

# Normal Postoperative Computed Tomography Findings after a Variety of Pancreatic Surgeries

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Pancreatic surgery remains the only curative treatment for pancreatic neoplasms, and plays an important role in the management of medically intractable diseases. Since the original Whipple operation in the 20th century, surgical techniques have advanced, resulting in decreased postoperative complications and better clinical outcomes. Normal postoperative imaging findings vary greatly depending on the surgical technique used. Radiologists are required to be familiar with the normal postoperative imaging findings, in order to distinguish from postoperative complications or tumor recurrence. In this study, we briefly review a variety of surgical techniques for the pancreas, and present the normal postoperative computed tomography findings.

**Keywords:** Pancreas; Pancreatic neoplasm; Pancreatic surgery; Postoperative; Computed tomography

## INTRODUCTION

Surgical resection is the treatment of choice for benign or malignant pancreatic diseases (1). After the introduction of distal pancreatectomy at the end of 19th century, and classic pancreaticoduodenectomy (Whipple operation) early in the 20th century, the mortality rate has gradually decreased from 25% to < 5% with advancement of surgical techniques and improvement of postoperative care. Besides

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the classic surgical methods, new techniques are developed to improve oncologic outcomes and prevent postoperative complications, such as pancreaticoduodenectomy (PPPD), central pancreatectomy, and anterior/posterior radical antegrade modular pancreatectomy (RAMPS) (2-5).

For benign pancreatic diseases, despite the development of minimally invasive endoscopic or interventional procedures, surgery still plays a critical role especially in medically intractable diseases. Procedures that are performed mainly for benign diseases, including Frey operation, Partington and Rochelle operation, cystojejunostomy, and transduodenal ampullectomy, are less frequent than Whipple operation or PPPD, and most radiologists may be unfamiliar with these surgeries.

Radiologists are required to be familiar with an overview of these surgical techniques for gainful communication with surgeons. Furthermore, ability to interpret postoperative images is required to differentiate between normal and abnormal findings. Herein, we briefly review a variety of surgical techniques and discuss the normal computed tomography (CT) findings after pancreatic surgery.

**CT Protocol**

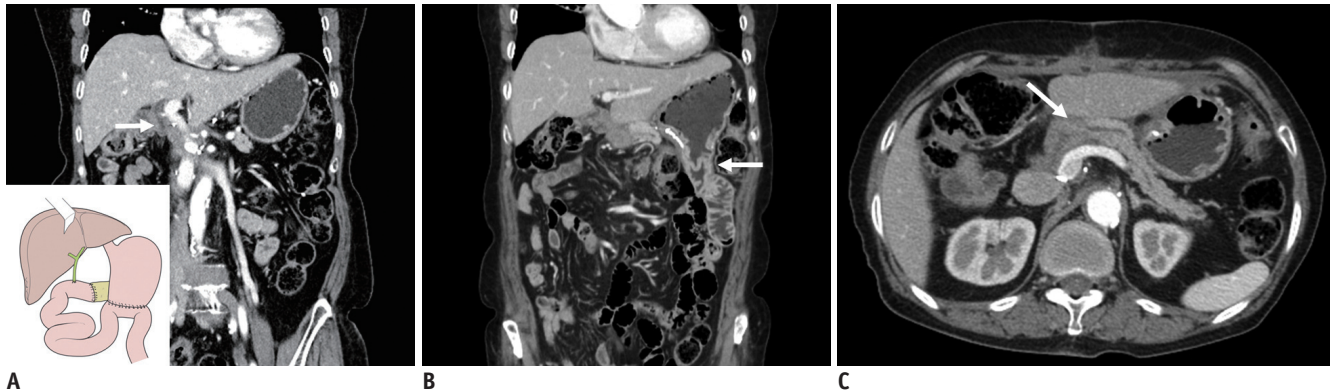
Postoperative CT scan is routinely performed 1 week after pancreatic surgery unless immediate postoperative complications are not suspected. A nonionic contrast medium (2 mL/kg) is administered with a fixed injection duration of 30 seconds, followed by 20 mL saline flush. By using a bolus-tracking technique, the late arterial or pancreatic phase is obtained at 25 seconds after the enhancement of the abdominal aorta has increased to 100 Hounsfield units (HU) compared with the noncontrast image, followed by portal venous or hepatic venous phase with scan delay of 25 seconds after the end of pancreatic phase acquisition. If only portal venous phase is acquired, a scan delay of 55 seconds is applied after the aortic HU increases to 100 HU (6). The acquisition parameters are

as follows: detector collimation, 128 x 0.6 mm; gantry rotation, 0.5 second; tube voltage, 100–120 kVp; reference mA, 170 mA with automatic exposure control; and slice thickness, 3 mm. Administration of an oral contrast agent (Gastrografin; Bayer, Alcalá de Henares, Spain; diatrizoate meglumine, diatrizoate sodium) before CT scan is recommended in cases with suspected leakage of the bowel anastomosis site.

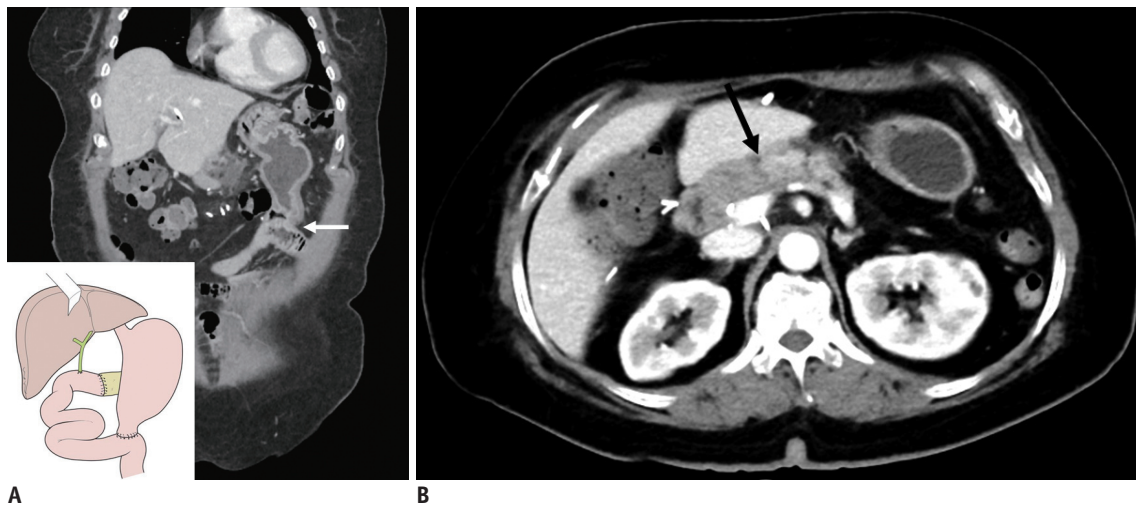
**Surgical Procedure and Normal Postoperative Imaging**

**Type of Pancreatic Head Resection**

In the classic Whipple operation, the pancreas head, duodenum, distal common bile duct (CBD), gall bladder, proximal jejunum, and distal stomach are removed (Fig.



**Fig. 1. Schema (lower left corner in A) and postoperative computed tomography coronal (A and B) and axial (C) images of Whipple operation.** Distal stomach is resected together with duodenum, distal common bile duct, and pancreas head. Choledochojejunostomy (arrow in A), gastrojejunostomy (arrow in B), and pancreaticojejunostomy (arrow in C) are made.



**Fig. 2. Schema of pancreaticoduodenectomy (lower left corner in A) and postoperative coronal (A) and axial (B) computed tomography images.** Stomach and proximal portion of duodenum are preserved, and choledochojejunostomy, duodenojejunostomy (arrow in A), and pancreaticojejunostomy (black arrow in B) are made.

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1). In PPPD, the stomach and the proximal portion of the duodenum are preserved (Fig. 2) (7). Although there are concerns on the oncologic outcomes of PPPD because it is less extensive, the overall survival is reportedly similar between the 2 methods (8). Furthermore, the operating time and intraoperative blood loss are significantly reduced in PPPD compared with the Whipple operation (8). After resection, 3 anastomoses are made: choledochojejunostomy, gastrojejunostomy (or duodenojejunostomy for PPPD), and pancreaticojejunostomy (7). Choledochojejunostomy is usually done, through an end-to-side manner, in the retrocolic area; whereas gastrojejunostomy or duodenojejunostomy can be done either through antecolic or retrocolic reconstruction. Differentiating between PPPD (i.e., duodenojejunostomy) and Whipple operation (i.e., gastrojejunostomy) might be challenging on postoperative imaging due to postoperative anatomic alteration. Pneumobilia is commonly seen because of choledochojejunostomy (Figs. 1, 2) (9). Jejunal edema frequently occurs around the gastrojejunostomy or duodenojejunostomy, which may be resolved on follow-up CT (9).

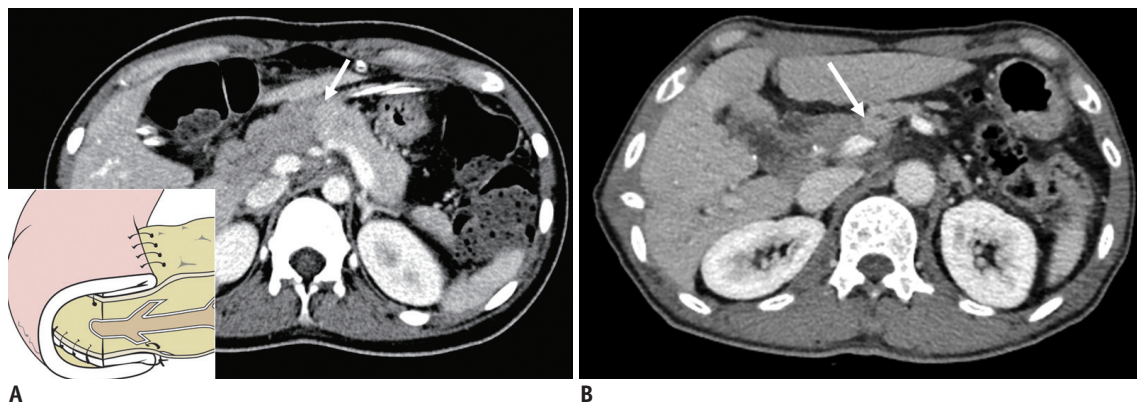
### Anastomosis Method of the Remnant Pancreas after PPPD

The morbidity rate after PPPD has remained at 20–60% over the past decades, despite markedly reduced mortality rate due to advancement of surgical techniques, improvement of anesthesiology, perioperative care, and interventional radiology (10, 11). Postoperative pancreatic fistula (POPF), which is defined as failure of healing or sealing of a pancreaticoenteric anastomosis or leakage from cut surface of the pancreas parenchyma, is considered

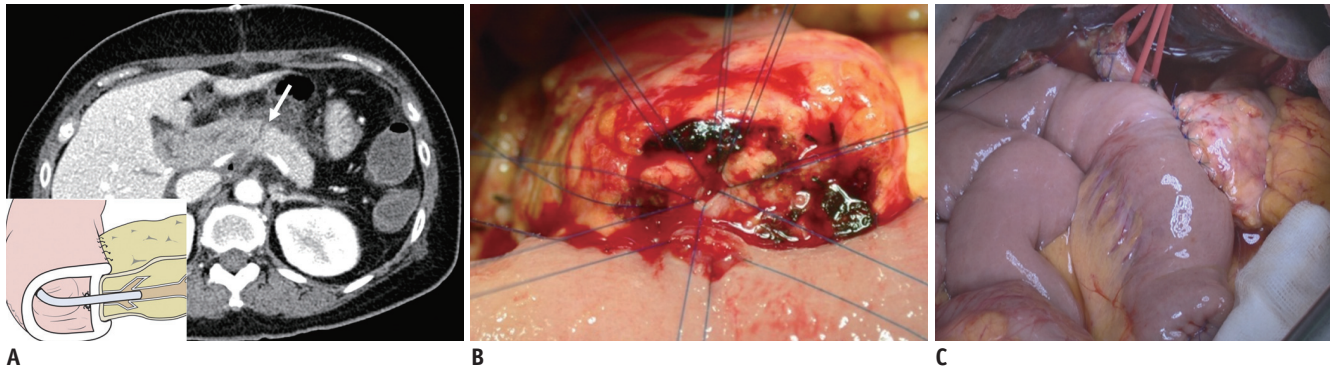
the most frequent major and a potentially life-threatening complication after pancreas head resection (12). Hence, among the 3 anastomoses during pancreas head resection, the most vulnerable point is the pancreaticoenteric anastomosis (11). Many technical variations are developed for pancreaticoenteric anastomosis for reducing POPF, which can be categorized into the invagination method (or dunking method) and the duct-to-mucosa method depending on the anastomosis technique, and pancreaticojejunostomy and pancreaticogastrostomy depending on the anastomosed organ.

### Invagination (Dunking Method) vs. Duct-to-Mucosa Pancreaticojejunostomy

In the invagination technique, the entire pancreatic remnant is dunked into the jejunal lumen (Fig. 3) through either an end-to-end or end-to-side manner, whereas the main pancreatic duct of remnant pancreas is sutured to the jejunal mucosa and reinforcement suture is done between the remnant pancreas and jejunal serosa in the duct-to-mucosa technique (Fig. 4) (11). The advantage of the invagination technique is its ease of performance, and drainage of all pancreatic juice into the jejunal lumen (13). However, this technique may be problematic if the pancreatic parenchyma is soft and friable due to risk of parenchymal laceration and consequent postoperative complications such as a pancreatic fistula (13). Although controversy surrounds technique selection in terms of POPF, a recent prospective randomized trial shows no significant difference in the POPF rate between the 2 methods (14); additionally, other factors including surgeon experience and surgical volumes might affect the incidence of POPF (11, 14). On CT, the distal portion of the remnant pancreas



**Fig. 3. Invagination pancreaticojejunostomy (dunking method) (schema: lower left corner in A).** Entire pancreatic remnant is dunked into jejunal lumen (arrow in A). Pancreaticojejunal anastomosis is anterior to superior mesenteric artery and splenic vein. Remnant pancreas can protrude into jejunal lumen, which can mimic tumor recurrence (arrow in B).

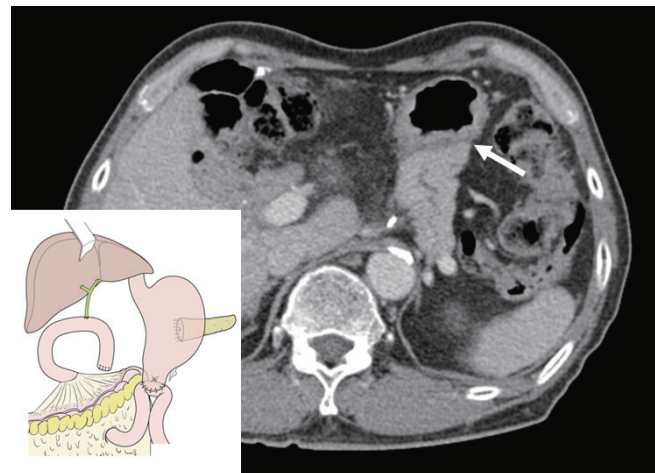


**Fig. 4.** (A-C) Postoperative computed tomography image (schema: lower left corner in A) and intraoperative images of duct-to-mucosa pancreaticojejunostomy (B, C). Main pancreatic duct of remnant pancreas is sutured to jejunal mucosa (B). Reinforcement sutures are done between remnant pancreas and jejunal serosa (C). At pancreaticojejunostomy site (arrow in A), pancreatic parenchyma is not protruding into jejunal lumen.

is protruded into the jejunal lumen, especially after the invagination technique, and can mimic tumor recurrence during follow-up (Fig. 3) (15, 16). Some fluid collection may be seen between the pancreas and jejunal wall, suggestive of pancreatic juice from tiny or accessory pancreatic duct; however, it does not always indicate pancreatic fistula (17). According to diagnostic criteria of POPF by The International Study Group of Pancreatic Surgery, radiologic documentation is not mandatory (12). The criteria of POPF is based on many clinical or biochemical findings including output via surgical placement of a drain or subsequent percutaneous drain of any measurable volume of drain fluid on or after postoperative day 3, with an amylase content greater than 3 times the upper normal serum value (12). Direct visualization of leaked oral contrast medium on CT or fluoroscopy is considered confirmatory for anastomosis site leakage by imaging (17).

***Pancreaticojejunostomy vs. Pancreaticogastrostomy***

In contrast to pancreaticojejunostomy, after the resection of the pancreas head, the remnant pancreas is dissected from its original location and splenic vessel, pulled forward, and the cut surface is then attached to the posterior wall of the proximal stomach during pancreaticogastrostomy (18). Although controversies still exist, a recent meta-analysis shows that the incidence of POPF is lower in pancreaticogastrostomy than in pancreaticojejunostomy (19). The incidence of overall postoperative complications and the mortality rate are not significantly different between pancreaticogastrostomy and pancreaticojejunostomy (19). The suggested mechanisms for pancreaticogastrostomy-mediated reduction in POPF include the prevention of tissue damage around the



**Fig. 5.** Postoperative computed tomography image and schema of pancreaticogastrostomy (lower left corner). Remnant pancreas is attached to posterior wall of proximal stomach (arrow) usually with duct-to-mucosa method.

pancreaticogastrostomy following inactivation of pancreatic enzyme by the acidic gastric environment, promotion of anastomosis site healing by the rich blood supply of the gastric wall, technical ease of anastomosis compared with pancreaticojejunostomy, and easier access with endoscopy after surgery, which can enable early diagnosis and treatment of postoperative complications (19). On imaging, the pancreas is attached to the posterior wall or greater curvature of the stomach and can be seen as a defect on upper gastrointestinal study (Fig. 5) (20).

**Distal Pancreatectomy**

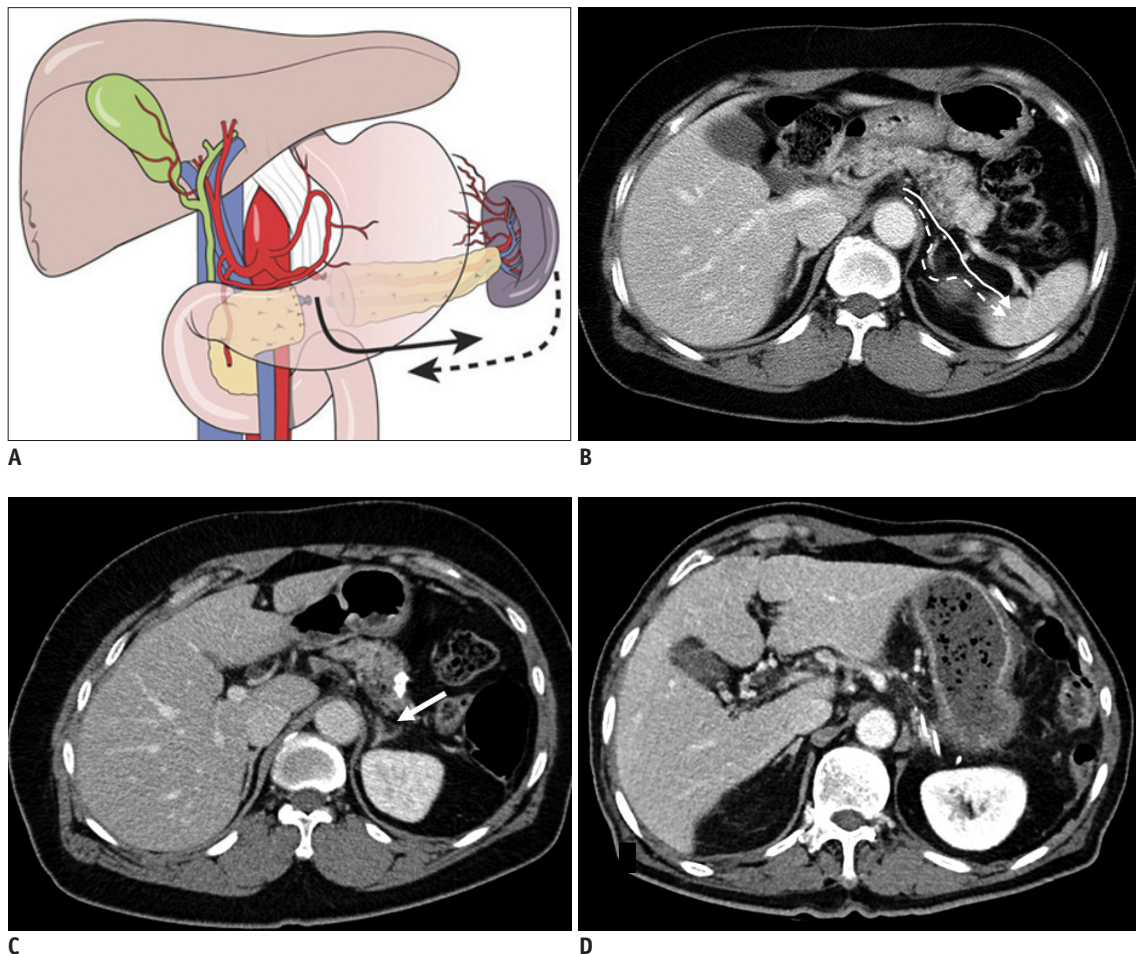
***Standard Retrograde Distal Pancreatectomy and RAMPS***

The distal part of the pancreas, including the tail and part of the body, is resected usually to the left

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side of the superior mesenteric vein (9). In contrast to pancreaticoduodenectomy, there is no anastomotic reconstruction of the jejunum or stomach, pancreas, and bile duct, and the end of remnant pancreas is sutured to prevent leakage, which manifests as an abrupt cut edge on CT (9). On standard retrograde distal pancreatectomy, the dissection starts from the spleen and proceeds to the neck of pancreas, just above the Gerota fascia with en bloc resection of the spleen and distal pancreas. The left adrenal gland is usually retained during this procedure (21). Recently, RAMPS is suggested for ability to properly visualize the posterior plane of dissection and superior N1 lymph node complete dissection to traditional distal pancreatectomy (Fig. 6A) (2, 21, 22). It also provides the option for selection of an oncologically appropriate

posterior margin depending on the tumor extent (2). In contrast to standard retrograde distal pancreatectomy, dissection begins from the neck of the pancreas and continues anteriorly to the adrenal gland, below the Gerota fascia (anterior RAMPS). When the posterior plane of the pancreas is broken by the tumor, the adrenal gland is resected en bloc, and dissection is continued with the posterior resection margin along the diaphragm and retroperitoneal muscles (posterior RAMPS) (Fig. 6B) (21-23). The drawbacks of RAMPs are increased operation time, increased possibility of major vessel injury during neck dissection, and relatively small remnant volume of the pancreas, resulting in postoperative pancreatic insufficiency (21). On postoperative CT, the adrenal gland can be detected after standard retrograde distal pancreatectomy

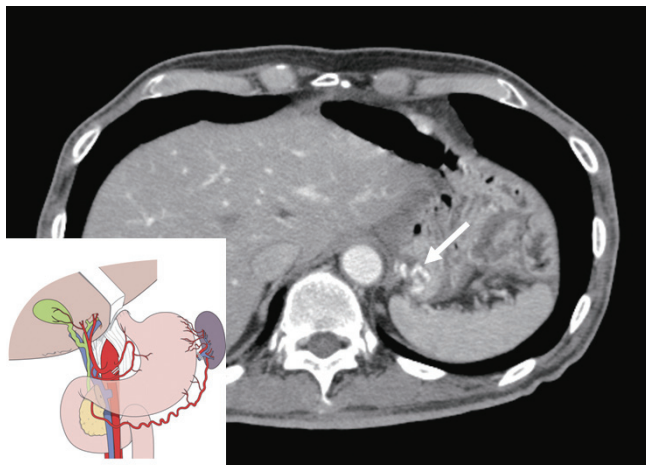


**Fig. 6. Schema and postoperative computed tomography image of distal pancreatectomy.**  
**A.** Schema of standard retrograde distal pancreatectomy (dashed arrow) and radical antegrade modular pancreatectomy (RAMPS) (arrow). Standard retrograde distal pancreatectomy starts from spleen and proceeds to pancreas neck. In contrast, RAMPS begins from neck of pancreas and dissection is continued in opposite direction. **B.** Surgical planes on computed tomography (CT) image of anterior and posterior RAMPS. In anterior RAMPS, dissection is done along Gerota fascia and anterior to adrenal gland (arrow). In posterior RAMPS, dissection is done posterior to adrenal gland (dashed arrow). **C.** Postoperative CT images of anterior RAMPS. Note that left adrenal gland is preserved (arrow). **D.** Postoperative CT image of posterior RAMPS. Note that left adrenal gland is not seen.

and anterior RAMPS, whereas it may not be visualized after posterior RAMPS (Fig. 6C, D) (9, 23).

**Spleen-Preserving Distal Pancreatectomy**

Splenectomy is routinely performed with distal pancreatectomy. Because asplenic patients are at a higher risk of complications such as abscesses or postsplenectomy sepsis, spleen-preserving distal pancreatectomy can be performed in patients with benign or low-grade malignant disease. During spleen preservation, splenic vessels can be preserved or sacrificed (Warshaw technique). If the splenic vessels are dissected, short gastric and left gastroepiploic vessels supply blood to the spleen, resulting in the development of perigastric varices in approximately one-fourth of postoperative patients (24). On postoperative CT, dilated collateral vessels can be seen (Fig. 7). Although



**Fig. 7. Schema of spleen-preserving distal pancreatectomy (Warshaw procedure) (lower left corner).** Note that spleen is preserved. Dilated collateral vessels are seen (arrow).

the incidence is very rare, postoperative splenic infarct can develop after Warshaw operation; hence, the perfusion status of the spleen requires evaluation on postoperative CT (25).

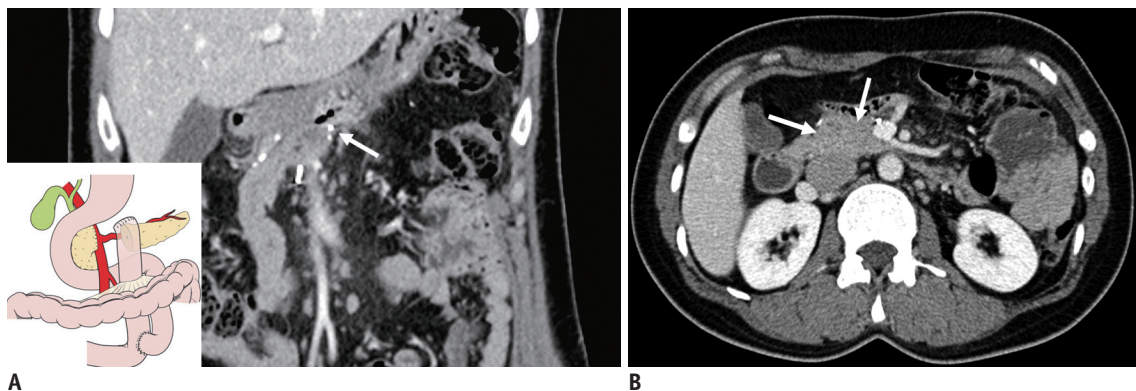
**Other Surgical Methods**

**Central Pancreatectomy**

Central pancreatectomy is performed as an alternative to distal pancreatectomy or pancreaticoduodenectomy for benign lesions or traumatic injury in the neck or body of the pancreas to preserve the function of the pancreas parenchyma, reduced postoperative complications, and maintenance of the endocrine/exocrine function (9). Central pancreatectomy can be done between the gastroduodenal artery to the right and at least 5 cm apart from the end of the pancreas tail for the pancreaticoenteric anastomosis (5). The proximal stump of the remnant pancreas is usually closed either with a mechanical stapler or manual suture, similar to distal pancreatectomy (5). The distal stump of the pancreas is anastomosed to the jejunum or posterior wall of the stomach (5). On CT, a separate remnant pancreas head with preservation of the anatomy of biliary drainage on the right side and distal part of the pancreas with pancreaticojejunostomy or pancreaticogastrostomy on the left side can be seen, respectively (Fig. 8) (9).

**Total Pancreatectomy**

Total pancreatectomy is only performed in limited situations, such as for whole gland or multicentric disease involvement, a positive surgical margin, or intraoperative bleeding during the partial pancreatectomy, because of high perioperative/postoperative morbidity and mortality,



**Fig. 8. Schema (lower left corner of A) and postoperative coronal (A) and axial (B) computed tomography images after central pancreatectomy.**

**A.** Distal part of remnant pancreas is anastomosed to jejunum (arrow). **B.** Pancreas head (arrows) is preserved while maintaining physiologic biliary drainage route.

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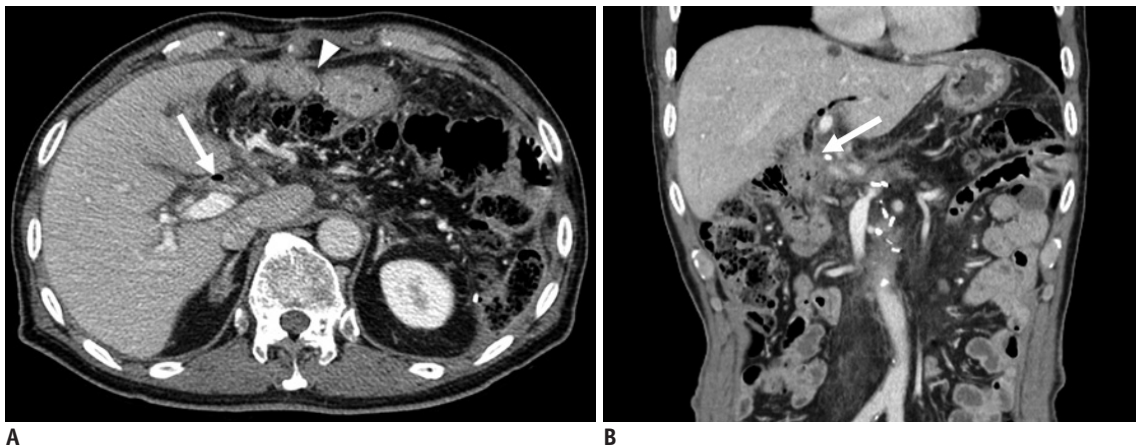
as well as the resulting poor quality of life (26, 27). On postoperative CT, the whole pancreas parenchyma is removed and 2 anastomoses, choledochojejunostomy for biliary drainage and duodenojejunostomy for gastric passage, can be seen (Fig. 9) (9).

**Side-to-Side Pancreaticojejunostomy and Frey Operation**

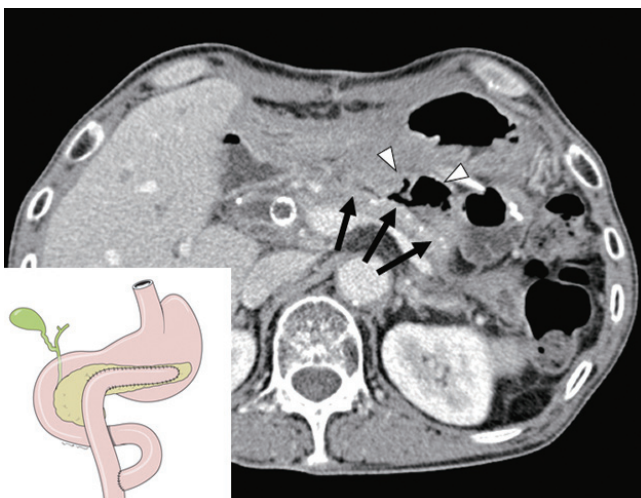
Side-to-side pancreaticojejunostomy (Partington and Rochelle operation) can be a treatment option if the main pancreatic duct is dilated to > 7 mm with absence of inflammatory mass at the pancreas head portion (9, 28).

During the procedure, the main pancreatic duct is opened longitudinally from the neck to the tail of the pancreas, followed by direct pancreaticojejunostomy (Fig. 10). Pancreatolithiasis can be removed during the procedure (28).

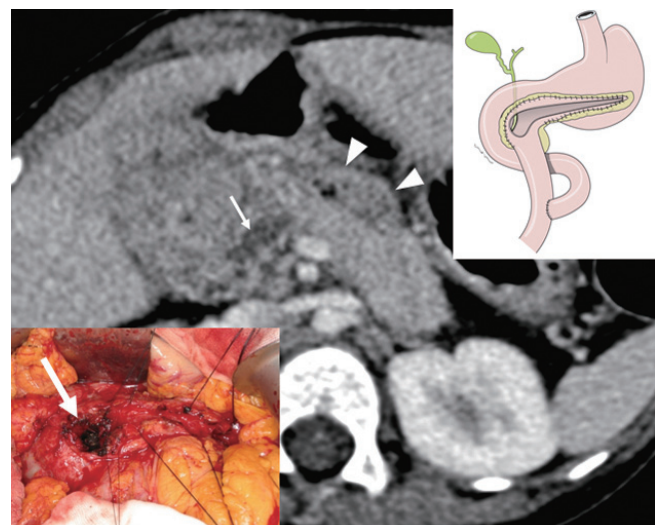
Frey operation (local resection of the pancreatic head with lateral pancreaticojejunostomy) is usually performed in patients with chronic pancreatitis for the drainage of the main and secondary pancreatic ducts without disruption of the biliary system (28). During the operation, the anterior shell of the pancreatic head tissue is excavated and the main pancreatic duct is opened longitudinally to the



**Fig. 9.** Postoperative axial (A) and coronal (B) computed tomography image of total pancreatectomy. Entire parenchyma of pancreas was removed and 2 anastomoses, choledochojejunostomy for biliary drainage (arrows in A, B) and gastrojejunostomy for food passage (arrowhead in A), were reconstructed.



**Fig. 10.** Schema (lower left corner) and postoperative computed tomography (CT) image of side-to-side pancreaticojejunostomy (Partington and Rochelle procedure). Main pancreatic duct is opened from neck to tail of pancreas. Pancreaticojejunostomy is then performed in side-to-side manner. Note that pancreatic duct at body portion (arrows) is anastomosed with jejunal lumen (arrowheads) on postoperative CT image.



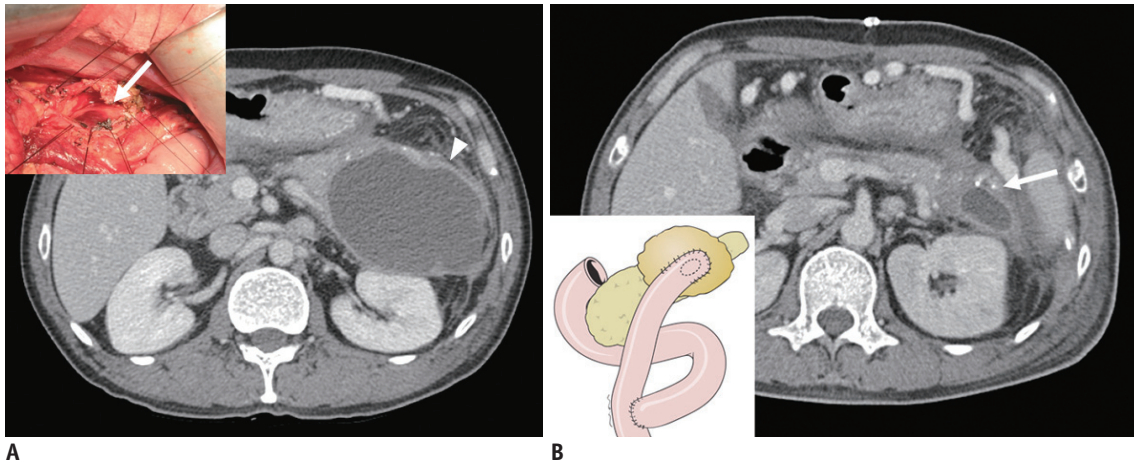
**Fig. 11.** Schema (upper right corner), intraoperative image (lower left corner), and postoperative computed tomography (CT) image of Frey operation. Because anterior shell of pancreas head is removed (thick arrow), cavitory lesion with air bubble and fluid collection can be seen at pancreas head on CT (thin arrow). Pancreatic duct is incised from head to tail, followed by anastomosis to jejunal Y-rim (arrowheads) in side-to-side manner.

pancreas tail, followed by pancreaticojejunostomy (28).

On postoperative CT, the long segment of the Roux-en-Y rim can be seen at the anterior aspect of the pancreas. Intraluminal gas, fluid collection, and oral contrast material within the main pancreatic duct or Roux-en-Y rim should not be misinterpreted as postoperative leakage, abscess, or hemorrhage (9). In case of the Frey operation, a large cavitory lesion with air bubble and fluid can be seen at the pancreas head, which is the excavation site of the pancreatic head tissue (Fig. 11). This cavitory lesion is usually shrunken on serial follow up CT (9). On long-term follow up CT, the collapsed Roux-en-Y loop may be confused with a neoplastic lesion depending on the surgical procedure performed (9).

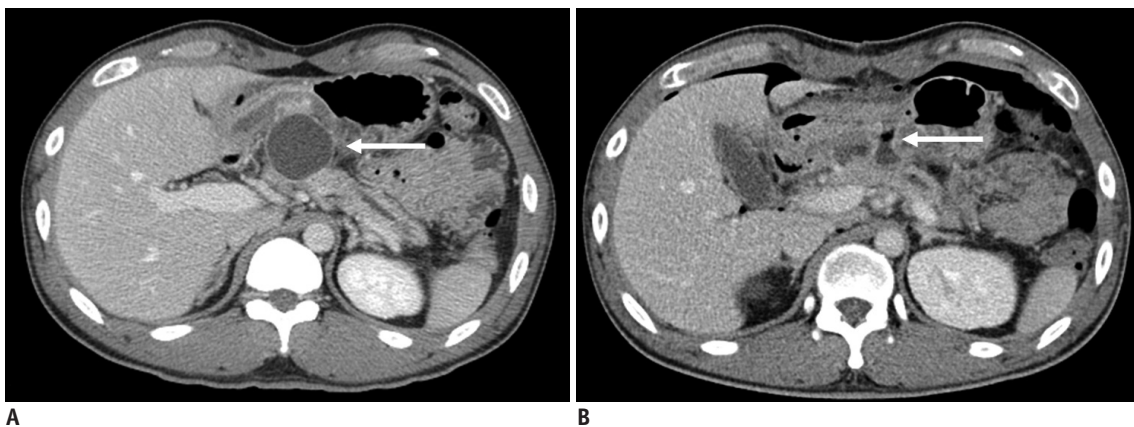
**Cystojejunostomy/Cystogastrostomy**

Cystojejunostomy/cystogastrostomy can be performed in patients with symptoms related to pseudocysts such as pain or gastric outlet obstruction, and if the complication is accompanied with a pseudocyst such as an infection, rupture, or pseudoaneurysm (9, 29). Cystogastrostomy can be performed if the pseudocyst is located adjacent to the posterior wall of the stomach. In most other cases, cystojejunostomy is performed with Roux-en-Y limb (28). Because incision is usually made in the caudal part of the pseudocyst, a jejunal limb can be seen at the inferior aspect of the pseudocyst on CT (28). An air-fluid level with gas bubbles within the pseudocyst can be seen after cystojejunostomy/gastrostomy (Figs. 12, 13) (9, 28).



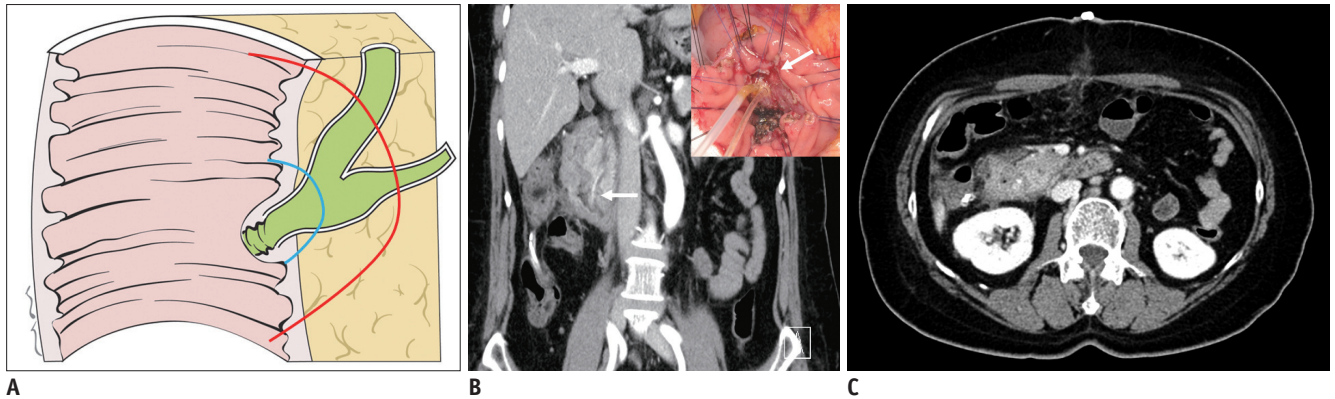
**Fig. 12. Computed tomography (CT) and schema of cystojejunostomy.**

**A.** Intraoperative image (upper left corner) and preoperative CT image of cystojejunostomy. Pseudocyst is opened (arrow) and anastomosed to jejunal Y-rim. Note that pancreatic pseudocyst is seen in pancreas tail on preoperative CT image (arrowhead). **B.** Schema of cystojejunostomy (lower left corner). Postoperative CT image shows that pancreatic pseudocyst is anastomosed to jejunal Y-rim (arrow).



**Fig. 13. Preoperative (A) and postoperative (B) computed tomography image of cystogastrostomy.** Pseudocyst is seen posterior to stomach (arrow in A). After cystogastrostomy, pseudocyst is decreased in size. Note anastomosis site between pseudocyst and posterior wall of stomach (arrow in B).





**Fig. 14. Computed tomography (CT) and schema of transduodenal ampullectomy.**

**A.** Schema of transduodenal ampullectomy. Different resection margins between ampullectomy and papillectomy are shown. Red line shows resection margin of ampullectomy, cutting pancreatic duct and common bile duct (CBD). In contrast, resection margin of papillectomy does not include pancreatic duct and CBD (blue line). **B, C.** Intraoperative image (upper right corner) showing ampulla removed through transduodenal approach. Postoperative CT image shows irregular wall of duodenum and adjacent fluid collection and fat infiltration. Postoperative coronal (**B**) and axial (**C**) CT images show irregular thickening of duodenal wall with adjacent fluid collection and fat infiltration. Inserted t-tube within duct is noted in coronal CT image and intraoperative photography just before repositioning between duodenal mucosa and bile duct and pancreatic duct. Internal short stents are inserted to bile duct and pancreatic duct (arrow in **B**).

### Transduodenal Ampullectomy

When the premalignant lesion or minimally invasive cancer is located at the ampulla of Vater and the desired resection margin cannot be sufficiently achieved, transduodenal ampullectomy can be used as an alternative technique to endoscopic ampullectomy or pancreaticoduodenectomy (30). In contrast to endoscopic ampullectomy, the intrapancreatic CBD and the most downstream pancreatic duct are resected during transduodenal ampullectomy (Fig. 14) (30). The cutting edge of the pancreatic duct and CBD is sutured together in a conjoined duct and anastomosed to the duodenal mucosa (30). On postoperative CT, duodenal wall thickening with adjacent fluid collection and fat infiltration can be seen (Fig. 14).

### CONCLUSION

Although various medical and minimally invasive treatment methods for pancreatic disease are developed, surgery remains as an important option both in neoplastic and inflammatory pancreatic disease. Furthermore, the methods are continuously evolving with the aim to reduce postoperative mortality/morbidity and improve patient outcomes. Accurate interpretation of postoperative CT for differentiating normal postoperative findings and complications involves an understanding of which part of the organ is removed and how the remaining structure is reconstructed for functional homeostasis. This review presents a brief description of surgical techniques and normal postoperative CT findings, which would be helpful

in interpretation of postoperative CT findings by the radiologist and adequate patient management by the surgeon.

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