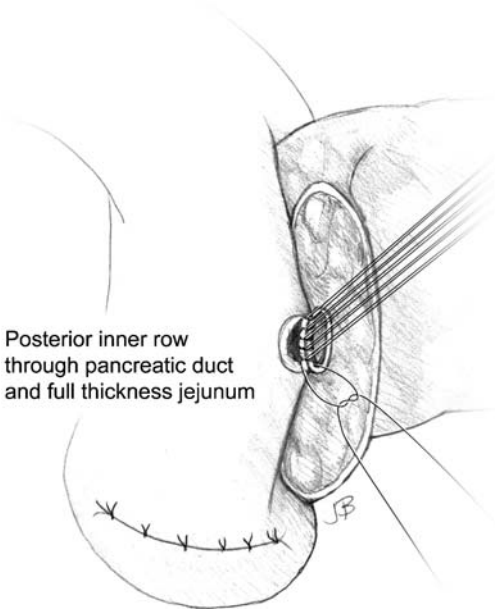

Figure 7 Duct-to-mucosa pancreaticojejunostomy: The posterior inner row of 5–0 PDS sutures has been placed into a 5-mm pancreatic duct. The bites on the jejunal side take all layers of the jejunal wall, while the bites on the pancreas side include the pancreatic duct and a small amount of pancreatic parenchyma surrounding the duct.

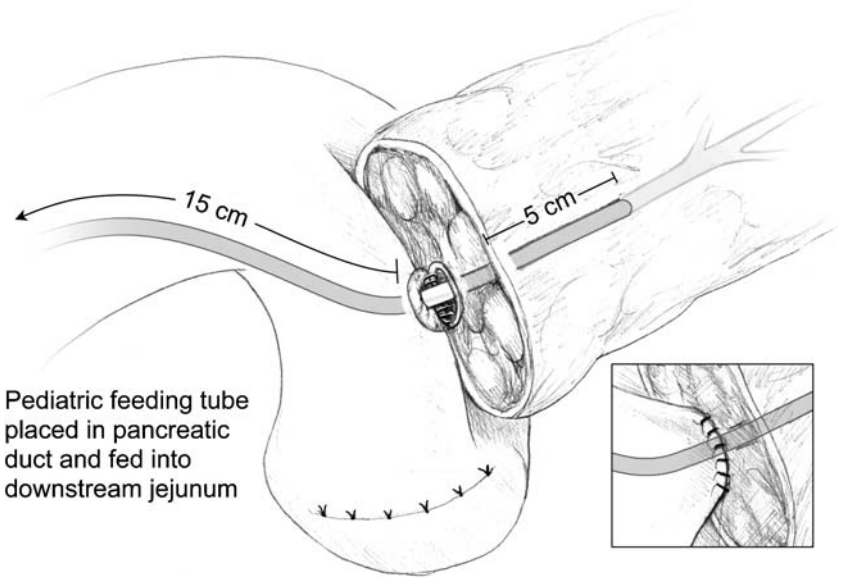

Figure 8 Duct-to-mucosa pancreaticojejunostomy: A pediatric feeding tube is cut to a length of 20 cm, and 5 cm are placed in the pancreatic duct and 15 cm fed into the downstream jejunum. Then (*inset*), the anterior inner row of 5–0 PDS sutures is placed, tied, and cut.

pancreatic duct and occlude the lumen. The anterior inner row is then performed using 5–0 PDS sutures, taking care to avoid snagging the pediatric feeding tube. The pediatric feeding tube is temporarily left in the lumen through the anastomosis, to be removed through the downstream jejunotomy made for the hepaticojejunostomy. Once these anterior inner row of sutures are tied and cut, then the anterior outer row of 3–0 silk sutures are placed, taking ample bites of the pancreatic parenchyma and capsule, and ample bites of the jejunum well away from the anastomosis, allowing the jejunum to be pulled up and over the anterior inner suture line (Fig. 9). Careful technique is used to avoid tearing the parenchyma of the pancreas when these anterior outer layer sutures are tied.

End-to-Side Hepaticojejunostomy

Approximately 10 cm downstream from the pancreaticojejunostomy, we perform a standard biliary-enteric reconstruction as an end-to-side hepaticojejunostomy. We have learned that this hepaticojejunostomy should be sufficiently downstream from the pancreaticojejunostomy to allow a bit of redundancy in the jejunal limb between the pancreaticojejunostomy and the hepaticojejunostomy. This is intentionally done in the rare chance that reoperation is necessary for failure of healing of the pancreaticojejunostomy or revision of the hepaticojejunostomy. Having the pancreaticojejunostomy and the hepaticojejunostomy at least 10 cm apart allows the surgeon to work on either the pancreaticojejunostomy or the hepaticojejunostomy separately and not have to disrupt both anastomoses at the time of reoperation.

We perform our hepaticojejunostomy using a single layer of 5–0 PDS sutures, first opening the jejunum with the cautery, sizing it appropriately to the internal diameter of the common hepatic duct (or common bile duct). At this point, the pediatric feeding tube used as a temporary pancreas duct stent for the duct-to-mucosa pancreaticojejunostomy is removed. We place the corner stitches at the 3 and 9 o'clock positions of the duct first, with the knots on the outside. We then place the remainder of our posterior sutures with the knots on the inside (Fig. 10), and we tie all the sutures. After checking for patency of the lumen of the common hepatic duct and the jejunum, we use an 8- to 12-French T-tube (cut to yield an "I-tube") to temporarily stent the internal aspect of the anastomosis during the time that we are placing the anterior row of sutures. The anterior row of 5–0 PDS sutures is then placed and subsequently tied down with the knots on the outside to

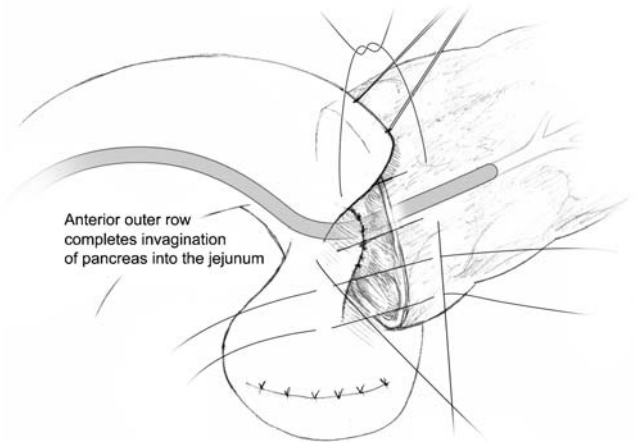

Figure 9 Duct-to-mucosa pancreaticojejunostomy: The anterior outer row of 3–0 silk sutures is placed, pulling the mobile jejunum over the immobile suture line, allowing apposition of the jejunal serosa to the pancreatic capsule.

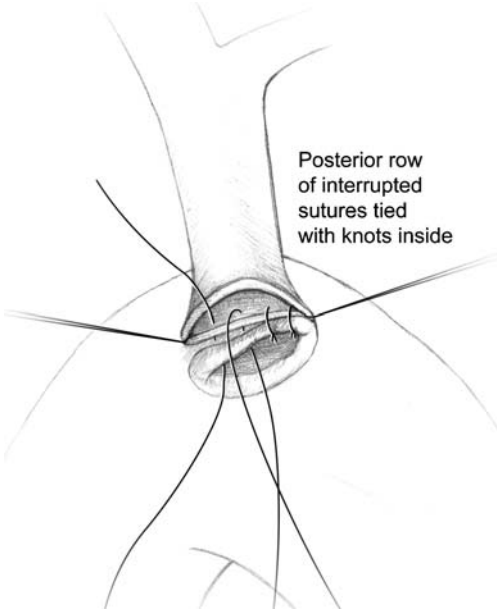

Figure 10 End-to-side hepaticojejunostomy: The posterior row is performed with interrupted 5–0 PDS sutures. For the corner stitches at 3 and 9 o'clock on the duct, the knots are tied on the outside, while for the posterior sutures, the knots are tied on the inside. If a pediatric feeding tube was used for the duct-to-mucosa pancreaticojejunostomy, it is removed via this jejunotomy.

yield a water-tight anastomosis without tension (Fig. 11). The temporary "I-tube" stent is left in place and removed through the downstream jejunotomy made for the subsequent duodenojejunostomy.

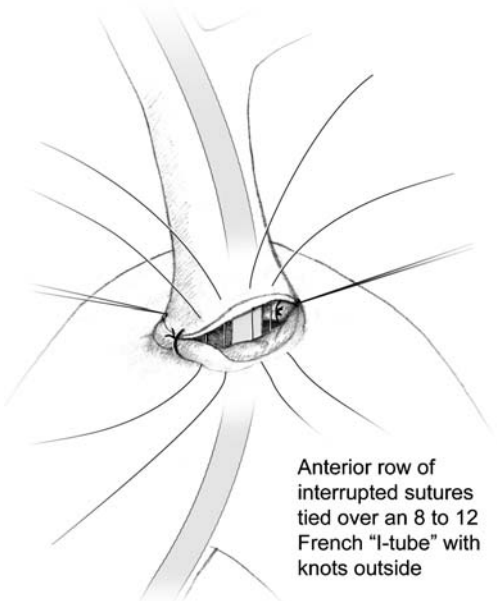

Figure 11 End-to-side hepaticojejunostomy: The anterior row is performed with interrupted 5–0 PDS sutures, over an 8- to 12-French "I-tube." The anterior row knots are tied on the outside.

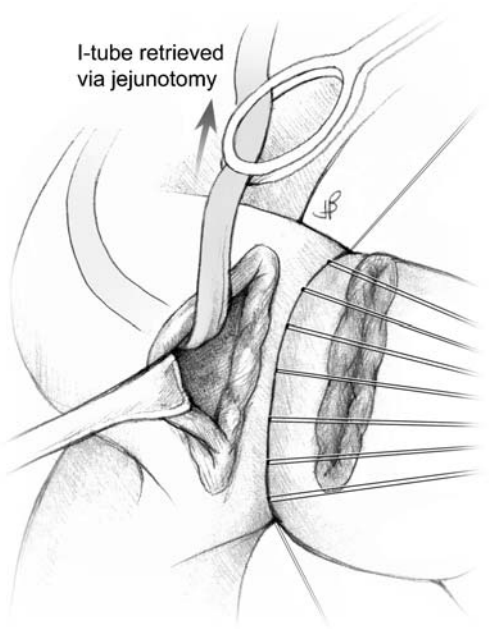

Figure 12 End-to-side duodenojejunostomy: After the posterior outer row of 3–0 silk sutures are placed and tied, the jejunum is opened, the duodenal staple line is excised, and the "I-tube" is retrieved via the jejunotomy.

End-to-Side Duodenojejunostomy

About 15 cm downstream from the hepaticojejunostomy, we perform a standard end-to-side duodenojejunostomy in retrocolic fashion. We first place an outer layer of interrupted 3–0 silk sutures, then excise the duodenal staple line and open the jejunum with the electrocautery. At this point, the I-tube used to "stent" the hepaticojejunostomy is removed through the jejunotomy (Fig. 12). The inner layer

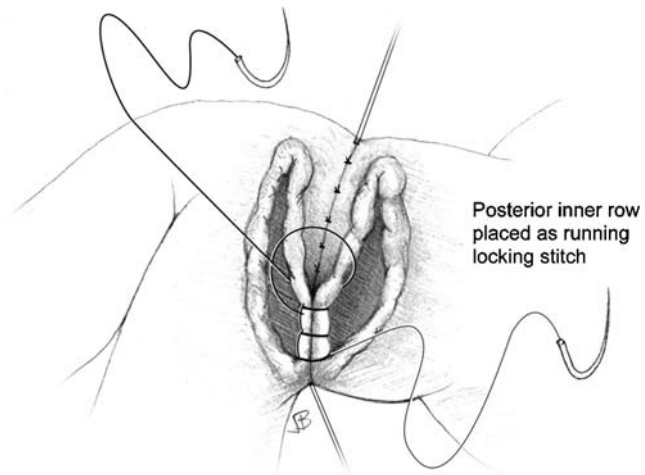

Figure 13 End-to-side duodenojejunostomy: The posterior inner layer is performed with running 3–0 polysorb, using a running locking technique.

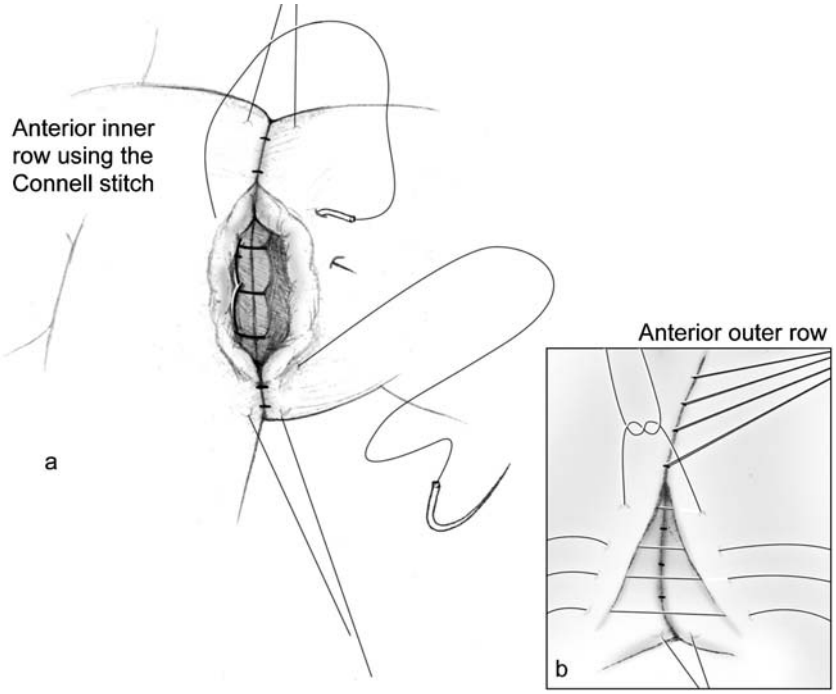

Figure 14 End-to-side duodenojejunostomy: The anterior inner layer is performed with 3–0 polysorb, as a Connell stitch, while the anterior outer layer (*inset*) is completed using interrupted 3–0 silk suture.

of the duodenojejunostomy is performed using running 3–0 polysorb, with locking sutures on the posterior aspect (Fig. 13), and the Connell suture anteriorly (Fig. 14). The anastomosis is completed with an outer anterior layer of interrupted 3–0 silk (Fig. 14, inset). About 6–8 cm downstream from the duodenojejunostomy, the efferent limb of the duodenojejunostomy is secured to the transverse mesocolon with interrupted 3–0 silk stitches, closing the mesenteric defect and leaving the pancreaticojejunostomy, hepaticojejunostomy, and duodenojejunostomy all cephalad to the transverse mesocolon (Fig. 15). We have observed a very low incidence of delayed gastric emptying with this reconstruction and have not felt the necessity to perform the duodenojejunostomy in antecolic fashion.

We do not place gastrostomy or jejunostomy tubes for venting or enteral feeding purposes. We do not leave the temporary pancreatic duct stent or I-tube in place. Our current practice is to place two 3/16″ round silastic drains through left- and right-sided flank stab incisions. The right drain is designed to drain the right subhepatic space and the retroperitoneal area posterior to the neoduodenum and adjacent to the superior mesenteric artery and vein. The left drain is brought through the gastrocolic ligament laterally and into the lesser sac, and it rests in the left subhepatic space, near but not touching the pancreaticojejunostomy. Our critical pathway for PD[5] targets removal of the nasogastric tube on postoperative day (POD) 1, a clear liquid diet on POD 2, solid food on POD 3, and hospital discharge on POD 6 or 7. Over 70% of our patients are able to adhere to this hospital discharge target.

Discussion

PD is one of the most challenging procedures performed by general surgeons. In addition to an often difficult dissection, the continuity of the GI tract is violated in four places and must be reconstructed with at least three separate anastomoses. Each of these anastomoses has a potential for leakage, with subsequent associated morbidity. Many approaches, particularly the ones focused on the pancreatic anastomosis, have been evaluated, and many have failed to show a consistent reduction in anastomotic leakage. One conclusion that is easily drawn from

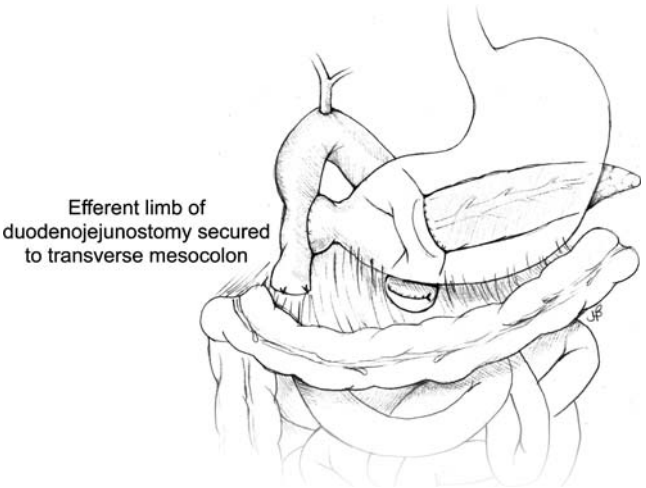

Figure 15 End-to-side duodenojejunostomy: The efferent limb of the duodenojejun-ostomy is secured to the transverse mesocolon using 3–0 silk sutures, closing the mesocolic rent, and leaving all anastomoses cephalad to the transverse mesocolon.

the compilation of many well-done studies is that underlying patient factors and surgery-related technical factors are important determinants of outcomes.

One common theme that can be identified running through the body of scientific literature surrounding reconstruction after PD is that many techniques often have exceptional results in the hands of the individual or small group of surgeons promoting that technique. When a certain technique is generalized in a large study, however, the results achieved tend to regress toward the mean in the literature. This leads one to question whether or not it is truly a certain approach that is critical or if it is the relationship between a particular surgeon and a particular approach that makes a difference. Perhaps, it is the precision employed and the lack of seemingly trivial technical missteps that occur when a surgeon has significant comfort and experience with a particular technique that results in superior outcomes. Development of that comfort level and emphasis on fine points of technique, such as those described in his article, should allow for excellent outcomes with many reconstructive approaches. The reconstruction after PPPD is a technically challenging endeavor, which, if it can be performed safely, frequently allows for a relatively short postoperative hospital stay and return toward optimal quality of life.

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