RadioGraphics

Multidetector CT Evaluation of the Postoperative Pancreas[1]

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CME FEATURE

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LEARNING OBJECTIVES FOR TEST 6

After completing this journal-based CME activity, participants will be able to:

- List the different surgical techniques for neoplastic and nonneoplastic pancreatic diseases.
- Identify the expected postoperative anatomic findings at CT imaging.
- Detect related complications and recurrent disease.

INVITED COMMENTARY

See discussion on this article by Mitchell (pp 764–766).

TEACHING POINTS

See last page

Several pancreatic diseases may require surgical treatment, with most of these procedures classified as resection or drainage. Resection procedures, which are usually performed to remove pancreatic tumors, include pancreatoduodenectomy, central pancreatectomy, distal pancreatectomy, and total pancreatectomy. Drainage procedures are usually performed to treat chronic pancreatitis after the failure of medical therapy and include the Puestow and Frey procedures. The type of surgery depends not only on the patient's symptoms and the location of the disease, but also on the expertise of the surgeon. Radiologists should become familiar with these surgical procedures to better understand postoperative changes in anatomic findings. Multidetector computed tomography is the modality of choice for identifying normal findings after surgery, postoperative complications, and tumor recurrence in patients who have undergone pancreatic surgery.

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Introduction

The pancreas is affected by different types of diseases, including tumors and acute and chronic pancreatitis. Despite advances in medical and radiation oncology, surgery remains the only curative option for pancreatic adenocarcinoma (1–3). Surgery is also the treatment of choice for patients with chronic pancreatitis in whom medical therapy has failed. Several types of pancreatic surgery and procedures have been described, including tumor resection, decompression of the main pancreatic duct, and removal of calculi (4). Knowledge of the types of surgery and anastomoses and the interval between surgery and imaging is essential for radiologic interpretation of imaging results.

Multidetector computed tomography (CT) can be used to depict normal findings after surgery and postoperative complications. Tumor recurrence and metastases to the liver and lymph nodes may also be depicted at delayed follow-up examinations.

The purpose of this article is to *(a)* briefly review the normal pancreatic anatomy, *(b)* describe the different techniques used in pancreatic surgery, and *(c)* discuss and illustrate normal postoperative findings and complications after pancreatic surgery. First, the pertinent anatomy is reviewed, including the normal pancreatic anatomy, the pancreatic arterial supply, and the pancreatic venous drainage. Then the protocol for CT and its indications and limitations are considered. The resection procedures of pancreatoduodenectomy and central, distal, and total pancreatectomy are covered, followed by the drainage procedures known as the Puestow procedure and the Frey procedure. Finally, the miscellaneous procedures of *(a)* necrosectomy and abscess drainage and *(b)* pseudocyst derivation are considered.

Review of the Pertinent Anatomy

Normal Pancreatic Anatomy

The pancreas is a lobulated gland located in the anterior pararenal space of the retroperitoneum. The pancreas is usually 15–20 cm in length and can be divided into four parts: the head, neck, body, and tail. The pancreatic head lies medial to the second portion of the duodenum, to the right of the superior mesenteric vein and anterior to the inferior vena cava. The uncinate process is a triangular prolongation of the caudal part of the head and is oriented posteriorly, behind the superior mesenteric vein and toward the left. The pancreatic neck is located to the left of the head, immediately ventral to the portal vein and the splenomesenteric venous junction. The pancreatic body and tail are located behind the lesser peritoneal sac and the stomach, ventral to the splenic vein, and anterior or anterolateral to the left kidney. Although there is no anatomic division between the tail and the body of the pancreas, both can be determined by measuring one-half of the distance between the neck and the end of the pancreas (Fig 1).

Pancreatic Arterial Supply

The pancreas has a complex arterial supply and anatomic variations, especially in the head (5,6). In the most common branching pattern, the superior pancreaticoduodenal arteries arise from the gastroduodenal artery. They anastomose with their inferior counterparts, the inferior pancreaticoduodenal arteries, which arise from the proximal jejunal artery or directly from the superior mesenteric artery to supply the pancreatic head and body.

The pancreatic body and tail are mostly supplied by the dorsal pancreatic artery, which originates directly from the celiac axis, proximal common hepatic artery, or splenic artery. The tail is also supplied by multiple branches of the splenic artery (great pancreatic artery and caudal pancreatic artery) and the superior mesenteric artery (7). Therefore, splenectomy may be necessary during caudal pancreatectomy (Fig 2).

Pancreatic Venous Drainage

Four small pancreaticoduodenal veins drain the head of the pancreas (8,9). The inferior pancreaticoduodenal veins (anterior and posterior) drain into the proximal jejunal veins, which drain into the superior mesenteric vein. The superior pancreaticoduodenal veins (anterior and posterior) drain into the main portal vein (posterior) and the gastrocolic trunk (anterior). Venous drainage of the body and tail of the pancreas is more variable but consists of multiple small branches draining into the splenic vein.

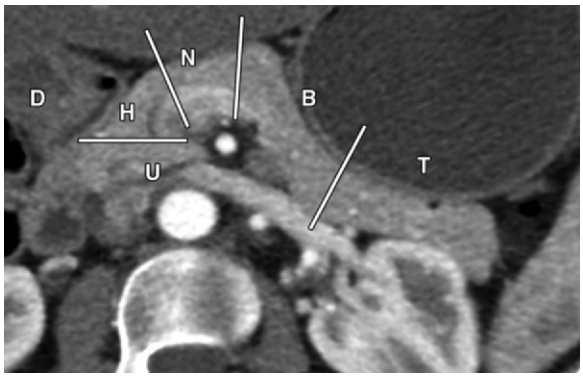
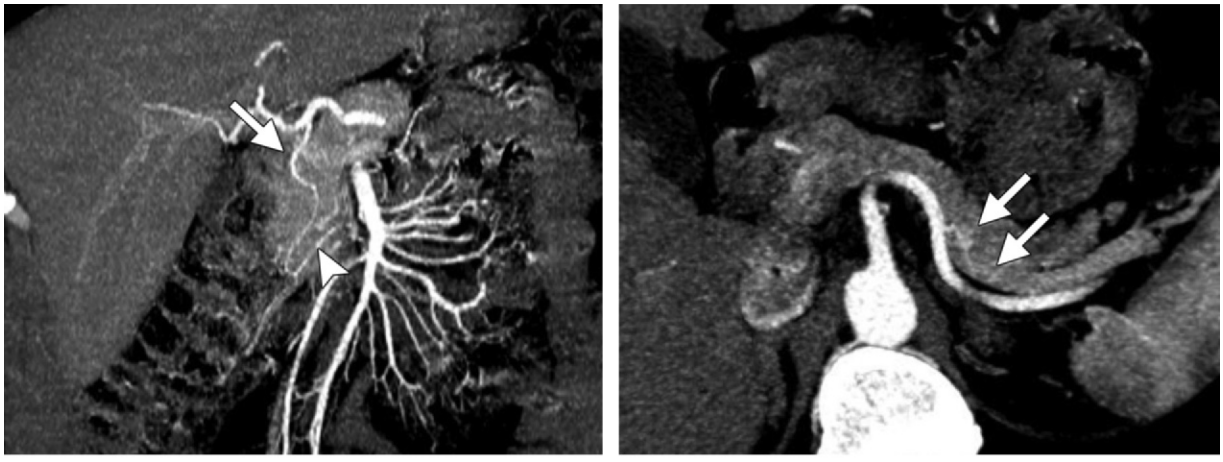


Figure 1. Pancreatic anatomy. Axial multidetector CT image shows the pancreatic head *(H);* the uncinate process *(U)* lying posterior to the splenomesenteric venous junction; the duodenum *(D)*; and the neck *(N)*, body *(B)*, and tail *(T)* of the pancreas. Lines show division of the pancreas into anatomic parts.



a. **b.**

Figure 2. Pancreatic arterial anatomy. **(a)** Coronal maximum intensity projection image shows the gastroduodenal artery (arrow) and the superior mesenteric artery branches (arrowhead), which form the pancreaticoduodenal arcade. **(b)** Axial maximum intensity projection image shows the splenic artery branches (arrows) supplying the pancreatic tail.

CT Protocol, Indications, and Limitations

Teaching Point

CT is the modality of choice for imaging the postoperative pancreas. CT is more readily available, is faster, and is more practical for debilitated patients. In addition, calcifications and gas in the biliary tree are less prone to technical and interpretive errors at CT than at magnetic resonance (MR) imaging.

At our institution, multidetector CT is performed, beginning approximately 1 hour after oral administration of 750 mL of a solution of a water-soluble positive contrast material (diatrizoate meglumine [Reliev 60%; BerliMed SA, Madrid, Spain], 50 mL diluted in 1500 mL of water), with an additional 250 mL of contrast material administered in the examination room. Oral administration of a positive contrast material helps differentiate fluid collections from bowel loops and also aids in the detection of fistulas. If bowel ischemia is suspected, however, a neutral contrast material (water) can be administered orally to the patient.

The CT scanning protocol consists of an examination of the upper portion of the abdomen before contrast material injection (unenhanced phase); this unenhanced examination helps in the detection of calcification and possible hemorrhage. After the mechanical injection of 130–150 mL of contrast material (iobitridol [Henetix 300; Guerbet, Rio de Janeiro, Brazil], 300 mg

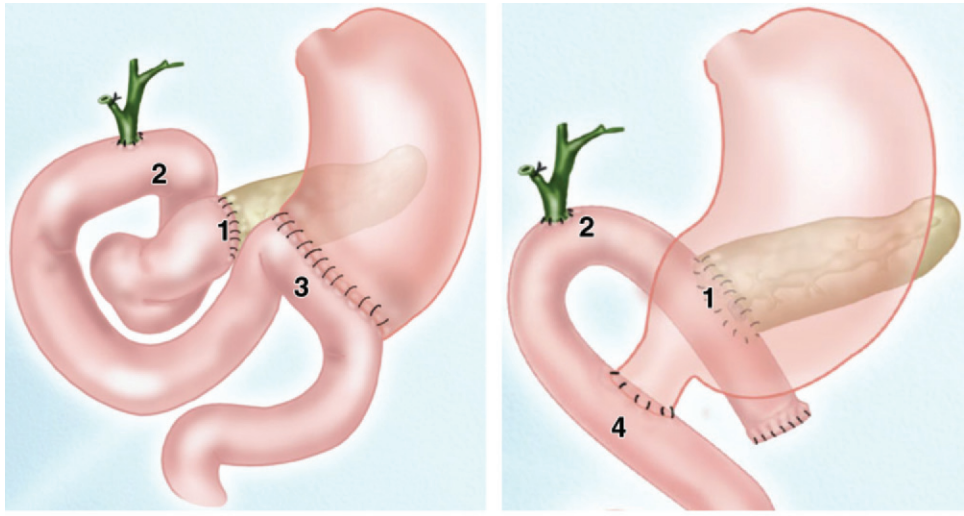


Figure 3. Pancreatoduodenectomy (Whipple procedure). Drawings show that the pancreatic head and the duodenum have been resected, resulting in pancreaticojejunostomy *(1)*, hepaticojejunostomy *(2)*, and either gastrojejunostomy or duodenojejunostomy. **(a)** Drawing of pancreatoduodenectomy with gastrojejunostomy *(3)*. **(b)** Drawing of pancreatoduodenectomy with duodenojejunostomy *(4)*, which is used when the pylorus is preserved. (Images courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

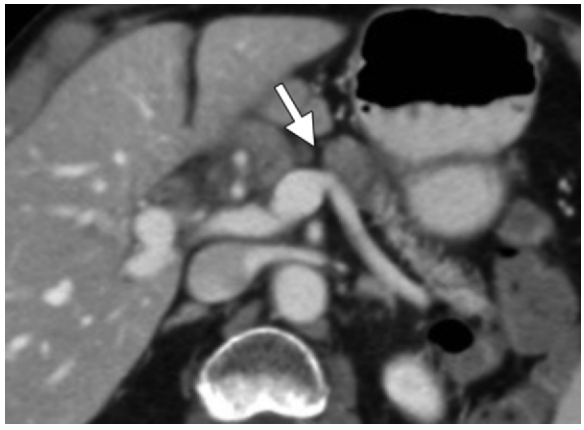


Figure 4. Normal postoperative findings after a pancreatoduodenectomy. Axial multidetector CT image obtained in the portal venous phase shows that the splenomesenteric venous junction lies to the right of and posterior to the resection margin of the pancreatic remnant (arrow).

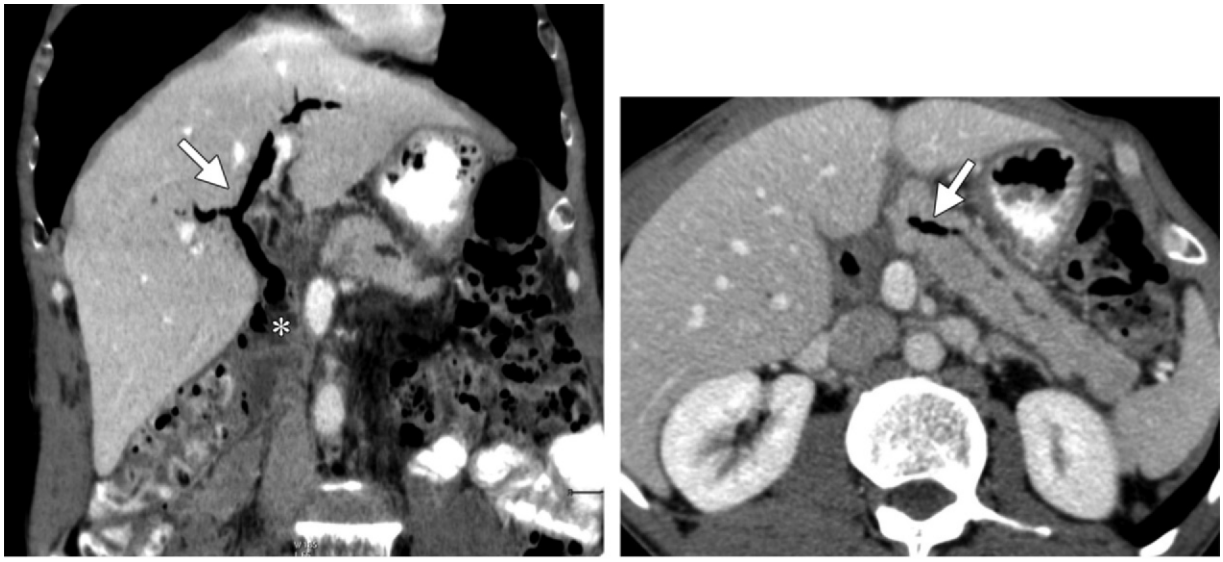
of iodine per milliliter), at a rate of 3.0 mL/sec, and after detection of the contrast material in the abdominal aorta, scanning consists of contrast-enhanced pancreatic (contrast material bolus tracking with a threshold of 150 HU and a delay of 15 seconds) and venous (delay of 40 seconds) phases. The pancreatic phase (delayed arterial phase) is crucial in the determination of vascular complications and for better depiction of the pancreatic parenchyma, and the portal venous phase helps characterize metastases to the liver and fluid collections. Reformatted sagittal and coronal views (3 × 3 mm) are also sent to the picture archiving and communication system (PACS). In addition, multiplanar reformatted images and maximum intensity projection images are helpful for evaluating vascular invasion and the resectability of pancreatic carcinoma, as well as vascular complications. If pneumobilia is present, reformatted coronal views with minimum intensity projection may help determine the site of biliary anastomosis.

Resection Procedures

Pancreatoduodenectomy

Teaching Point

Pancreatoduodenectomy, also known as the Whipple procedure, consists of resection of the pancreatic head, the duodenum, a short segment of the jejunum, and the gastric antrum, followed by *(a)* pancreaticojejunostomy, *(b)* hepaticojejunostomy, and *(c)* gastrojejunostomy or duodenojejunostomy (Fig 3).



a. b.

Figure 5. Normal postoperative findings after a pancreatoduodenectomy. **(a)** Coronal multidetector CT image obtained in the portal venous phase shows pneumobilia (arrow), which is often useful in identifying the biliary anastomosis (*). **(b)** Axial multidetector CT image obtained in the portal venous phase shows air (arrow) in the main pancreatic duct, which is also an expected finding.

Indications.—The major indications for pancreatoduodenectomy are periampullary neoplasms, including duodenal tumor, distal cholangiocarcinoma, and carcinomas of the pancreatic head and papilla of Vater (10). The procedure is also indicated for pancreatic head trauma and selected cases of chronic pancreatitis with predominant involvement of the cephalic region, essentially those cases in which it is not possible to differentiate an inflammatory mass from a tumor.

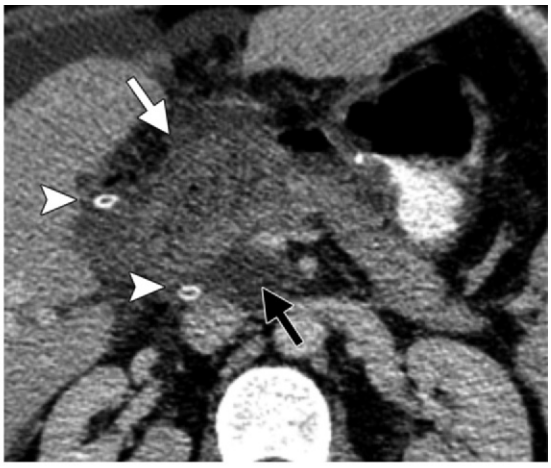
Advantages and Disadvantages.—Pancreatoduodenectomy is the only curative option for resection of pancreatic head lesions and carcinomas of the periampullary region. Pylorus-preserving pancreatoduodenectomy has been shown to lead to long-term improvements in gastrointestinal function. However, this procedure is frequently accompanied by delayed gastric emptying during the early postoperative period (11). Because of its high morbidity, some surgeons no longer consider this procedure to be the most appropriate surgery for patients with chronic pancreatitis.

Normal Postoperative Anatomy.—The normal postoperative anatomic findings consist of the surgical anastomoses of gastrojejunostomy, hepaticojejunostomy, and pancreaticojejunostomy. When possible, a pylorus-sparing procedure is performed, which creates a duodenojejunostomy instead of a gastrojejunostomy (12). After the resection of the pancreatic head, the superior mesenteric vein and splenomesenteric venous junction lie to the right of the pancreatic remnant and more posteriorly, closer to the inferior vena cava (Fig 4).

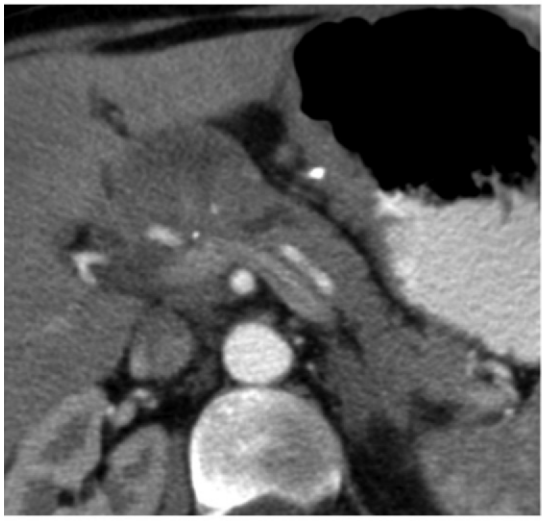
Multidetector CT Findings.—The most common postoperative finding is pneumobilia, which is useful in identifying the hepaticojejunostomy (13). Air may also be depicted in the main pancreatic duct as a normal postoperative finding (Fig 5).

Reactive adenopathy consists of small lymph nodes (short axis < 1 cm). This reactive adenopathy should regress at follow-up imaging (14).

Appreciable edema is often observed at the gastrojejunostomy or duodenojejunostomy and usually regresses at follow-up examinations (Fig 6). Good gastric distention before the examination may help in identifying the anastomoses, which lie to the right of the gastric remnant.



a.



b.

c.

Figure 6. Normal postoperative findings after a Whipple procedure performed for a pancreatic head adenocarcinoma. **(a)** Axial multidetector CT image through the surgical bed in the early postoperative period shows a thick and edematous loop (white arrow), which is an expected finding. Fluid collections (black arrow) and catheters (arrowheads) are also depicted. **(b)** Follow-up axial multidetector CT image obtained 3 months later still shows some edema of the pancreaticojejunostomy loop, which should not be mistaken for tumor recurrence or an abscess. The folds of the jejunal loop help in this differentiation. **(c)** Axial multidetector CT image obtained 6 months after the image in **b** shows resolution of these changes.

The pancreaticojejunostomy is located anterior to the superior mesenteric artery, near the level of the splenic vein. This anastomosis is often difficult to identify when the remnant gland is atrophic.

Most patients who undergo a Whipple procedure receive adjuvant chemotherapy and radiation therapy, which can result in thickening of the gastric antrum or gastrojejunostomy, fatty infiltration of the liver, and stranding of the mesenteric fat within the radiation treatment field.

Pitfalls.—Perivascular cuffing, which manifests as soft-tissue stranding in the mesenteric fat, can occur within the surgical bed and surrounding the celiac axis and the superior mesenteric and hepatic arteries. This cuffing is likely inflammatory in patients with negative surgical margins and should not be mistaken for local recurrence. Follow-up images are essential to distinguish perivascular cuffing from local recurrence.

The presence of unopacified anastomotic bowel loops in the porta hepatis can also be mistaken for local recurrence, lymphadenopathy, or fluid collections (Fig 7). The use of multiplanar reconstructions and the identification of the valvulae conniventes help in making this distinction (15).

Transient fluid collections often occur during the early postoperative period (first 2 weeks), usually in the surgical bed and at the sites of anastomoses (16). The presence of air bubbles in these collections does not necessarily indicate infection but should raise concern about pancreatic fistulas (17–19).

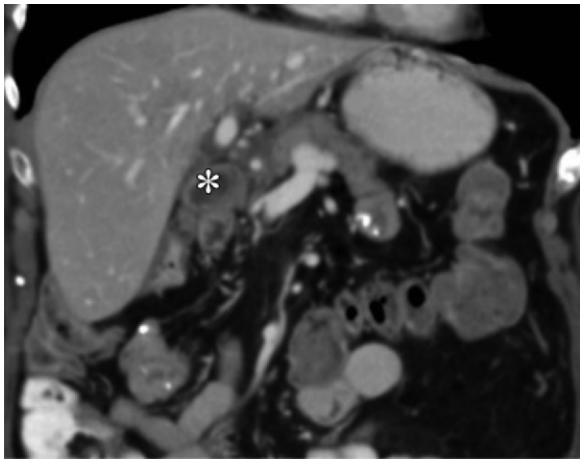
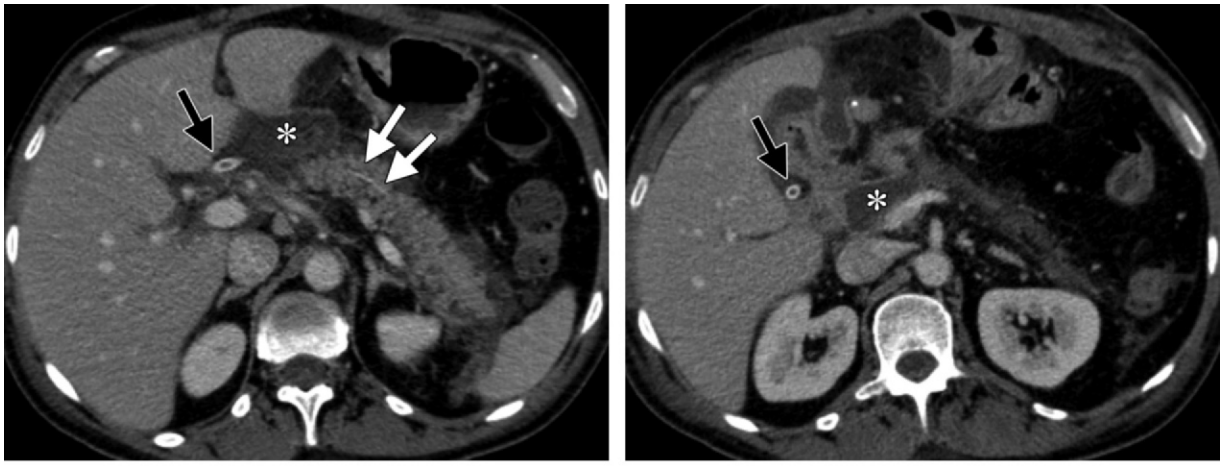


Figure 7. Pancreatoduodenectomy. Coronal reformatted multidetector CT image shows that jejunal loops (*) may fill the porta hepatis and the pancreatic bed and may simulate local recurrence, adenopathy, or fluid collections when not filled with oral contrast material.



a. **b.**

Figure 8. Acute pancreatitis after a recent pancreatoduodenectomy. Axial multidetector CT images obtained at the level of the pancreatic body **(a)** and slightly more caudad through the surgical bed **(b)** show peripancreatic fluid (*) and fat stranding. A drain (black arrow) is located near the anastomosis, and a pancreatic duct stent (white arrows in **a**) is depicted inside the main pancreatic duct. This stent may be used for draining the pancreaticojejunostomy to avoid obstruction when there is no pronounced dilatation of the main pancreatic duct.

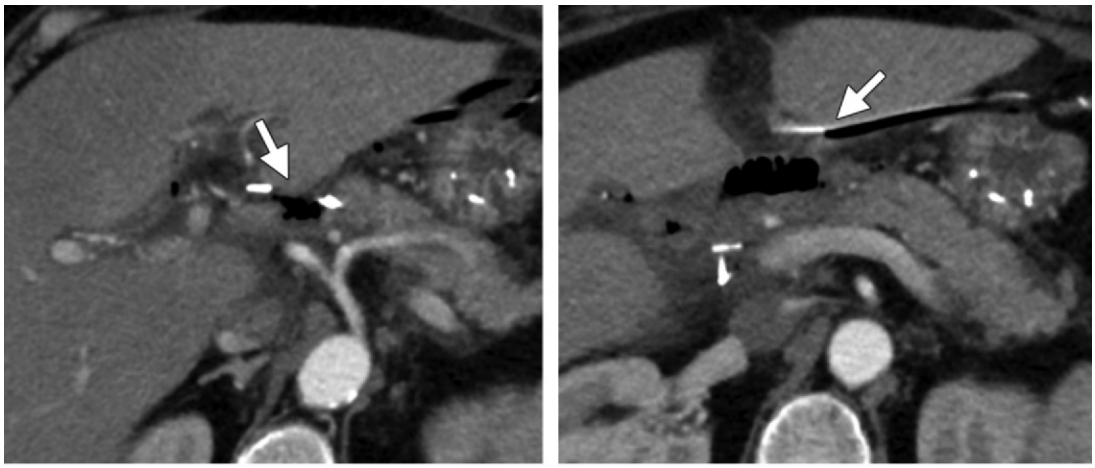
Complications.—Delayed gastric emptying is the most frequent complication after pylorus-preserving pancreatoduodenectomy, occurring in as many as 50% of patients during the early postoperative course (11). Gastric outlet obstruction, manifesting as a distended stomach with narrowing of the gastric outlet, may also occur but is found infrequently.

Although rare, the afferent loop syndrome has been reported after the Whipple procedure (20), similar to its occurrence after Billroth II reconstruction for gastric surgeries (21). Intravenous administration of biliary contrast material has been shown to be effective for better evaluation of the afferent loop (biliopancreatic limb) (22).

Teaching Point

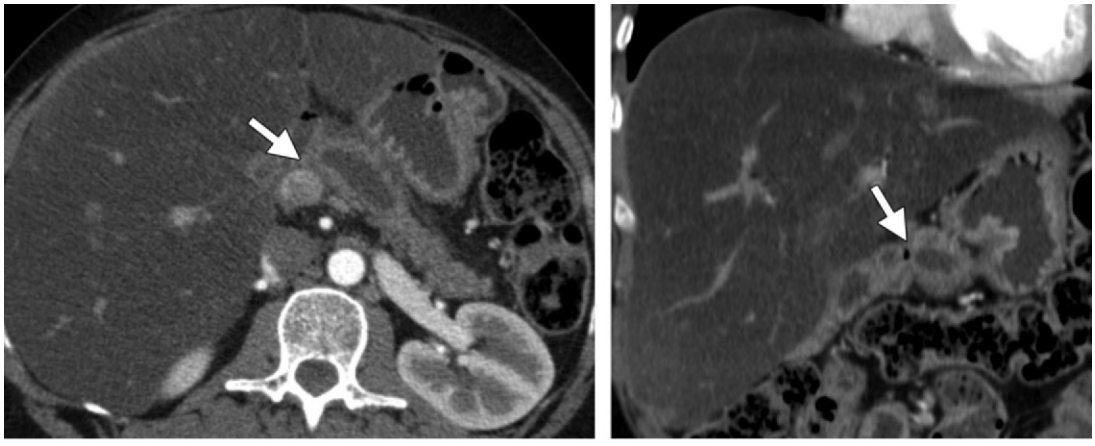
Besides delayed gastric emptying, the most common complications of the Whipple procedure are pancreatic fistulas (17%), wound infection (9%–10%), abdominal abscess, intraabdominal bleeding, and anastomotic leakage, leading to peritonitis and pancreatitis of the remnant gland (Fig 8).

A pancreaticojejunal fistula is diagnosed clinically on the basis of the detection of amylase-rich fluid in the drainage from the surgical bed after the 10th postoperative day (Fig 9). Surgery is not necessarily required for treatment.



a. b.

Figure 9. Early postoperative findings after a Whipple procedure. **(a)** Axial multidetector CT image shows gas (arrow) near the pancreaticojejunal anastomosis, a finding that raised concern about a fistula. **(b)** Axial multidetector CT image (more caudad than image in **a)** shows an amylase-rich fluid in the surgical bed drain (arrow), a finding that helped confirm a fistula.



a. b.

Figure 10. Late postoperative findings 1 year after a Whipple procedure performed for a Frantz tumor in the pancreatic head. Axial **(a)** and coronal **(b)** multidetector CT images obtained in the pancreatic phase (delayed arterial phase) show dilatation of the main pancreatic duct and a stricture in the pancreaticojejunostomy (arrow).

Anastomotic leaks usually occur at the pancreaticojejunal anastomosis during the early postoperative period (first 2 weeks) after pancreatoduodenectomy. These leaks can be diagnosed on the basis of the presence of oral contrast material in the peritoneal cavity and are associated with peripancreatic fluid collections.

Stenosis of a pancreaticojejunostomy is another cause of pancreatitis and is often a late complication (Fig 10). Vascular complications are relatively uncommon and include hepatic artery injury, portal vein thrombosis, aneurysms, and splenic infarction (Fig 11).

Biliary stricture formation is an infrequent complication (<3% of cases), usually developing 1 year after surgery, and can be managed successfully in most patients by performing percutaneous biliary dilation and inserting a short-term stent. Biliary strictures in patients who have undergone a Whipple procedure for malignant disease are usually benign and should not be automatically attributed to anastomotic tumor recurrence (23).

Locally recurrent disease is sometimes difficult to depict on the earliest postoperative images. Locally recurrent disease appears as an infiltrating mass that exhibits soft-tissue attenuation in the surgical bed, with perineural invasion and encasement of the mesenteric vessels (24). Follow-up examinations with CT and with dual-modality imaging with the combination of positron emission tomography (PET) and CT (PET/CT) can help differentiate postoperative inflammatory changes from local recurrences (Figs 12, 13).

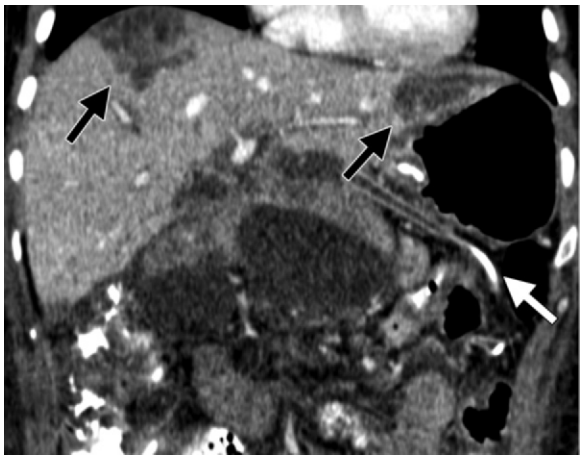
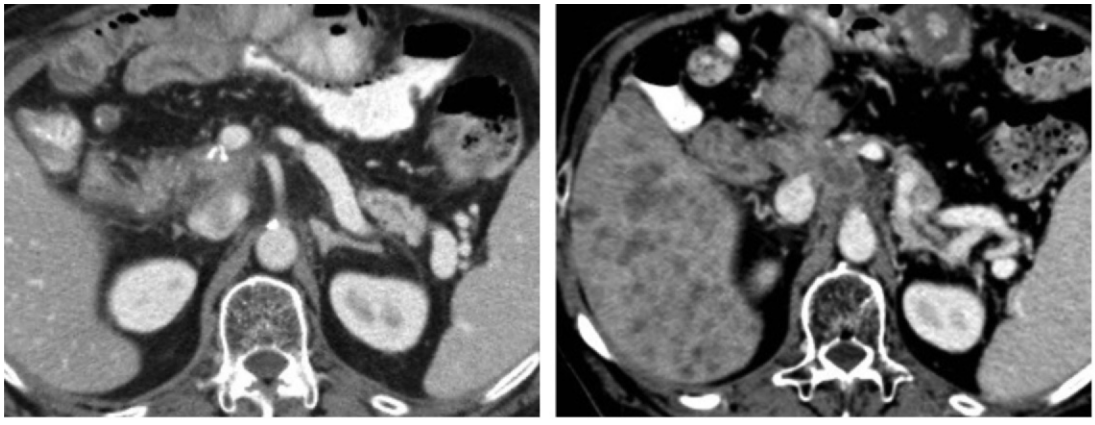
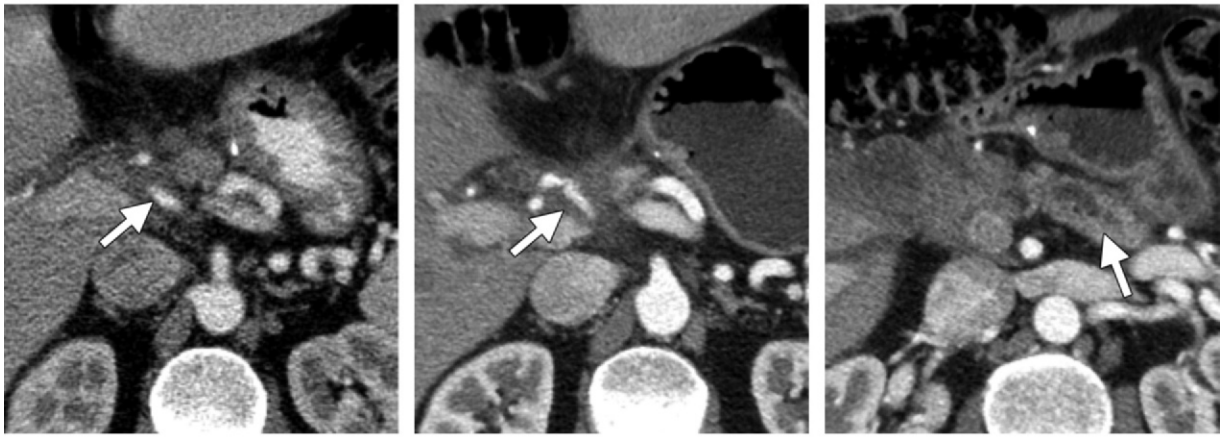


Figure 11. Hepatic artery injury after a pancreatoduodenectomy. Coronal reformatted multidetector CT image obtained in the early postoperative period shows multiple areas of hepatic infarction (black arrows) after hepatic artery injury and also shows drainage tubes (white arrow).

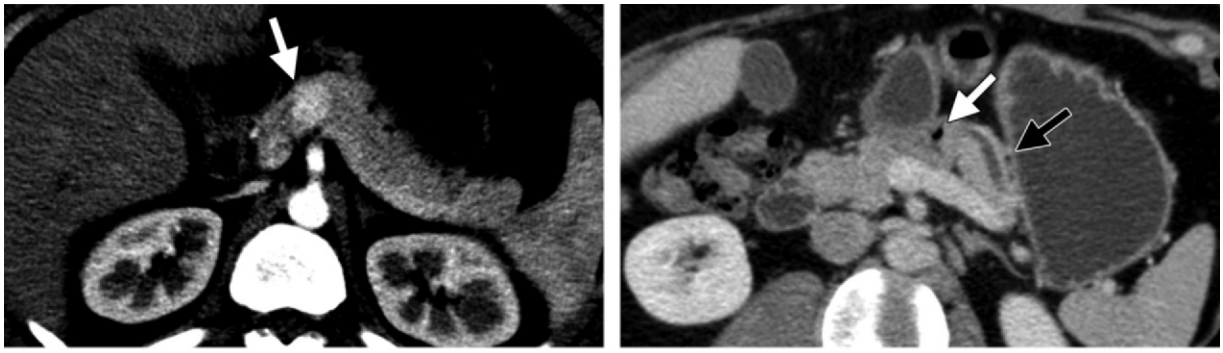


12a. 12b.



13a. 13b. 13c.

Figures 12, 13. **(12)** Locally recurrent disease after a Whipple procedure performed for a pancreatic head adenocarcinoma. **(a)** Axial multidetector CT image obtained in the early postoperative period shows stranding in the surgical bed, which could be an expected finding but is indistinguishable from tumor recurrence. **(b)** Follow-up axial multidetector CT image shows encasement of the mesenteric vessels and multiple hepatic metastases, findings that indicate tumor progression. **(13)** Local tumor recurrence after a pancreatoduodenectomy. **(a)** Axial multidetector CT image obtained in the early postoperative period, 3 months after resection of a pancreatic head adenocarcinoma, shows perivascular cuffing around the hepatic artery (arrow), which could be a normal postoperative finding. **(b, c)** Axial pancreatic phase multidetector CT images obtained 8 months later (**c** more caudad than **b**) show progression of the soft-tissue stranding encasing the hepatic artery (arrow in **b**), a finding that indicates local tumor recurrence. Note the dilatation of the main pancreatic duct (arrow in **c**).



a. b.

c.

Figure 14. Central pancreatectomy. **(a)** Preoperative axial multidetector CT image shows a hypervascular nodule (arrow) in the pancreatic neck. The findings at histopathologic examination helped confirmed that the nodule was a neuroendocrine tumor. **(b, c)** Postoperative axial oblique **(b)** and coronal oblique **(c)** reformatted multidetector CT images show the normal postoperative findings: the jejunal loop (white arrow) and the pancreatic tail (black arrow).

Central Pancreatectomy

This procedure consists of resection of part of the neck or body of the pancreas, followed by a Roux-en-Y pancreaticojejunostomy to the distal pancreatic remnant. The distal pancreatic end can also be anastomosed to the stomach. The proximal cut edge is sutured.

Indications.—Central pancreatectomy has been performed primarily in patients with traumatic pancreatic transection and intractable chronic pancreatitis. Currently, central pancreatectomy has also been proposed for selective management of pancreatic neck lesions that are benign or have low malignant potential. Indications include neuroendocrine tumors, cystic neoplasias (serous and mucinous cystadenomas), true epithelial cysts, Frantz tumor, and intraductal papillary mucinous neoplasms (25,26).

Advantages and Disadvantages.—Preservation of pancreatic parenchyma appears to have functional advantages. Such preservation is associated with fewer major complications and better maintains the endocrine and exocrine functions of the pancreas without substantially increasing postoperative morbidity, compared with the more commonly performed pancreatoduodenectomy.

Normal Postoperative Anatomy.—The Roux-en-Y bowel stands at the level of the splenomesenteric venous junction, separating the head of the pancreas from the body and tail (Fig 14).

Multidetector CT Findings.—Frequent postoperative findings include stranding of the peripancreatic fat and minimal fluid collection. Mild enlargement of the pancreas is another normal postoperative finding.

Pitfalls.—The bowel of the pancreaticojejunostomy may be mistaken for tumor recurrence when not filled with contrast material.

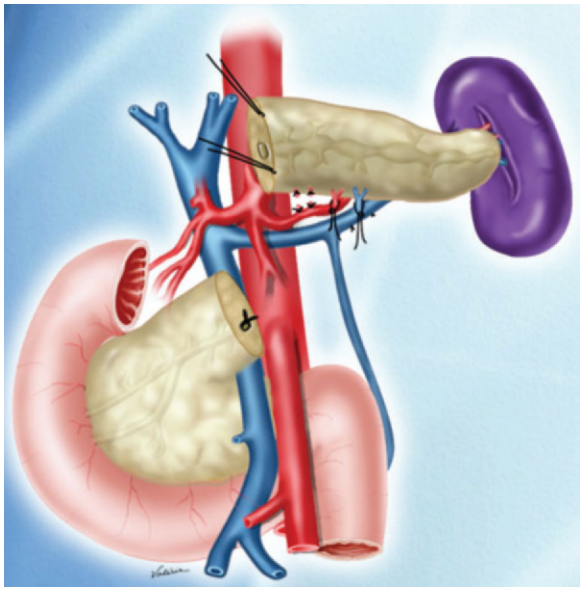


Figure 15. Distal pancreatectomy. Drawing shows that the cut edge is sutured to prevent leakage of pancreatic juice, and splenectomy is often performed. (Image courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

Complications.—The most common complication of central pancreatectomy is pancreatic anastomotic leakage, which usually does not require reoperation. Other complications include hemorrhage, acute pancreatitis, and intraabdominal fluid collection. Stenosis of the pancreaticojejunostomy is a rare and late complication and can lead to atrophy of the distal pancreatic remnant.

Distal Pancreatectomy

The distal portion of the pancreas is resected, usually at or to the left of the superior mesenteric vein, and the cut edge is sutured to prevent leakage of pancreatic juice. Because the blood supplying the pancreatic tail comes primarily from branches of the splenic artery, splenectomy may be necessary when distal pancreatectomy is performed (Fig 15).

Indications.—Distal pancreatectomy is performed when a tumor is located in the body or tail of the pancreas. Indications include focal chronic pancreatitis, cystic neoplasia (serous cystadenoma and mucinous cystic neoplasia), pancreatic adenocarcinoma, and neuroendocrine tumor (27).

Advantages and Disadvantages.—Splenic preservation eliminates any infective and hematologic effects. However, it is associated with a longer postoperative stay. As with pancreatoduodenectomy, distal pancreatectomy can be performed with minimal perioperative mortality and acceptable morbidity.

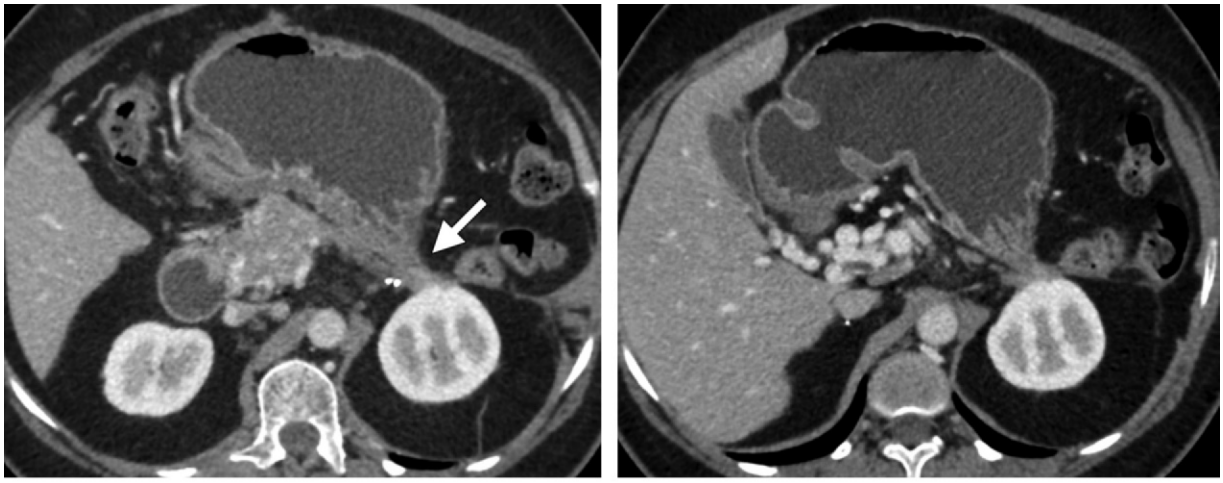
Normal Postoperative Anatomy.—Because there are no anastomoses, postoperative imaging evaluation is easier: The pancreas ends in an abrupt fashion, indicating the cut-edge point, and the surgical bed should not contain any bowel loop related to the stomach, duodenum, or pancreas.

Multidetector CT Findings.—The most common finding is transient fluid collections, which usually have resolved at follow-up examinations. Air should not be seen in the biliary tree because there are no biliary anastomoses.

Pitfalls.—As in the Whipple procedure, transient fluid collections may make it more difficult to evaluate pancreatic fistulas, and the latter cannot be diagnosed reliably with CT. A clinical diagnosis of pancreatic fistula is made when there is prolonged or elevated output of amylase-rich fluid through an intraoperatively placed drain.

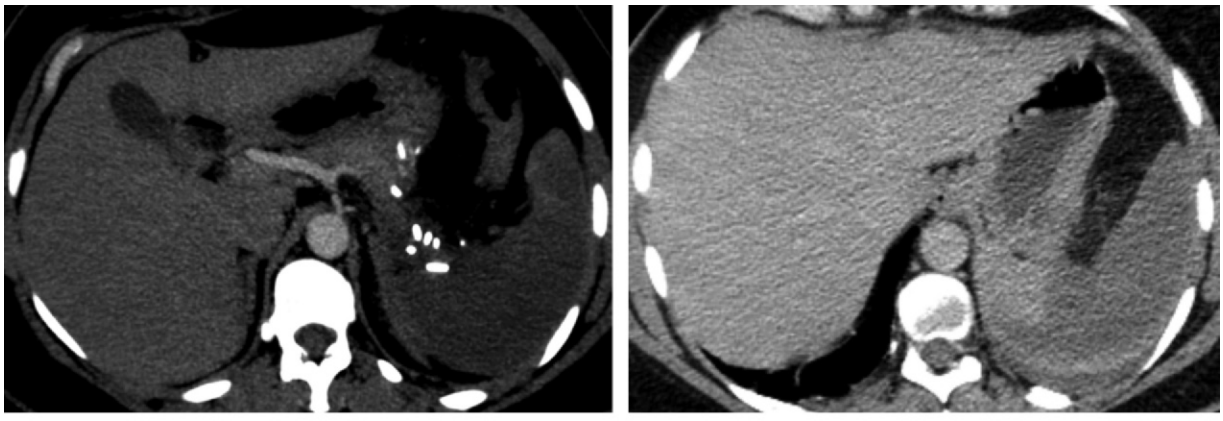
Teaching Point

Complications.—The most common complications of distal pancreatectomy are the new onset of insulin-dependent diabetes (8%), pancreatic fistula (5%), intraabdominal abscess (4%), small bowel obstruction (4%), and postoperative hemorrhage (4%) (27). Vascular complications usually represent extensions of splenic vein thrombosis to the main portal vein (Fig 16). When the spleen is preserved, infarction may occur because of injury to the splenic artery (Fig 17).



a. b.

Figure 16. Portal vein thrombosis after a caudal pancreatectomy and splenectomy. **(a)** Axial multidetector CT image obtained in the portal venous phase (more caudad than image in **b**) shows adhesions in the surgical bed, which involve the gastric fundus and the Gerota fascia (arrow). **(b)** Axial multidetector CT image obtained in the portal venous phase shows multiple collateral vessels in the hepatic hilum, a finding that indicates portal vein thrombosis with cavernous transformation.



a. b.

Figure 17. Splenic infarction complicating a caudal pancreatectomy with splenic preservation. Axial multidetector CT images obtained in the pancreatic phase (delayed arterial phase) **(a)** and the portal venous phase **(b)** show hypoperfusion and infarction of the splenic parenchyma.

Total Pancreatectomy

Also known as the double Whipple procedure, total pancreatectomy consists of the removal of the entire pancreas and removal of the spleen, portions of the duodenum, the common bile duct, and the gallbladder.

Indications.—Total pancreatectomy is indicated for emergency situations and a limited range of elective procedures. Emergency indications are related to perioperative complications after pancreatic resections. Elective indications include patients with pancreatic diseases involving the whole gland, such as familial pancreatic cancer, intraductal pancreatic mucinous neoplasm, neuroendocrine tumors, and pancreatic metastases (28,29). Total pancreatectomy may also be end-stage therapy for some patients with chronic pancreatitis that is not responsive to less-aggressive surgical techniques.

Advantages and Disadvantages.—After total pancreatectomy, endocrine-metabolic and digestive sequelae are more severe because patients develop total endocrine and exocrine insufficiency of the pancreas. When total pancreatectomy is

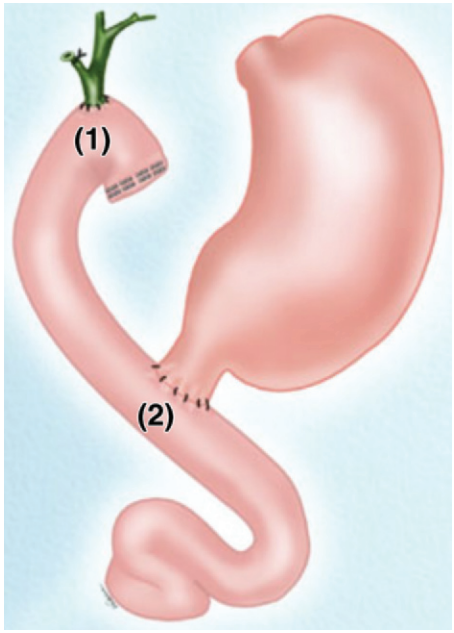


Figure 18. Total pancreatectomy. Drawing shows that the entire pancreas, the spleen, and portions of the duodenum are removed. The distal common bile duct and the gallbladder are also removed, which results in two anastomoses: a hepaticojejunostomy *(1)* and a duodenojejunostomy *(2)*. (Image courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

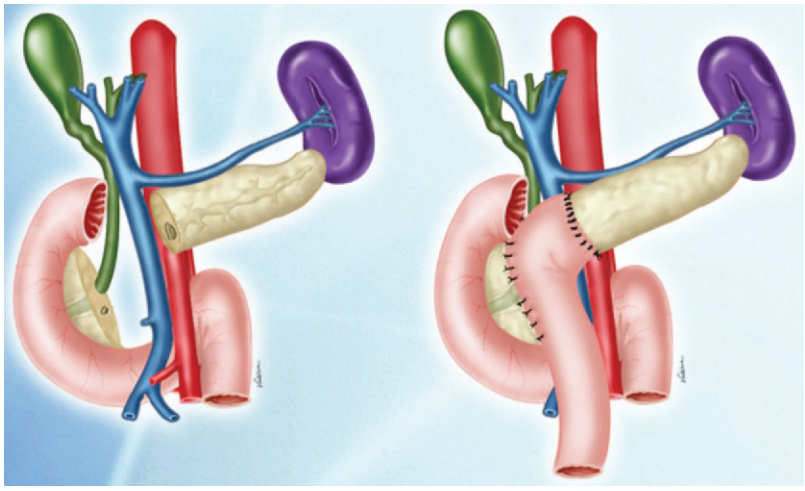


Figure 19. Beger procedure. Drawings show resection of the pancreatic neck and excavation of the pancreatic head, with sparing of the duodenum, the intrapancreatic common bile duct, and the inferior portion of the uncinate process. (Images courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

secondary to perioperative complications (trouble or technical difficulties) after other pancreatic resection procedures, total pancreatectomy is accompanied by extremely high morbidity and mortality rates.

Normal Postoperative Anatomy.—Total pancreatectomy results in two anastomoses: one for the biliary tree (hepaticojejunostomy) and the other for the gastric transit (duodenojejunostomy) (Fig 18).

Multidetector CT Findings.—As in the Whipple procedure, edema may be depicted at the duodenojejunostomy. Good gastric distention before the examination is helpful in identifying the anastomoses, which lie to the right of the gastric remnant. Transient fluid collections can also occur.

Pitfalls.—The bowel from the hepaticojejunostomy can mimic an abscess or local recurrence when not filled with contrast material.

Complications.—Complications of total pancreatectomy are similar to those after pancreatoduodenectomy and may include abscess, hemorrhage, delayed gastric emptying, and biliary stricture.

Beger Procedure

The Beger procedure is a less-radical surgical procedure consisting of the excavation or removal of the pancreatic head while sparing the duodenum, the intrapancreatic common bile duct, and the inferior uncinate process. The Beger procedure has also been described as a duodenum-preserving pancreatic head resection (Fig 19).

Indications.—This alternative procedure may be performed in patients with alcoholic chronic pancreatitis who have untreatable pain or an inflammatory mass in the pancreatic head. The Beger procedure has also been proposed for selective management of pancreatic head lesions that have low malignant potential.

Advantages and Disadvantages.—The main advantages of the Beger procedure are its ability to treat complications related to the inflammatory process in the head of the pancreas, relieving pain and preserving the bilioduodenal anatomy. The Beger procedure results in a change in the natural course of the disease, including pain status, the frequency of acute episodes, the need for further hospital admission, late death, and the quality of life (30).

Normal Postoperative Anatomy.—After the resection of the pancreatic head, a pancreaticojejunostomy is performed at two sites of the Roux-en-Y limb. A sleeve of the pancreas remains with the duodenum to preserve the blood supply of the latter.

Multidetector CT Findings.—The Roux-en-Y limb appears as a loop of small bowel between the pancreatic tail and a thin shell of the pancreatic head. This loop usually shows wall thickening, a common early postoperative finding. The duodenum is spared in its normal location in the lateral aspect of the pancreatic head, and oral contrast material should help in its identification. Air in the main pancreatic duct and air in the common bile duct are normal findings.

Pitfalls.—Transient fluid collections are frequently observed soon after surgery and should not be mistaken for abscesses or fistulas.

Complications.—Transient delayed gastric emptying is a common complication of the Beger procedure and is usually caused by edema of the anastomosis. A nasogastric tube is often placed in the first postoperative days.

Because the duodenal blood supply arises from the pancreaticoduodenal arteries, complete resection of the pancreatic head while preserving the common bile duct and the duodenum sometimes causes necrosis of the latter two structures that is due to ischemia. Although edema can lead to minimal dilatation of the common bile duct during the early postoperative period, prolonged dilatation associated with increasing serum bilirubin concentrations should raise concerns about ischemic injury.

Other complications include pancreatic fistulas, wound infection, intraabdominal bleeding, leakage at the anastomosis, and pancreatitis of the remnant gland, complications that are similar to those of pancreatoduodenectomy.

Drainage Procedures

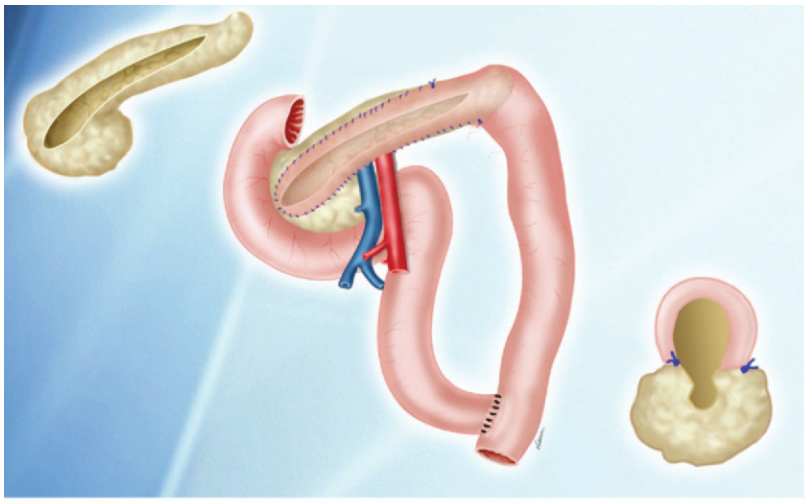
Puestow Procedure

Puestow and Gillesby (31) first described a longitudinal pancreaticojejunostomy combined with caudal pancreatectomy in 1958, which was further modified by Partington and Rochelle (32) in 1960 to involve longitudinal pancreaticojejunostomy without caudal pancreatectomy. The dilated pancreatic duct is longitudinally opened from the uncinate process to the tail, ductal calculi are removed, and the pancreatic duct is directly anastomosed to a similarly longitudinally opened Roux-en-Y loop of the jejunum, creating a side-to-side longitudinal pancreaticojejunostomy (Fig 20).

Teaching Point

Indications.—In patients with chronic pancreatitis, the primary indication for surgical drainage of the pancreatic duct is the relief of incapacitating abdominal pain that cannot be managed with medical therapy. This procedure is best suited to patients with diffuse pancreatic duct dilatation who have duct diameters greater than 6 mm, involving mostly the body and tail of the pancreas, with relative preservation of the head of the pancreas and an absence of biliary duct dilatation (33,34).

Advantages and Disadvantages.—Surgical drainage of the pancreatic duct has been shown to provide pain relief, weight gain, and a better quality of life. The main advantage of the lateral pancreaticojejunostomy compared with resectional procedures is the preservation of the pancreatic parenchyma and consequent endocrine and exocrine pancreatic function. In patients with disease involving the pancreatic head who develop biliary stenosis, the Puestow procedure



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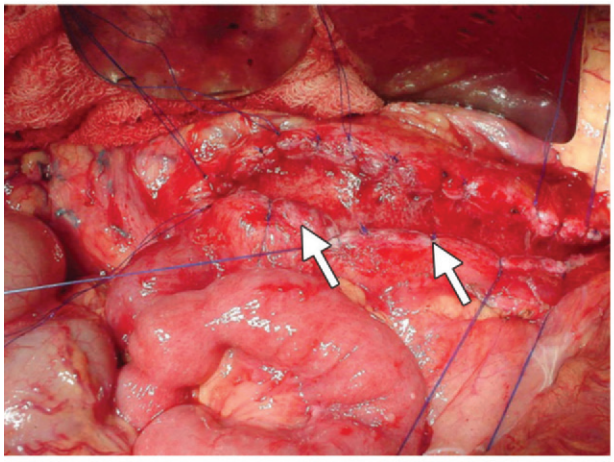

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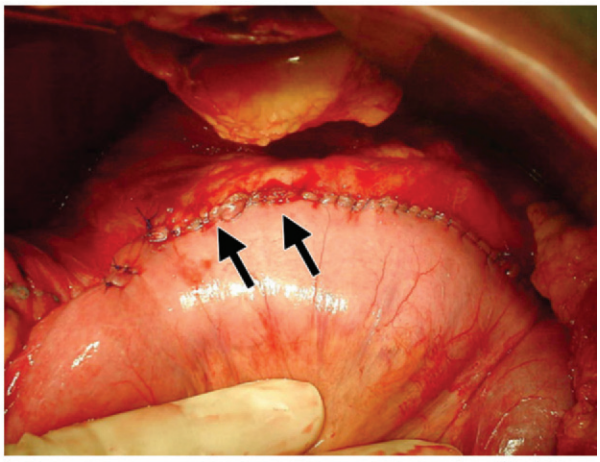


c.

Figure 20. Puestow procedure. **(a)** Drawings of a Puestow procedure show the longitudinally opened main pancreatic duct (left), the lateral pancreaticojejunostomy (center), and a cross-section of the lateral pancreaticojejunostomy (right). **(b)** Intraoperative image shows the main pancreatic duct longitudinally opened (arrows). **(c)** Later intraoperative image was obtained after the lateral pancreaticojejunostomy (arrows). (Fig 20a courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

is no longer a surgical option because there is no biliary approach.

Normal Postoperative Anatomy.—After the exposure of the main pancreatic duct and the removal of calculi, a side-to-side pancreaticojejunostomy is performed, draining the main and secondary pancreatic ducts into the jejunum over an 8–10-cm segment. The Roux-en-Y loop lies immediately anterior to the pancreatic body or tail.

Multidetector CT Findings.—The pancreaticojejunal anastomosis appears as a soft-tissue bulge anterior to the pancreas and, on sequential images, will become contiguous with the Roux-en-Y loop. The Roux-en-Y loop of the bowel has an appearance similar to that of the afferent loop after the Whipple procedure and may contain intraluminal gas, fluid, or oral contrast material. The Roux-en-Y loop can also collapse, making it difficult to distinguish the anastomosed loop from the adjacent jejunum (35).

Pneumobilia is an unexpected finding, except in patients who have undergone concomitant surgical anastomosis of the biliary system to the gastrointestinal tract.

Peripancreatic soft-tissue stranding, which results from postsurgical inflammation and edema, is also a common finding during the immediate postoperative period. Because the appearance of peripancreatic soft-tissue stranding is similar to that of acute pancreatitis, a clinical diagnosis is required.

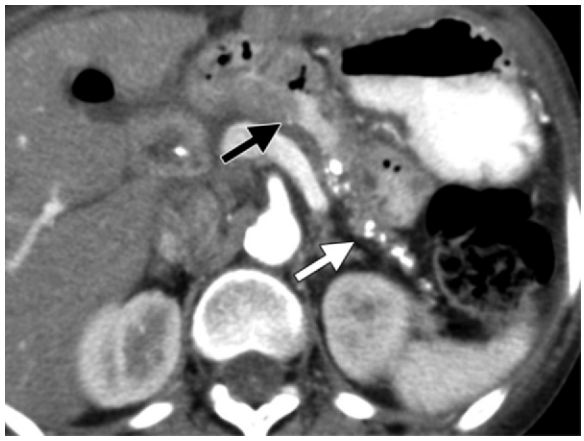


Figure 21. Chronic pancreatitis treated with the Puestow procedure. Axial multidetector CT image shows normal postoperative findings: The pancreaticojejunostomy loop (black arrow) is retrograde filled with oral contrast material. This finding should not be confused with an abscess or leakage of the anastomosis. Note the residual calculi (white arrow).

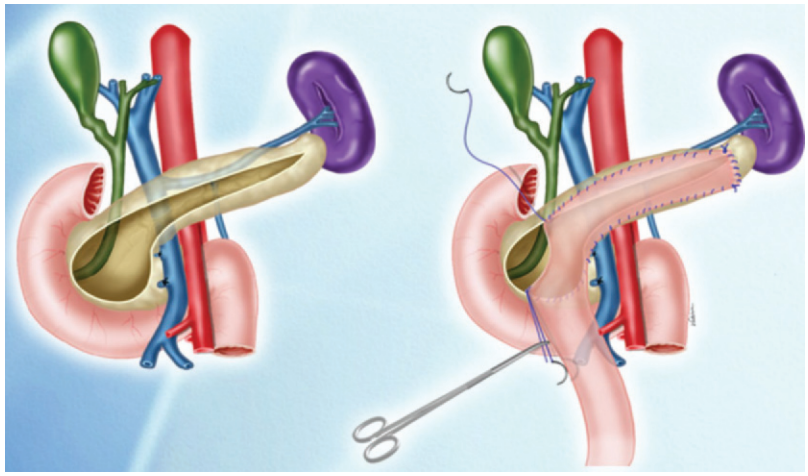


Figure 22. Frey procedure. Left: Drawing shows that initially the main pancreatic duct is exposed and the head is excavated, preserving a rim of pancreatic tissue and the biliary duct. Right: Drawing shows the next step, a longitudinal side-to-side pancreaticojejunostomy. (Images courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

Residual calculi can be depicted, essentially in the pancreatic head and uncinate process. Thus, unenhanced images are important for this diagnosis.

Transient fluid collections are a normal postoperative finding and presumably indicate seromas and small hematomas. Aspiration or drainage of these collections should be based on the clinical setting because it is difficult to determine with certainty the presence of infection by using imaging parameters alone (36).

Pitfalls.—Roux-en-Y loops containing fluid and gas may be mistaken for abscesses if the type of surgery performed is not known. Loops totally filled with fluid may also be mistaken for pseudocysts. The use of oral contrast material and changing the decubitus position, the characteristic location and course of the loop, and the presence of valvulae conniventes may help prevent this pitfall. Oral contrast material or gas in the pancreatic duct is an uncommon but expected finding and should not be mistaken for anastomotic leakage (Fig 21). In contrast, the absence of gas in the pancreatic duct does not imply obstruction of the anastomosis.

When a pancreaticojejunal anastomosis collapses, it may assume a rounded configuration, mimicking a tumor. Inflammatory masses in patients with chronic pancreatitis may be difficult to differentiate from pancreatic carcinoma clinically, radiologically, and histopathologically. Follow-up with CT or with PET/CT or even biopsy may be required to make the distinction.

Complications.—Transient fluid collections and hematomas are common early postoperative complications of the Puestow procedure. Other early

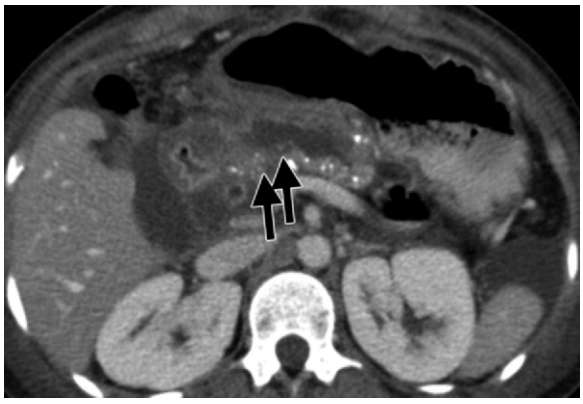


Figure 23. Pitfall after the Frey procedure. Axial multidetector CT image obtained in the early postoperative period shows that the afferent loop of bowel (arrows) that drains the pancreatic duct may be edematous during the first 3 weeks after surgery. This appearance may be mistaken for bowel ischemia, abscess, or hemorrhage.

complications include obstruction of the Roux-en-Y loop owing to adhesions and anastomotic breakdown. During the late postoperative period, patients may develop recurrent pancreatitis, pseudocysts, abscess, or pancreatic carcinoma.

Frey Procedure

This procedure consists of the excavation of the pancreatic head and opening the main pancreatic duct but preserving a rim of pancreatic tissue and the integrity of the biliary duct. This is followed by longitudinal opening of the pancreatic duct and pancreaticojejunostomy (Fig 22) (37).

Indications.—In patients in whom medical therapy has failed, the Frey procedure is the most effective method of reducing acute exacerbations and chronic symptoms of pancreatitis, especially untreatable pain. The Frey procedure is also considered the best option when chronic pancreatitis occurs predominantly in the head of the pancreas. In addition, when an underlying malignancy cannot be reliably excluded with imaging findings, the Frey procedure is a good surgical approach (38). At our institution, the Frey procedure is the most frequently performed technique in patients with chronic pancreatitis.

Advantages and Disadvantages.—The main benefits of the Frey procedure are pain relief, weight gain, and better preservation of the endocrine and exocrine status of the pancreas. The Frey procedure also improves decompression of the head of the pancreas, which is not achieved with standard longitudinal pancreaticojejunostomy, with morbidity rates markedly less than those of the Whipple procedure performed for chronic pancreatitis. The disadvantage of the Frey procedure is its inability to deal with duodenal and biliary strictures.

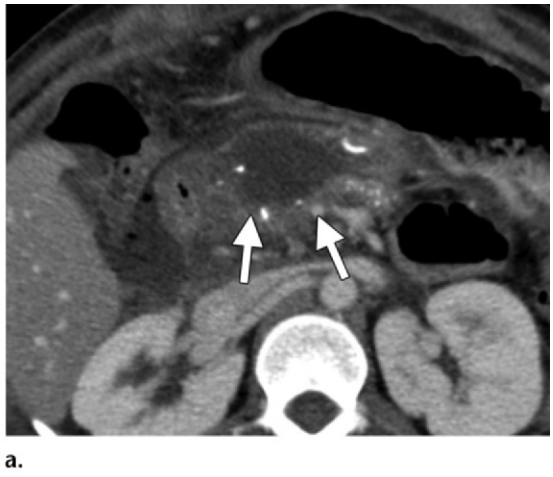
Normal Postoperative Anatomy.—Although the head of the pancreas is resected, the duodenum and the biliary duct remain intact. A longitudinal pancreaticojejunostomy is performed, similar to the Puestow procedure.

Multidetector CT Findings.—Gas can be seen in the main pancreatic duct and is useful in identifying the pancreaticojejunostomy. The Roux-en-Y loop lies immediately anterior to the body and tail of the pancreas; and, as in the Puestow procedure, the Roux-en-Y loop may collapse or contain intraluminal gas, fluid, or oral contrast material.

Pneumobilia, periportal edema, and peripancreatic soft-tissue stranding are normal findings during the early postoperative period. Transient fluid collections are often seen during the 1st month after pancreatic surgery and do not require drainage unless clinically indicated.

Pitfalls.—The afferent loop of the bowel that drains the pancreatic and biliary ducts may be edematous during the first 3 postoperative weeks after the Frey procedure (Fig 23). The afferent loop should not be mistaken for bowel ischemia or hemorrhage.

When the Roux-en-Y loop is filled with gas and fluid, it may be mistaken for an abscess. In these cases, oral contrast material and changing the decubitus position may help in the differentiation.



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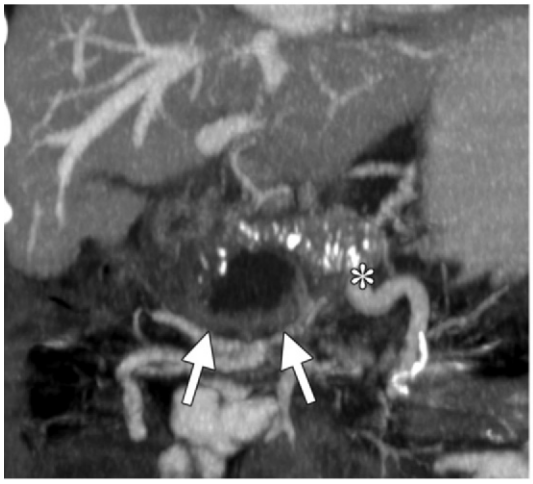

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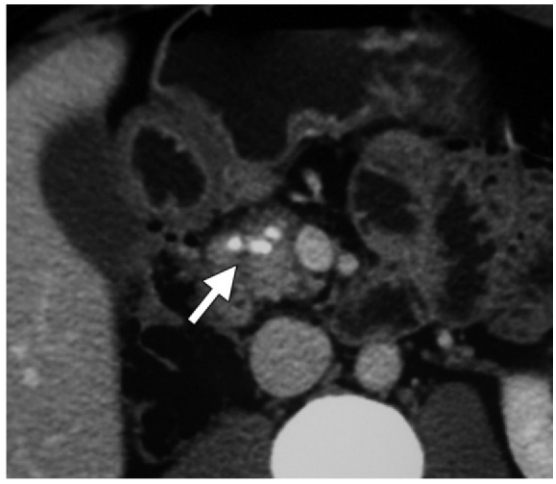


c.

Figure 24. Normal anatomic findings after the Frey procedure. **(a, b)** Axial **(a)** and coronal **(b)** multidetector CT images obtained in the early postoperative period show a large cavity (arrows) in the pancreatic head that corresponds to the area of excavation. Residual calculi (* in **b**) are also noted. **(c)** Follow-up axial multidetector CT image shows resolution of the cavity (arrow).

After the Frey procedure, a large cavity may be seen in the pancreatic head, corresponding to the area of excavation, and may be mistaken for a pseudocyst or cystic neoplasm. With time, the size of this cavity should decrease (Fig 24).

Complications.—Early complications of the Frey procedure that require surgery are mainly related to arterial bleeding from the splenic artery or from the stump of the gastroduodenal artery. Small gastroenteric fistulas to the Roux-en-Y limb are usually managed conservatively with a nasojejunal tube.

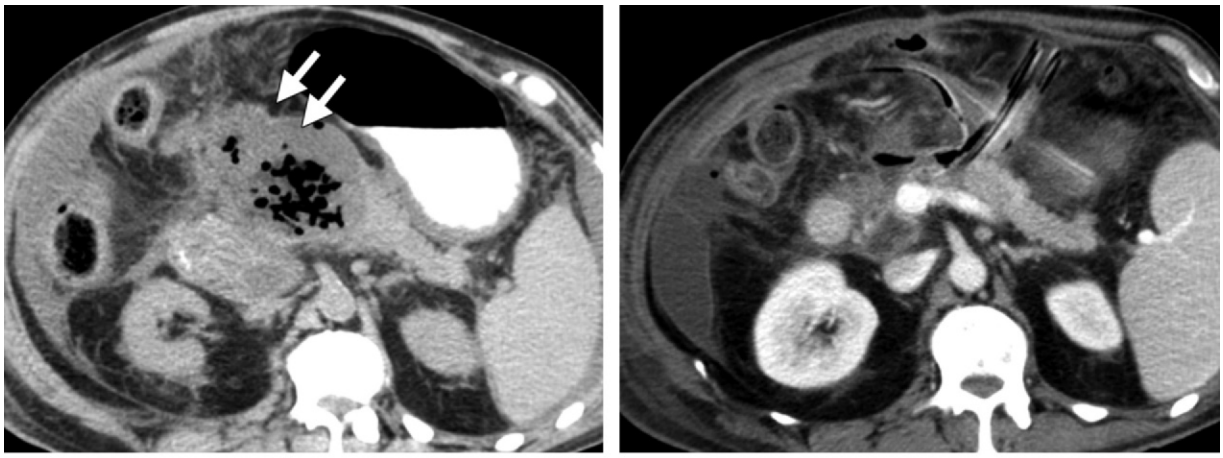
As in the Beger procedure, necrosis of the common bile duct or duodenum caused by ischemia may occur if the area of excavation of the pancreatic head is too large, resulting in a duodenal stricture or biliary dilatation.

Biliopancreatic limb obstruction is a rare late complication and should be differentiated from fluid collections. The presence of valvulae conniventes, the course of the obstructed fluid-filled loops of bowel, and the use of coronal reformatted images are helpful for this differentiation.

Miscellaneous Procedures

Necrosectomy and Abscess Drainage

Indications.—Because infected pancreatic necrosis is the major risk factor for morbidity and mortality in patients with severe acute pancreatitis, this necrosis is an indication for surgery or radiologic drainage in patients with clinical signs and symptoms of sepsis (39).



a. b.

Figure 25. Subacute pancreatitis with infected necrosis. **(a)** Preoperative axial multidetector CT image shows extensive pancreatic necrosis with mottled gas bubbles (arrows), which indicate infection. **(b)** Postoperative axial multidetector CT image obtained after pancreatic necrosectomy and abscess drainage shows minimal fat stranding and reduction of the fluid collections. Drainage catheters are depicted in the abscess bed.

Advantages and Disadvantages.—The main advantages of surgical necrosectomy and abscess drainage are *(a)* the removal of bacteria and necrotic material and *(b)* the emptying of vasoactive and toxic substances. However, because patients are seriously ill, surgical management is usually associated with elevated morbidity and mortality rates.

Multidetector CT Findings.—During the first 2 weeks after an acute attack of pancreatitis, the natural evolution of sterile fluid collections is unpredictable. Although not a sensitive radiologic sign, the evidence of gas bubbles in these fluids is highly specific for infection (Fig 25). An enteric fistula is part of the differential diagnosis for extraluminal gas bubbles.

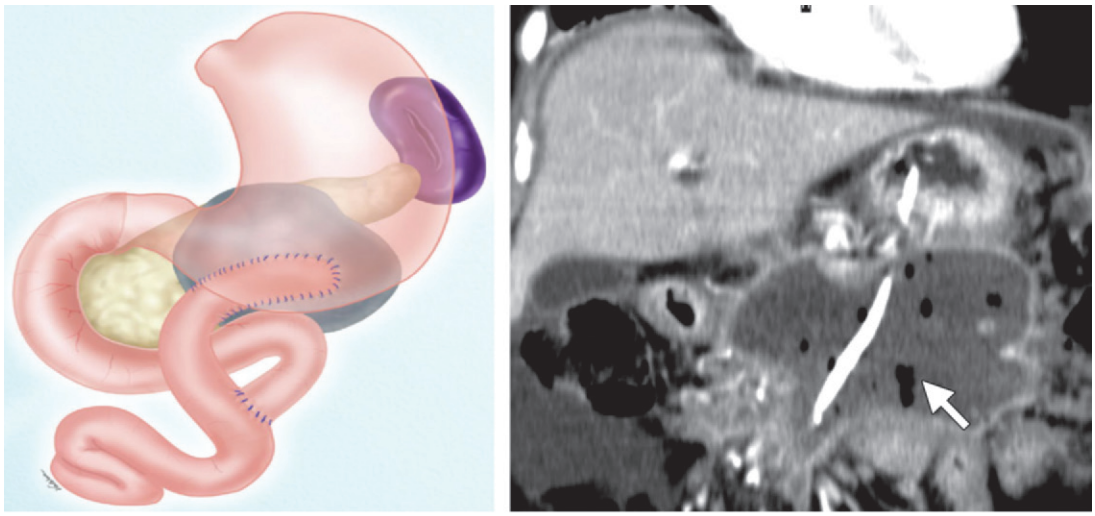
Pitfalls.—Necrotic collections, including acute necrotic collections and walled-off necrosis (previously named steatonecrosis), should not be mistaken for fluid collections because the two entities have different courses and management. Fluid collections are homogeneous and have no discernible wall, and most of the time, they are spontaneously reabsorbed in the first weeks and rarely become infected. Necrotic collections are more heterogeneous, reflecting their internal components of nonliquefied material (blood and pancreatic parenchymal and fat necrosis); and most of the time, necrotic collections need to be removed, whether by the percutaneous approach (abscess drainage) or surgically (necrosectomy) (40,41). In addition, surgery should be considered in patients with necrotic collections who have refractory abdominal pain or are critically ill, even without clear signs of infection.

Complications.—The complications of the interventional procedures of necrosectomy and abscess drainage in patients with acute pancreatitis include the development of pancreatic fistulas and intraabdominal bleeding. These complications are more prominent when surgery is performed within 14 days after the onset of acute pancreatitis. Whenever possible, surgery should be postponed for 4 weeks.

Pseudocyst Derivation

Indications.—Pseudocyst derivation is performed in patients with complications, such as secondary infection, hemorrhage, rupture, and obstruction of other abdominal organs.

Normal Postoperative Anatomy.—Pseudocysts are surgically treated by creating a connection between the cyst and either the stomach, the duodenum, or the jejunum. Drainage may be performed with radiologic guidance, endoscopically, or through surgical decompression (Fig 26).



a. b.

Figure 26. Pseudocyst derivation. **(a)** Drawing of a surgically performed pseudocyst derivation. **(b)** Coronal multidetector CT image shows an alternative endoscopically performed pseudocyst derivation, with placement of a catheter. After the procedure, the cavity may contain gas bubbles (arrow) and should reduce in size at follow-up examinations. (Fig 26a courtesy of Valéria Simões Lira de Fonseca, São Paulo, Brazil.)

Multidetector CT Findings.—Complications in pseudocysts develop late in the course of an acute episode of pancreatitis, usually after the 4th week or even years later. Therefore, the most common finding is a well-delimited cyst with thick walls. After the derivation, the cavity should reduce in size at follow-up examinations.

Pitfalls.—Gas inside the pseudocyst cavity is a normal finding after the procedure and should not be mistaken for a sign of infection.

Conclusions

Knowledge of the different surgical techniques used to treat neoplastic and nonneoplastic pancreatic diseases and the patterns of their CT findings make CT a useful tool in the evaluation of the postoperative pancreas. Familiarity with the early and late postoperative anatomic findings is essential to distinguish normal findings from surgical complications or recurrent disease.

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RadioGraphics

Multidetector CT Evaluation of the Postoperative Pancreas

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CT is the modality of choice for imaging the postoperative pancreas. CT is more readily available, is faster, and is more practical for debilitated patients. In addition, calcifications and gas in the biliary tree are less prone to technical and interpretive errors at CT than at magnetic resonance (MR) imaging.

Page 746 (Figure on page 746)
Pancreatoduodenectomy, also known as the Whipple procedure, consists of resection of the pancreatic head, the duodenum, a short segment of the jejunum, and the gastric antrum, followed by *(a)* pancreaticojejunostomy, *(b)* hepaticojejunostomy, and *(c)* gastrojejunostomy or duodenojejunostomy (Fig 3).

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Besides delayed gastric emptying, the most common complications of the Whipple procedure are pancreatic fistulas (17%), wound infection (9%–10%), abdominal abscess, intraabdominal bleeding, and anastomotic leakage, leading to peritonitis and pancreatitis of the remnant gland (Fig 8).

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As in the Whipple procedure, transient fluid collections may make it more difficult to evaluate pancreatic fistulas, and the latter cannot be diagnosed reliably with CT. A clinical diagnosis of pancreatic fistula is made when there is prolonged or elevated output of amylase-rich fluid through an intraoperatively placed drain.

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In patients with chronic pancreatitis, the primary indication for surgical drainage of the pancreatic duct is the relief of incapacitating abdominal pain that cannot be managed with medical therapy. This procedure is best suited to patients with diffuse pancreatic duct dilatation who have duct diameters greater than 6 mm, involving mostly the body and tail of the pancreas, with relative preservation of the head of the pancreas and an absence of biliary duct dilatation (33,34).