The postsurgical pancreas

Das postoperative Pankreas

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ABSTRACT

Background Partial pancreatic resections are among the most complex surgical procedures in visceral tumor medicine and are associated with a high postoperative morbidity with a complication rate of 40–50 % of patients even in specialized centers.

Methods Description of typical surgical resection procedures and the resulting postoperative anatomy, typical normal postoperative findings, common postoperative complications, and radiological findings.

Results and conclusion CT is the most appropriate imaging technique for rapid and standardized visualization of postoperative anatomy and detection of clinically suspected complications after partial pancreatic resections. The most common complications are delayed gastric emptying, pancreatic fistula, acute pancreatitis, bile leakage, abscess, and hemorrhage. Radiologists must identify the typical surgical procedures, the postoperative anatomy, and normal postoperative findings as well as possible postoperative complications and know interventional treatment methods for common complications.

Key points:
- Morbidity after pancreatic surgery remains high.
- CT is the best method for visualizing postoperative anatomy and is used for early detection of complications.
- Pancreatic fistula is the most common relevant complication after pancreatic resection.
- The ability of a center to manage complications is crucial to ensure the success of therapy.

ZUSAMMENFASSUNG

Hintergrund Partielle Pankreasresektionen gehören zu den komplexesten Operationen in der viszeralen Tumormedizin und sind auch heute selbst in spezialisierten Zentren mit einer hohen postoperativen Morbidität bei einer Komplikationsrate von 40–50 % der Patienten verbunden.

Methode Beschreibung der typischen chirurgischen Resektionsverfahren und der resultierenden postoperativen Anatomie, typischer normaler postoperativer Befunde und der häufigen postoperativen Komplikationen sowie der radiologischen Befunde.

Ergebnisse und Schlussfolgerung Die CT ist das geeignetste bildgebende Verfahren zur schnellen und standardisierten Darstellung der postoperativen Anatomie und zum Nachweis von klinisch vermuteten Komplikationen nach partieller Pankreasresektion. Die häufigsten Komplikationen sind die Magenentleerungsstörung, Pankreasfistel, akute Pankreatitis, Galleleckage, Abszess und Hämorrhagie. Die Radiologen müssen die typischen chirurgischen Verfahren, deren postoperative Anatomie und normale postoperative Befunde ebenso wie die möglichen postoperativen Komplikationen sicher identifizieren und interventionelle Behandlungsmethoden der häufigen Komplikationen kennen.

Introduction

Pancreatic surgery is mainly performed to treat pancreatic cancer and cystic tumors, distal cholangiocarcinoma, and complications of chronic pancreatitis. In Germany, approximately 10 000 pancreatic surgeries are performed each year [1]. Pancreatic surgeries to treat a primary malignancy of the pancreas or the extrahepatic bile ducts are among the most complex surgical procedures in visceral tumor medicine [2]. The mortality rate in a Germany-wide study was 7.3 % for proximal pancreatectomy and 22.9 % for total pancreatectomy with splenectomy [3]. The mortality and morbidity rates fluctuate depending on the experience of the surgeon, the operation volume of the hospital, and the ability of the center to manage complications [4, 5]. The Germany-wide results differ significantly from the published results of individual centers with a 30-day mortality rate of less than 3 % [2]. It must be taken into consideration in the international comparison that postoperative mortality also includes patients after more than 30 days of inpatient care [5]. In spite of improvements in surgical techniques and peri- and postoperative care after partial pancreatic resection, the postoperative morbidity rate even at specialized centers is still high (30 %) resulting in long hospital stays [6]. The most common complications are pancreatic fistulas (10–35 %), bile leaks (3–9 %), bleeding, and acute pancreatitis [7–10]. Relaparotomy is needed in approximately 5–10 % of cases [1].

In the case of a postoperative complication, detection as early as possible and targeted management are essential to minimize problems. Postoperative imaging is extremely important for further categorization of patients and determination of treatment. Computed tomography (CT) is the method of first choice here [11, 12]. Other imaging methods like magnetic resonance imaging (MRI) and fluoroscopy are less helpful and are only used in individual cases. Knowledge of surgical methods, postoperative anatomy, and the spectrum of complications is decisive for the interpretation of radiological images. The goal of this article is to describe typical resection methods and normal postoperative anatomy and to present typical postoperative findings, common complications, and their management.

Surgery

Depending on the type of underlying lesion and its location, different surgical resection methods are used. The most common resections are proximal pancreatic resection with duodenectomy (pancreaticoduodenectomy) and distal pancreatic resection. Central pancreatectomy is a rare operation and is performed in the case of benign lesions or low malignant potential tumors. The pancreatic duct and cut surface of the body of the pancreas are oversewn. The tail of the pancreas is drained via a jejunal loop.

Distal pancreatectomy is performed in the case of malignancies in the body or tail of the pancreas. The distal part of the pancreas is resected to the left of the superior mesenteric vein (▶ Fig. 1a). Distal pancreatectomy typically also includes a splenectomy. This procedure does not involve any anastomoses and the postoperative anatomy is almost normal.

Proximal resection is performed in malignant diseases like periampullary neoplasms, cancer of the head of the pancreas, distal cholangiocarcinoma, and chronic pancreatitis. Resection of the head of the pancreas is the most common intervention since two thirds of pancreatic malignancies affect the head of the pancreas. The classic Kausch-Whipple procedure includes resection of the head of pancreas, the distal stomach, the duodenum, the gallbladder, the distal bile duct, the proximal jejunum, and the regional lymph nodes. This extensive resection requires multiple reconstructions.

In the classic Kausch-Whipple procedure, gastrointestinal continuity is achieved by gastrojejunostomy after resection of the gastric antrum (▶ Fig. 1b). As a rule, resection of the head of the pancreas is currently performed using a pylorus-preserving tech-
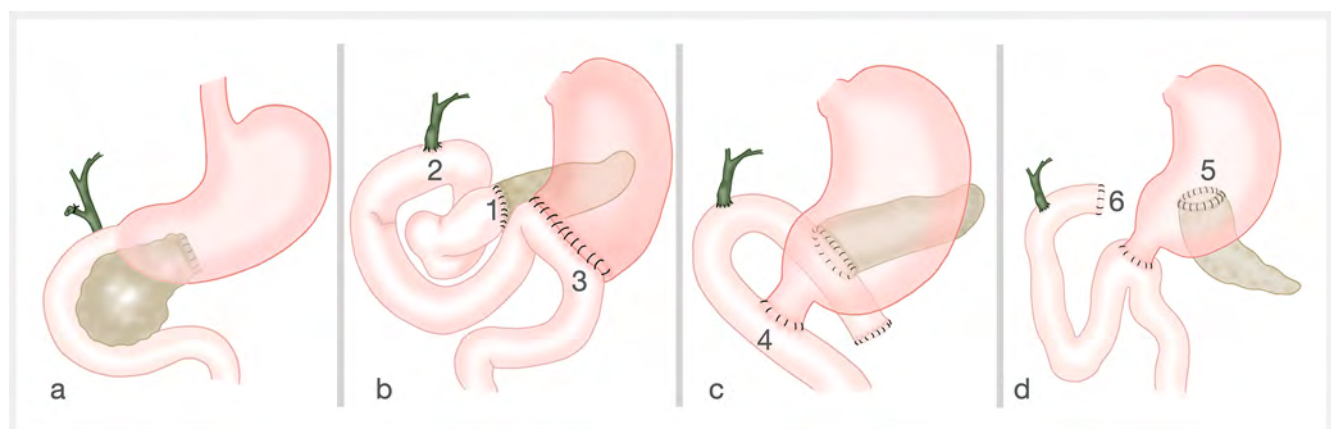
▶ Fig. 1 Surgical methods of partial pancreatic resection. **a** Distal pancreatic resection: the pancreatic head remains in place. The pancreatic body and tail are resected, anastomoses are not necessary. **b** Pancreaticoduodenectomy as a classic Whipple operation: the pancreatic head, gastric antrum, duodenum, proximal jejunum, and gallbladder are resected. The remaining pancreas is anastomosed to the jejunum in the form of a pancreaticojejunostomy (1). Bile is drained via a hepaticojejunostomy (2). The gastric antrum is connected to the jejunum (3) distal to the biliodigestive anastomosis. **c** Pylorus-preserving pancreaticoduodenectomy (PPPD): the stomach and pylorus are preserved and a duodenojejunostomy (4) is created. The pancreas is anastomosed to a jejunum loop. **d** Using both procedures, the residual pancreas can be inserted into the stomach as a pancreaticogastrostomy (5). In this case the proximal jejunum is closed as a blind loop (6). Source: Maike Venhofen

nique (PPPD) (▶ **Fig. 1c**) so that the proximal duodenum is connected to an efferent jejunal loop. PPPD was originally introduced with the goal of improving gastric motility by preserving the stomach and reducing the incidence of anastomosis ulcers and alkaline gastritis. However, this goal was not able to be achieved in practice [13, 14]. The advantage of PPPD is the shorter operation time and the lower intraoperative blood loss [13, 15]. With respect to mortality, morbidity, and oncological effectiveness, a large meta-analysis showed no differences between the two methods [16].

The remaining pancreas is either anastomosed to a jujenal loop in the form of a pancreaticojejunostomy (▶ **Fig. 1b, c**) or is inserted into the body of the stomach as a pancreaticogastrostomy (▶ **Fig. 1 d**). These two types of pancreatic anastomosis have comparable perioperative complication rates. A meta-analysis showed a tendency toward a lower occurrence of pancreatic fistulas for pancreaticogastrostomy [17]. In contrast, the prospective multicenter RECOPANC study from 14 German centers yielded a rate of 20 % significant pancreatic fistulas for pancreaticojejunostomy compared to 22 % for pancreaticogastrostomy [18]. Bile is drained via the biliodigestive anastomosis created by a hepaticojejunostomy (▶ **Fig. 1**).

Patients with chronic pancreatitis can be treated with pancreaticoduodenectomy or with a less extensive resection with preservation of the duodenum. In the case of duodenum-preserving pancreatic head resection (DPPHR), a jejunal loop is sewn to the anterior surface of the pancreas after excavation of the head of the pancreas and further distal a jejunojejunostomy is performed analogously to a Roux-en-Y reconstruction [11].

Pancreatic resection can be performed as an open, minimally invasive laparoscopic, or robot-assisted procedure. In the data published to date, no significant differences in overall morbidity or mortality can be seen between the procedures [19–21]. While open surgery is shorter, minimally invasive procedures tend to have advantages with respect to less blood loss, fewer relevant pancreatic fistulas, and a shorter hospital stay [21, 22]. Left pancreatic resection has the advantage of minimally invasive surgery with respect to reconvalescence and quality of life, but there are no significant differences regarding the postoperative complication rate [23].

Postoperative imaging

If the early postoperative course is complication-free, there is no indication for routine imaging. In the case of suspicion of complications, CT is typically the best imaging modality [11, 12, 24]. It allows quick examination of the entire abdomen with high spatial and contrast resolution including the vascular anatomy. In the early postoperative phase, CT should be performed using a multiphase protocol. The non-contrast examination of the upper abdomen is used to detect hyperdense material (clips, stents, or blood). Contrast-enhanced imaging of the upper abdomen is performed in the late arterial phase (bolus track in the abdominal aorta, 120 HU threshold, 15 s delay) and the venous phase (60 s delay after the threshold is reached). Patients receive 0.4 g iodine/kg body weight in a highly concentrated non-ionized contrast agent

with an iodine delivery rate of 1.2 g iodine/s (corresponding to approx. 120 ml of a contrast agent with 300 mg/ml iodine and a flow rate of 4 ml/s) followed by a 50-ml saline bolus.

The late arterial phase is used to visualize the pancreatic parenchyma and vascular and bleeding complications. The portal venous phase with visualization of the entire abdomen is used to evaluate organ perfusion, drainage tube position, and intestinal passage and to detect fluid collections. If the patient is capable of drinking, the upper gastrointestinal tract is distended with 500–700 ml of water prior to the CT examination. If the explicit goal is to visualize a fistula or gastric anastomotic insufficiency, diluted contrast agent can be administered orally. In addition to axial slices (3–5 mm slice thickness), additional coronal and sagittal multiplanar reconstructions (MPRs) and maximum intensity projections (MIPs) are helpful for examining vascular issues.

When evaluating early postoperative CT examinations, surgical anastomoses of a gastrojejunostomy or duodenojejunostomy, hepaticojejunostomy, and pancreaticojejunostomy or pancreaticogastrostomy must be examined. After resection of the head of the pancreas, the superior mesenteric vein and the venous confluence are to the right of the remaining pancreas and further dorsal in the vicinity of the vena cava. In pancreaticojejunostomy, the anastomosis is anterior to the superior mesenteric artery (▶ **Fig. 2**). Gastrojejunostomy or duodenojejunostomy is usually performed as an antecolic procedure. After duodenum-preserving pancreatic resection, a jejunal loop is anastomosed to the remaining pancreas and jejunojejunostomy is performed. Anastomoses usually have edematous changes in the early postoperative phase with corresponding thickening of the intestinal and gastric walls. Perivascular edema around the large vessels as well as bands of edema in the surrounding fatty tissue are also common (▶ **Fig. 3**). Soon after the operation – particularly in the case of R0 resection – these changes should not be evaluated as residual tumor tissue or local recurrence. After creation of a biliodigestive anastomosis, pneumobilia, which is often more pronounced on the left, is normal. The remaining lymph nodes can swell as a result of postoperative reactive adenopathy and the short-axis diameter can be greater than 1 cm (▶ **Fig. 3**). This type of reactive lymphadenopathy should resolve within 6 months at the latest. Fluid collections in the surgical area and at the anastomoses are common findings in the first two weeks and are seen in almost one third of patients [10]. These homogeneous water-equivalent collections are difficult to differentiate from a pancreatic fistula or insufficiency of the hepaticojejunostomy on imaging.

Pancreatic fistula

The most common complication after pancreatic resection is pancreatic fistula or anastomotic insufficiency. A pancreatic fistula is clinically detected on the basis of amylase in the fluid drained from the surgical area [7, 25]. The incidence varies between 10 % and 35 % and is associated with the type of intervention. Fistulas occur 10–30 % more frequently after distal pancreatic resection or enucleation than after pancreaticoduodenectomy (10–15 %) [6, 9]. The definition of a pancreatic fistula was standardized by the International Study Group for Pancreatic Surgery (ISGPS) in 2005 and modified in 2016 [7, 26]. A fistula is present when the
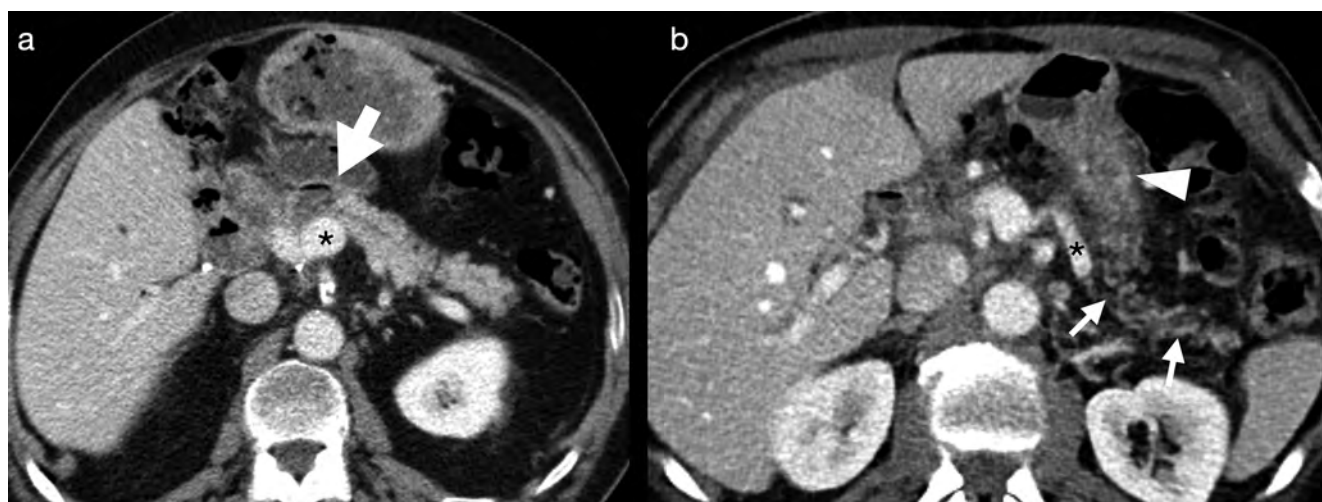
▶ **Fig. 2** Pancreatic anastomoses after pancreatic head resection. **a** Pancreaticojejunostomy: the residual pancreas is anastomosed with a mobilized jejunum loop. The anastomosis (arrow) is ventral to the axis of the superior mesenteric artery at the level of the confluence venosum (*). **b** Pancreaticogastrostomy: the residual pancreas (small arrows) is inserted into the posterior wall of the stomach (arrowhead). The pancreas is easily identified by the course of the lienal vein (*).

▶ **Fig. 3** CT on the 4th postoperative day after PPPD with pancreaticogastrostomy. **a** Axial section at the level of the pancreaticogastrostomy. The anastomosis (arrowhead) is edematously altered. The pancreas bulges slightly into the stomach. The gastric lumen is marked after oral contrast administration. The fatty tissue in the surgical area between the stomach and the hepatic orifice is edematous. **b** Coronary reformation at the level of the hepaticojejunostomy (arrow). The hepatic duct is air-filled and visible. Aerobilia of the central intrahepatic bile ducts (small arrow). Lymph nodes (black arrows) periaortic, mesenteric, and cranial to the lienal vein are reactively enlarged and enhance after contrast medium application.

amylase content in the drained fluid is more than three times the maximum normal serum concentration on the third postoperative day. Pancreatic fistulas are classified as grade A to grade C. Grade A can only be detected as a laboratory finding due to the absence of fluid collection on CT. It does not have any clinical consequences. Therefore, this situation is referred to as a biochemical leak and not as a fistula in the classification that was modified in 2016. In the case of grade B or C fistulas, CT shows peripancreatic fluid. In the case of grade B fistulas, the patient's postoperative management must be adapted and is characterized by drainage tubes being left in place for more than 3 weeks or by the percutaneous or endoscopic placement of new drainage tubes. Grade C corresponds to a persistent fistula requiring revision surgery, fistula-related organ failure, or mortality [26].

CT imaging can confirm clinical suspicion by detecting fluid near the pancreatic anastomosis, in the pancreatic bed, and in a peripancreatic location (▶ **Fig. 4**). After distal pancreatic resection, a fluid collection with a diameter of more than 4 cm indicates the presence of a clinically relevant fistula [27]. In the case of major insufficiencies, peritoneal leakage of orally administered contrast agent can be seen or contrast agent can be detected in the drainage tube (▶ **Fig. 5**). Small air inclusions in the fluid are not pathognomonic for an infection but can indicate a pancreatic fistula. Increases in density and a heterogeneous image are suspicious for the presence of pancreatic fluid collections or a superinfection. Pancreatic fistulas are treated as conservatively as possible or minimally invasively with percutaneous or endoscopic

▶ **Fig. 4** Patient with superinfected pancreatic fistula after distal pancreatectomy. **a** With elevated inflammation lab results 12 days after surgery and wound drains already removed, there is a homogeneous fluid accumulation (*) in the pancreatic bed. The infected fluid was drained percutaneously with CT-guided puncture. **b** After 4 weeks of drainage treatment, there is only a small residual cavity (arrow) and the drain was removed.
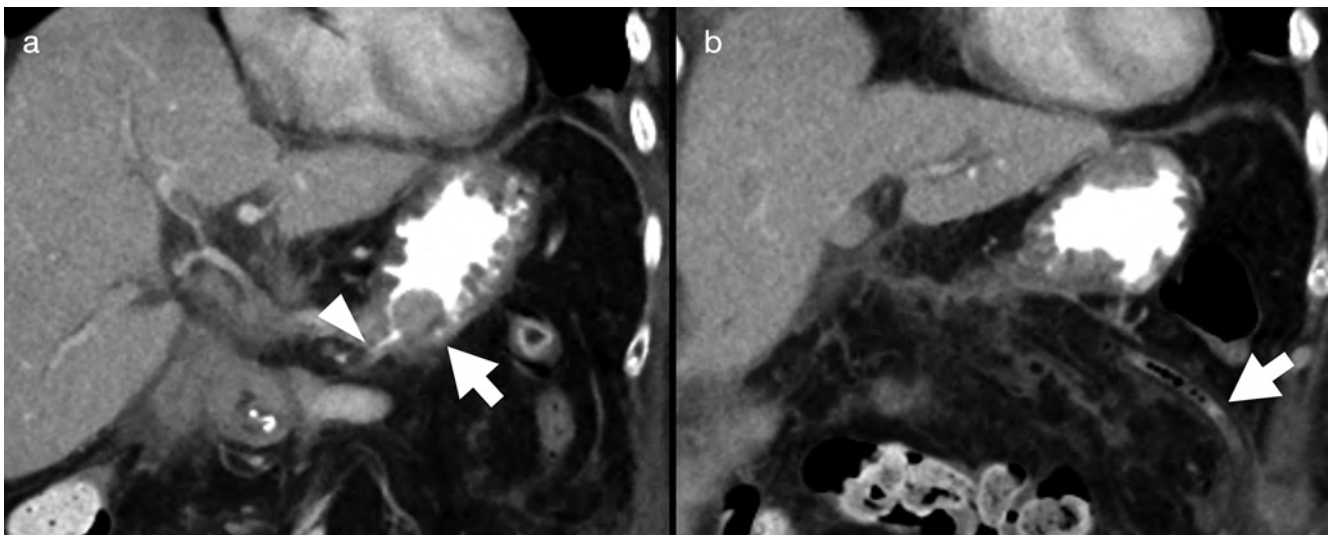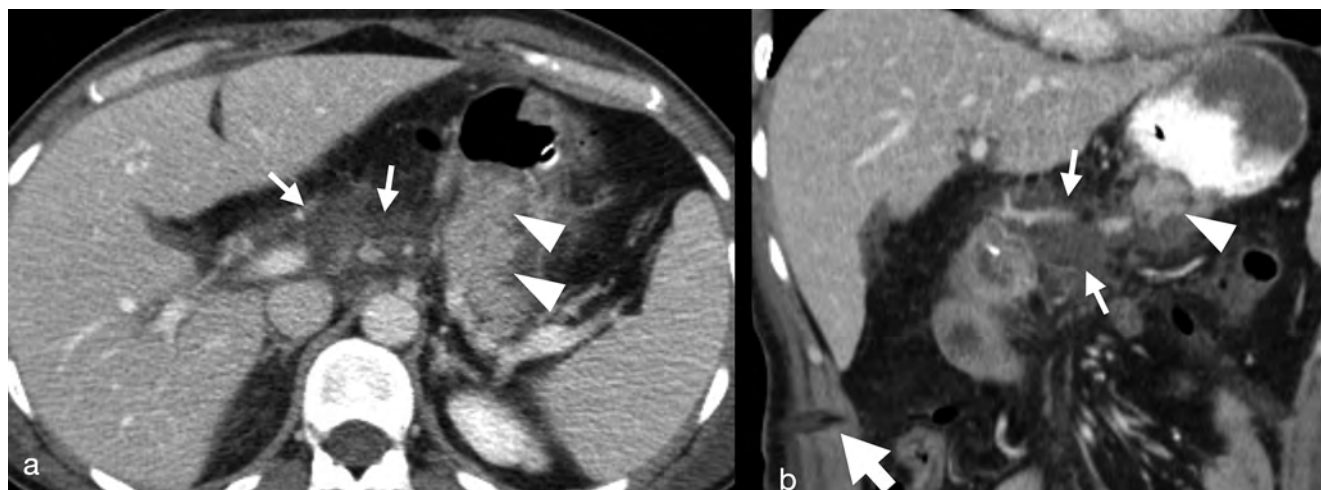

▶ **Fig. 5** Patient after PPPD and pancreaticogastrostomy with persistent pancreatic fistula and elevated amylase in the drainage fluid. **a** Coronary reformation of a CT scan after oral contrast administration. The pancreas is visible as a protrusion in the gastric lumen (arrow). A fine contrast medium extraluminate lies at the level of the anastomosis (arrowhead). **b** Contrast medium leakage via the indwelling drain (arrow).

drain placement since revision surgery is associated with a high complication rate and mortality of up to 60 % [1].

Biliary fistula

Insufficiency of a biliodigestive anastomosis is primarily the result of surgical-technical problems. It is diagnosed clinically when the bilirubin concentration in the drained fluid is three times higher than the normal serum bilirubin concentration three days after surgery. The incidence is between 3 % and 9 % of patients with hepaticojejunostomy [1]. Patients show clinical signs of biliary peritonitis and homogeneous fluid collections on CT (▶ **Fig. 6**) prima-

rily in the vicinity of the biliodigestive anastomosis [12]. Finally, reliable differential diagnosis between biliary fistula and pancreatic fistula on imaging is difficult without a clinical correlation due to the close vicinity to the anastomoses. Treatment must be determined on an interdisciplinary basis. In addition to creation of a new biliodigestive anastomosis, an attempt can be made to cure the fistula after the fluid is drained via CT-guided drainage or by percutaneous transhepatic cholangiodrainage (PTCD).

▶ **Fig. 6** Patient after PPPD and pancreaticogastrostomy. Elevated bilirubin concentration in the drained fluid on day 5. **a** The pancreas (arrowhead) inserts into the posterior wall of the stomach. Some fluid is evident perigastrically and peripancreatically. Fluid retention at the porta hepatis and between the vena cava and the aorta (small arrows). **b** Fluid is seen next to a jejunal loop and along the course of the extrahepatic portal vein (small arrow) in the coronary reformation. A surgical drain is depicted caudal to the liver (arrow).
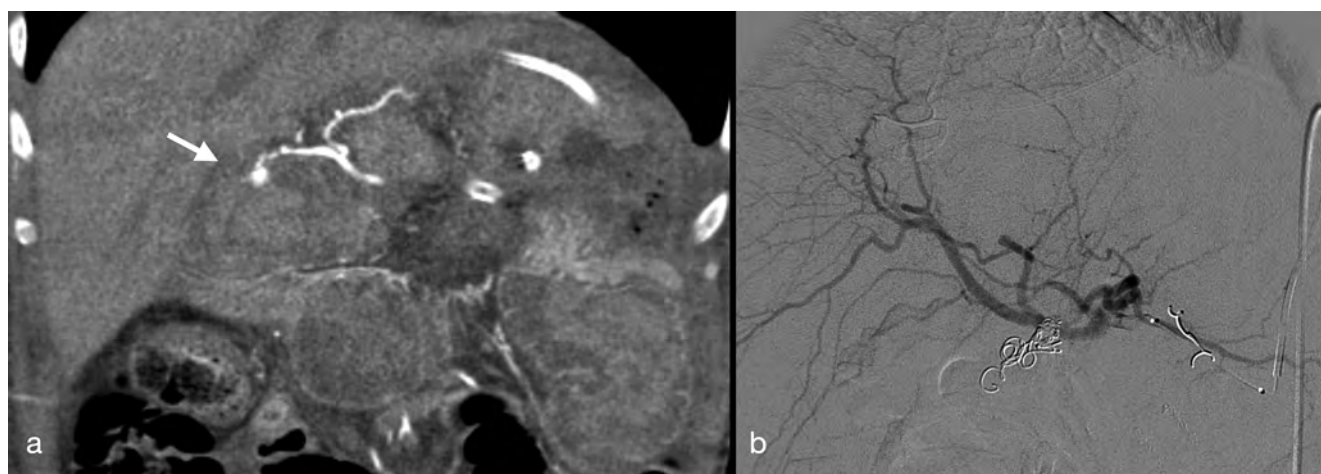
▶ **Fig. 7** Patient after PPPD with active bleeding via the drain. **a** CT in arterial phase shows a false aneurysm (arrow) at the origin of the cystic artery with surrounding hematoma. **b** The bleeding was successfully controlled by coil embolization.

Postoperative bleeding

Bleeding occurs in 2–16 % of cases and is a serious complication with a high mortality rate [9, 28]. In a prospective study, relevant bleeding complications were seen in 9 % of pancreaticogastrostomies compared to 4 % of pancreaticojejunostomies [18]. Early postoperative bleeding complications within 24 hours of the intervention are usually due to surgical-technical problems and are typically treated surgically [29]. Later bleeding due to inflammatory vascular erosion or pseudoaneurysms (▶ **Fig. 7**) is rarer (1.5–5 %) but more complicated with a mortality rate of greater than 60 %. Extraluminal retroperitoneal bleeding with blood loss via the drainage tube is most common. Intraluminal bleeding is rarer and manifests as hematemesis or melena. On non-contrast CT, bleeding is visible as an intraluminal or extraluminal fluid collection with increased density. A pseudoaneurysm or extravasation can be detected on contrast-enhanced imaging [24]. Late bleeding is often also treated surgically. Particularly in the case of hemodynamically stable patients, interventional treatment should be attempted due to the high technical success rate and the 50 % lower mortality rate [30–32].

Circulatory disorder

Ischemic complications are usually the result of surgery-related occlusion of the hepatic artery or the celiac trunk or more rarely the portal vein [33]. Increasing age of surgical patients results in an increase in the prevalence of arteriosclerotic vascular changes with involvement of the celiac trunk or the inferior mesenteric artery and thus the risk for postoperative intestinal ischemia or hepatic infarction even without intraoperative vascular occlusion [12]. A hepatic infarction is seen as a non-contrast-enhanced par-
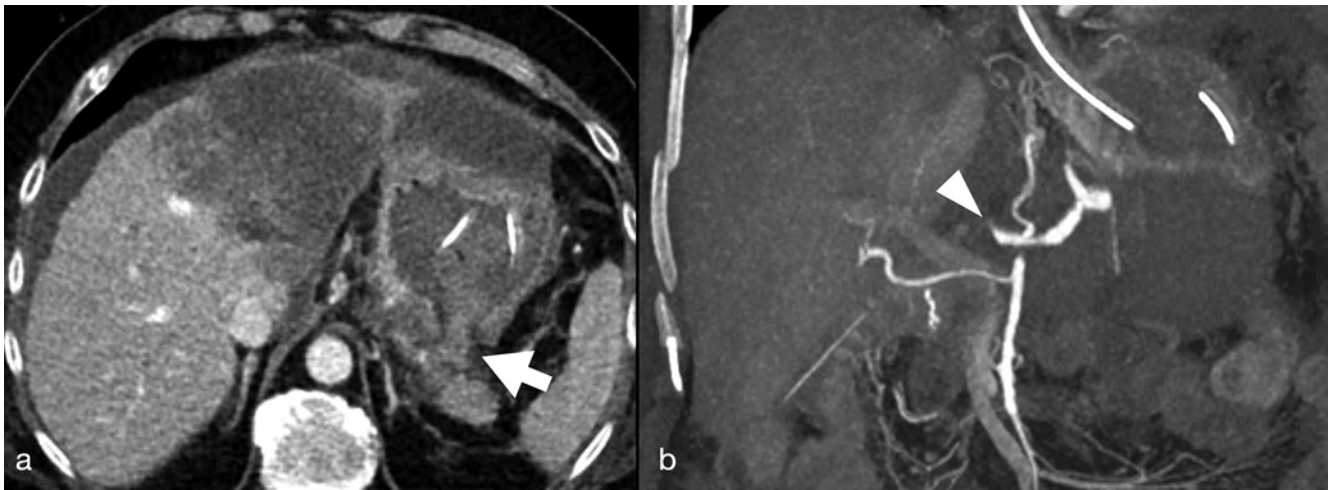
▶ **Fig. 8** Patient with signs of inflammation and liver failure on day 10 after PPPD and pancreaticogastrostomy. **a** Axial contrast-enhanced CT in portal venous phase showing hypodensity of the functional left hepatic lobe and free fluid ventral to the liver. The residual pancreas inserts into the posterior wall of the stomach (arrow). **b** MIP reconstruction of the arterial phase. The common hepatic artery is ligated proximal to the gastro-duodenal artery (arrowhead). The left hepatic artery is not perfused. The arterial supply to the right lobe of the liver is via the right hepatic artery with the origin from the superior mesenteric artery.

enchyma typically extending to the liver capsule without signs of a space-occupying lesion (▶ **Fig. 8**).

Abscesses

An abscess is usually the result of a superinfection of an undrained or insufficiently drained pancreatic fistula and can be diagnosed on imaging as a fluid collection with a thickened and enhanced wall in a patient with signs of infection. The incidence is around 6 % [1, 9, 24]. The treatment of choice is CT-guided puncture and percutaneous drainage.

Impaired gastric emptying

With up to 60 %, impaired gastric emptying is the most common complication after pancreatic head resection [12]. Current data from a German registry (StuDoQ Pancreas Registry) including 5080 patients yielded an incidence of 20.6 % for postoperative impaired gastric emptying [14]. Risk factors for the development of postoperative impaired gastric emptying were advanced age, long operation duration, and reconstruction with pancreaticogastrostomy. The term impaired gastric emptying is used when a patient cannot consume any solid food a week after surgery, or the patient has not been able to fully return to solid food by the 14th day after surgery. Impaired gastric emptying is detected endoscopically or dynamically under fluoroscopy as small bowel transit using a water-soluble contrast agent (▶ **Fig. 9**). CT can be performed to rule out a pancreatic fistula or an abscess.

Late complications

With a frequency of 4–8 %, the most common late complication is a stricture of the pancreaticojejunostomy or the hepaticojejunostomy due to scarring with a frequency of 4–8 % [24]. CT shows dilation of the intrahepatic bile ducts or the pancreatic duct with increasing parenchymal atrophy of the remaining pancreas. MRI

▶ **Fig. 9** Dynamic gastric contrast study using fluoroscopy with oral application of a water soluble contrast agent on the seventh day after PPPD in a patient with vomiting. The stomach is distended and atonic. The contrast medium is slowly emptying into the attached jejunum.
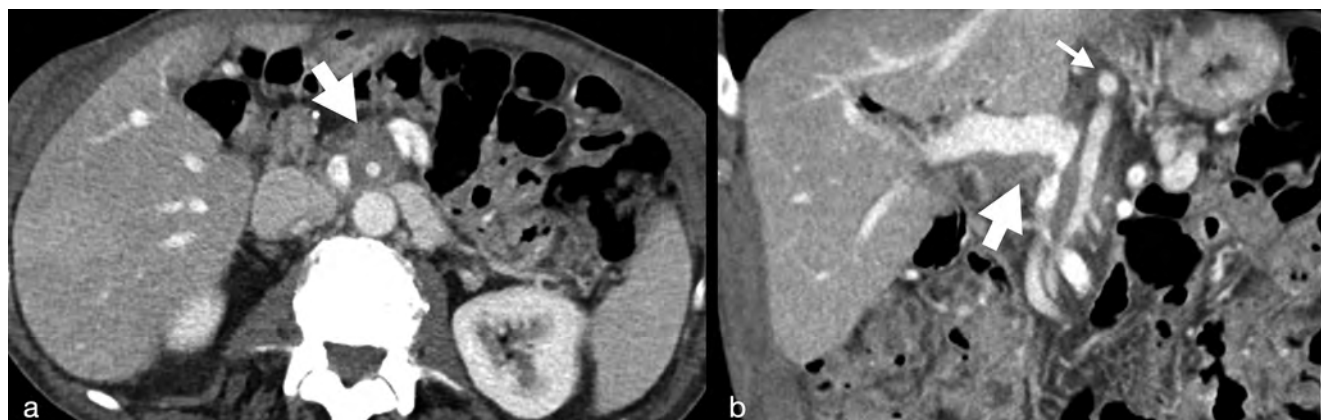
► **Fig. 10** Patient three years after PPPD and new weight loss. **a** Axial CT shows soft tissue around the superior mesenteric artery (arrow). **b** Coronary reformation depicts the extensive tumor recurrence along the superior mesenteric artery and at the level of the venous confluence with obstruction of the superior mesenteric vein. The celiac trunk is also encased (small arrow).

with MRCP is the most suitable method for visualizing the ducts and anastomoses. Fibrosis must be differentiated from a duct obstruction due to tumor recurrence. Local recurrence is seen in one third of cases. Infiltrating growth of soft tissue in the pancreatic bed in the region of the anastomoses or around the superior mesenteric artery or the celiac trunk is a typical finding (► **Fig. 10**). New lymph node enlargement is also suspicious for lymphogenic recurrence. Distant hematogenous metastases primarily affect the liver and later the lungs.

Conclusion

Globally, pancreatic cancer has one of the worst prognoses and only few patients can be treated surgically or with a curative approach at the time of diagnosis. Major pancreatic surgery continues to be associated with a high morbidity rate [18], with early detection of complications and inclusion of interventional-radiological options being essential for targeted complication management [3, 4]. Imaging is an important part of the postoperative evaluation of complications after pancreatic resection. Due to the fast examination and the good spatial and contrast resolution, CT continues to be the most important and best method particularly for early postoperative imaging, making it possible to respond quickly, safely, and successfully to potentially life-threatening complications. The interpreting radiologist must be familiar with the postoperative anatomy, normal postoperative findings, and manifestation of typical complications. Many imaging findings must be interpreted in the clinical context and together with the laboratory results, particularly when diagnosing anastomotic insufficiency. Therefore, close collaboration between radiology and visceral medicine is essential for good management. In the case of persistent fistulas or abscesses as well as in the case of bleeding complications, interventional radiology treatment options are characterized by high efficiency with a low complication rate.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgement

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