Percutaneous Biopsy and Drainage of the Pancreas

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Abstract

Percutaneous biopsy and drainage of pancreatic lesions, though less frequent due to advancements in endoscopic techniques, remain vital skills for interventional radiologists. This review details the indications, options, approaches, and technical considerations for pancreatic biopsy and (peri)pancreatic fluid drainage by examining a comprehensive range of literature. The importance of a multidisciplinary approach is emphasized to ensure optimal patient care and outcomes, highlighting current best practices and recent advancements.

Keywords

- pancreatic biopsy
- pancreatic cancer
- pancreas rejection
- percutaneous drainage
- interventional radiology

Pancreatic Biopsy

Percutaneous image-guided biopsy is a procedure performed daily by interventional radiologists. Biopsy of pancreatic lesions percutaneously has become less frequently requested with the development and improvement of endoscopic ultrasound (EUS) techniques. However, it is still important for interventional radiologists to be familiar with percutaneous approaches to access pancreatic lesions. Some centers do not have gastroenterologists who perform EUS, and even in those who do, not every lesion is accessible by EUS due to its location in the pancreas or surgically altered anatomy. Additionally, in the case of a nondiagnostic EUS, a larger biopsy needle than what is available endoscopically may be needed to obtain an adequate specimen on the repeat biopsy. A clear understanding of the advantages and disadvantages of both techniques is important to deliver the best care to patients.

Endoscopic Biopsy

Pancreatic cancer continues to carry a high mortality rate, with surgery and chemotherapy as the main treatments. The majority of patients present with borderline resectable or unresectable lesions. In this age of personalized medicine, adequate tissue samples for precision treatment are important prior to any neoadjuvant or palliative chemotherapy. For the small minority of potentially resectable patients, a definitive diagnosis is essential prior to surgery to avoid unnecessary operations in patients with chronic pancreatitis, autoimmune pancreatitis, or lymphomas.[1–3]

The advent of EUS-TA (tissue acquisition) techniques, which have high diagnostic accuracy for pancreatic primary tumors, has become the mainstay for diagnosis. Information obtained by EUS may help with staging as well. Information such as tumor involvement of the portal system, characterization of locoregional lymph nodes, and diagnosis of small amounts of ascites may be obtained by EUS.[4]

It is important for interventional radiologists to understand the EUS biopsy terminology and the capabilities of the EUS techniques to provide meaningful consultation and appropriate care to patients. EUS-TA can be divided into two types, EUS-FNA (fine needle aspiration) and EUS-FNB (fine needle biopsy), a term that is different from the IR literature. FNA refers to biopsies that are performed with 22- to 25-gauge Menghini needles, which have a similar tip to a Chiba needle. EUS-FNB refers to biopsies performed with more recently developed needle tips for EUS, such as Franceen and Forked, which are 22 gauge or larger. However, needles larger than 22 gauge are stiffer and more difficult to maneuver through the scope.[5] The literature refers to these as "core biopsy" specimens, which is a different technique

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from a core biopsy specimen obtained with a biopsy gun, as is typical for percutaneous biopsies. ►**Table 1** illustrates a summary of the two techniques.

A meta-analysis of the performance of these newer-generation EUS-FNB needles (forked and crown) demonstrated excellent diagnostic accuracy of 96% for solid pancreatic lesions.[6] There is insufficient evidence to recommend a specific number of needle passes to allow for genomic testing and personalized medicine. However, the likelihood of obtaining a specimen adequate to do so was found to be higher with EUS-FNB than with EUS-FNA (90.9 vs. 66.9%; $p = 0.02$) as demonstrated in a retrospective study from 2019. The most notable difference was present in tumors 3 cm or smaller.[7] The same study demonstrated no significant difference in the adequacy of samples obtained with ROSE (rapid on-site evaluation) available versus not available. A small randomized controlled trial of EUS-FNA versus EUS-FNB for pancreatic and nonpancreatic lesions published in 2022 demonstrated a significant improvement in the quality of the histological specimen of FNB over FNA.[8] In contrast, gross visual inspection of the sample by the endosonographer (macroscopic on-site evaluation or MOSE) has been found to correlate positively with the adequacy of the specimen if a core is identified,[9–11] and with adequacy for next-generation sequencing (NGS) if that core is 30 mm or greater.[12]

Percutaneous Biopsy

Although EUS-TA has become the first line for pancreatic biopsy, smaller or more rural institutions may lack access to advanced endoscopists, which could delay diagnosis and care. There are also situations when percutaneous biopsy may be preferred due to patient factors, such as surgically altered anatomy (e.g., gastric bypass, Billroth 2, previous pancreaticoduodenectomy, or Whipple procedure), in patients where comorbidities significantly increase the risk of the general anesthesia required for endoscopy, or the location of the lesion in a particular patient is not accessible from the gastrointestinal tract (e.g., some lesions of the body and tail, or pancreatic transplants).[13]

Accessing pancreatic lesions directly can be challenging, but the transorgan approach, particularly with FNA, has proven to be safe and effective (►**Fig. 1**). There may be hesitancy on the part of some interventional radiologists to perform biopsies via a transorgan or transmesenteric approach. However, these image-guided approaches were well described by Sundaram et al in a 1982 case series, using a 20-gauge FNA needle with minimal complications.[14] It is also important to note that EUS-TA always involves the transgression of the bowel, yet complications are low.[5] A 2009 article reported a coaxial 17-gauge cannula/18-gauge percutaneous core biopsy of nine pancreatic lesions obtained

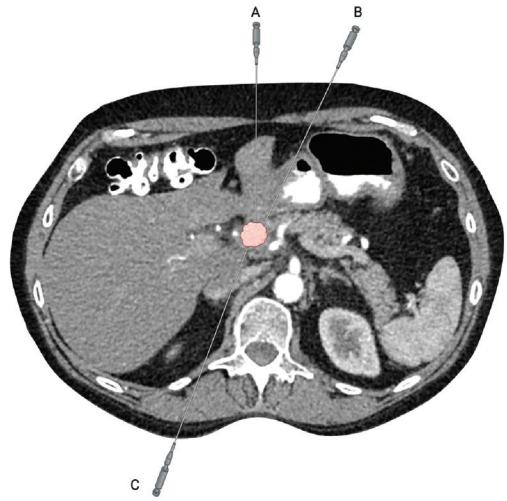

Fig. 1 Axial CT of the upper abdomen showing a pancreatic head mass and various transorgan fine-needle aspiration approaches. A indicates the anterior transhepatic approach, B indicates the anterior transgastric approach, and C indicates the posterior approach. (Created with BioRender.com.)

Table 1 Comparison between EUS-FNA and EUS-FNB

	EUS-FNA	EUS-FNB
Recommended needle caliber	22–25 gauge	22 gauge or thicker
Recommended negative pressure	Suction or wet suction	Stylet retraction
Recommended puncture technique	Fanning or DKM	Fanning or torque
Recommended number of needle passes	1–3 times for histological diagnosis, depending on site and size	Three times for NGS
Diagnostic accuracy	FNB $\geq$ FNA	FNB $\geq$ FNA
Tissue volume	FNB $\geq$ FNA	FNB $\geq$ FNA
Suitability for NGS	FNB $\geq$ FNA	FNB $\geq$ FNA
MOSE	Recommended for use in combination	Recommended for use in combination
Complications	Rare	Rare
Cost-effectiveness	FNB $\geq$ FNA	FNB $\geq$ FNA

Abbreviations: DKM, door knocking method; EUS, endoscopic ultrasound; FNA, fine-needle aspiration; FNB, fine-needle biopsy; MOSE, macroscopic on-site evaluation; NGS, next-generation sequencing.
Source: adapted from Masuda et al.[5]

via transgastric access with no incidence of peritonitis and only one asymptomatic self-limited pneumoperitoneum.[15] Another series from 2015 of CT-guided core biopsies of pancreatic lesions demonstrated an 8.7% complication rate, all self-limited, consisting of retroperitoneal and subcapsular hepatic hematomas as well as symptomatic and asymptomatic pancreatitis.[16] A large retrospective study of US-guided FNA published in 2016 reviewed more than 2,000 cases over 10 years and found a complication rate of 0.8%.[17]

A recent retrospective study comparing percutaneous core needle biopsy (CNB) and percutaneous FNA methods with CT guidance demonstrated similar diagnostic efficacy and safety for solid pancreatic lesions by either method. Accuracy ranged from 95.31 to 100% between the groups ($p = 0.6$). Core biopsy was specifically avoided when the lesion was <1.5 cm from major blood vessels, and one to two specimens were obtained for CNB, with three to five specimens for FNA. Some patients in both groups had access obtained through the liver and stomach, but only the FNA group had transintestinal access. The authors recommend the avoidance of normal pancreatic tissue and puncture of the pancreatic duct, as the most common complications were found to be hyperamylasemia (asymptomatic), abdominal pain, and low-grade fever, with no symptomatic pancreatitis and the same incidence in both groups. Some of the specimens were sent for next-generation sequencing from both groups, and all specimens sent were adequate for this purpose.[18]

Another recent study comparing percutaneous ultrasound (US) and EUS-guided pancreatic solid lesion biopsies found diagnostic accuracy of 89.8% for EUS-FNA and 95.2% for US-CNB/FNA ($p = 0.001$), with the caveat that EUS-FNA performed better for hypoechoic lesions, lesions <2 cm, and lesions in the uncinate process.[19]

A study comparing the newer EUS-FNB needles and techniques with percutaneous image-guided CNB/FNA biopsy has yet to be published but would be helpful for a direct comparison of performance. Additionally, advances in diagnostic imaging in recent years could potentially influence results by improving lesion visibility for access. For these reasons, older studies or those with long retrospective data collection may no longer reflect current capabilities. The studies referenced earlier demonstrate a high level of diagnostic accuracy and safety for the newest techniques, both endoscopic and percutaneous, and so it makes sense that the selection of the appropriate technique for tissue acquisition should ideally be multidisciplinary and dependent on the patient/lesion anatomy, comorbidities, availability of imaging, and advanced techniques, as well as expertise. This will be very institution dependent.

As with any percutaneous image-guided biopsy, routine preprocedure workup should include a review of history and imaging as well as medications (some of which may affect coagulation), and laboratory assessment of platelet count and PT/INR. According to the 2019 SIR Standards of Practice guidelines, pancreatic biopsy, as with any deep organ biopsy, is in the "high-risk" category for bleeding, and requires a platelet count of 50×10^9/L and an INR less than 1.8, based on the existing standard for major surgery.[20] Patients are typically nothing by mouth for the safe administration of conscious sedation and reducing the risk of gas obscuring the pancreas if the procedure is to be performed under US guidance. Postprocedure observation times vary, but many centers observe for 3 to 4 hours.[13] At our institution, postprocedure observation might be shortened to 1 to 2 hours for direct access FNA without immediate complications.

The approach may vary based on anatomy. With CT guidance, in addition to the usual supine or prone positioning, changing the patient's position to oblique or decubitus may displace structures like the colon, allowing direct lesion access (►**Fig. 2**). Additionally, hydrodissection or pneumodissection techniques may also be used to displace structures to obtain direct access to a lesion.[13,16]

For the special situation of pancreatic transplant biopsy, the allograft is typically more superficial than a native pancreas, and easily accessed by US in most patients. The transplant is anastomosed to a loop of the bowel or the bladder, often accompanied by a renal transplant. Allograft biopsy is critical for the accurate diagnosis and treatment of rejection.[21] An 18-gauge core biopsy of the body or tail, directed longitudinally away from the head/vessels, is preferred with low complication rates reported.[21]

Percutaneous Drainage in Pancreatitis

Introduction

Acute pancreatitis (AP) is a common cause of hospital admission. The severity is variable, and prompt diagnosis and stratification of severity are important for timely and appropriate management.[22] The revised Atlanta classification (RAC) is an international consensus that classifies severity as mild, moderate, or severe depending on systemic complications and organ failure (OF), and has been shown to reliably predict outcomes based on the assessment of the physiologic status.[23,24] Additionally, the RAC divides pancreatitis into two types: interstitial edematous pancreatitis (IEP) and necrotizing pancreatitis (NP), and describes the imaging findings of both (►**Table 2**).

Most patients with AP develop IEP, which on contrast-enhanced CT (CECT) shows relatively homogeneous enhancement and some inflammatory haziness or stranding in the peripancreatic fat. Patients may develop fluid or fluid collections (to be described later). Symptoms usually resolve within a week, which is considered the acute phase, in the majority of patients.[25] ►**Fig. 3** juxtaposes the CT appearances of IEP and necrotizing pancreatitis-related fluid collections in different patients, illustrating their distinct imaging features and progression.

About 5 to 10% of patients develop NP, which is necrosis of portions of the pancreas and/or peripancreatic tissues. Necrosis may involve only the peripancreatic tissues in up to 20% of cases.[26] Imaging is most useful for identifying necrosis and local complications after 5 to 7 days.[27] Changes in perfusion may be patchy and heterogeneous in the early phase, but any nonenhancing area in the pancreas after the first week is considered necrosis.[23] Peripancreatic necrosis contains heterogeneous fluid and solid components on

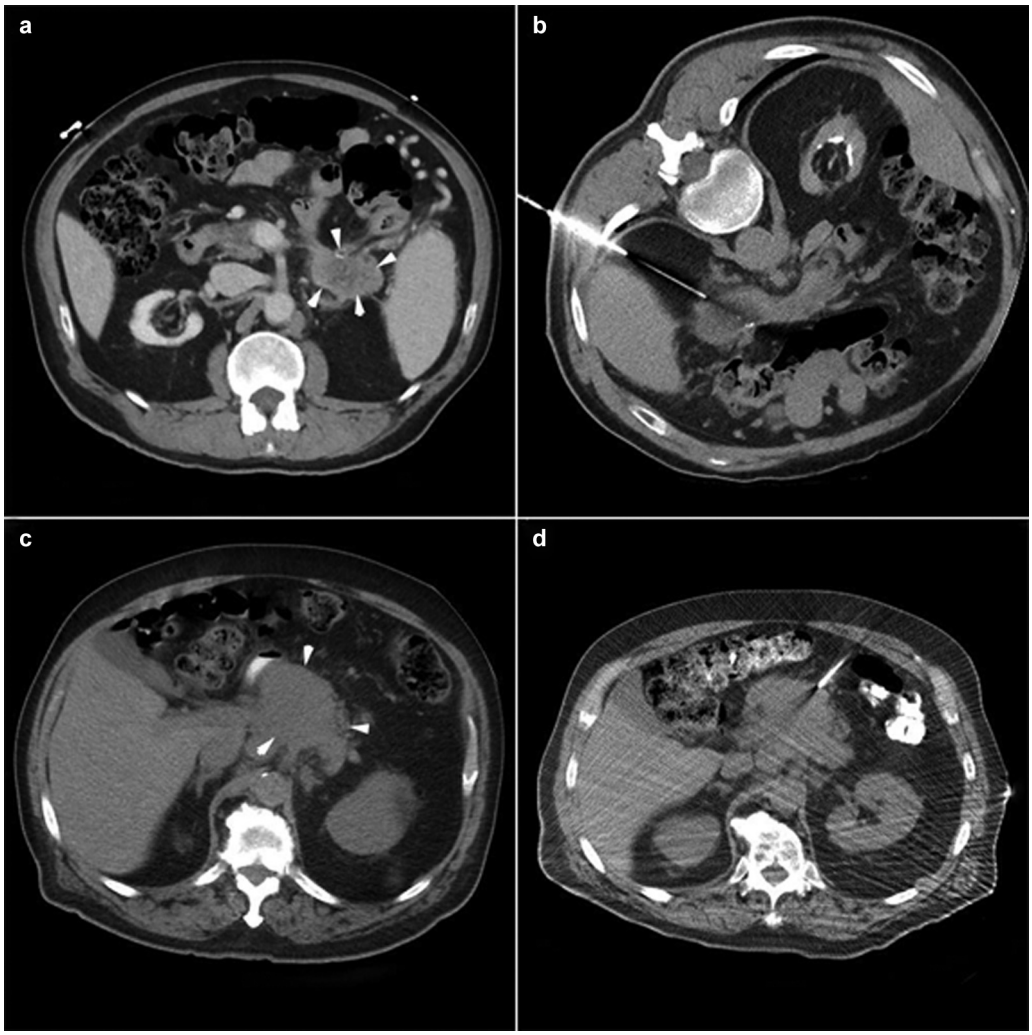

Fig. 2 (**a**) A 53-year-old male with a history of chronic pancreatitis presented with abdominal pain and was found to have a pancreatic tail mass (outlined by white arrowheads). (**b**) Core biopsy was performed in the left anterior oblique position, with the needle placed through a posterior approach. (**c**) A 78-year-old male presented with abdominal pain and was found to have a pancreatic neck/body mass (outlined by white arrowheads). (**d**) Core biopsy was performed supine, with the needle inserted through a left anterior lateral approach.

Table 2 Summary of pancreatitis-associated fluid collections as per revised Atlanta classification

	Interstitial edematous pancreatitis	Necrotizing pancreatitis
< 4 wk	**Acute (peri)pancreatic fluid collection**	**Acute necrotic collection**
	Homogenous fluid adjacent to the pancreas without a recognizable wall	Intra- and/or extra-pancreatic necrotic collection without a well-defined wall
≥4 wk	**Pancreatic pseudocyst**	**Walled-off necrosis**
	Encapsulated, well-defined, (peri)pancreatic fluid collection with minimal solid debris	Intra- and/or extra-pancreatic necrotic collection with a well-defined wall

Source: Adapted from Banks et al.[23]

CECT.[27] The natural history of this necrotic pancreatic and/or peripancreatic tissue is variable and dictates the need for interventions.[23]

The chronic phase of pancreatitis starts around the second week in patients with moderately severe or severe pancreatitis who may have persistent OF and/or local complications and may last for weeks to months.[23] Complicated pancreatic disease often requires a multidisciplinary approach involving surgeons, gastroenterologists, interventional radiologists, and critical care specialists to improve outcomes.[28]

Pancreatic and Peripancreatic Fluid Collections

Pancreatis-associated fluid collections are currently classified into four types based on their duration (acute if they are <4 weeks or chronic if >4 weeks) and the presence of necrosis.[23,28] IEP may lead to an acute peripancreatic fluid

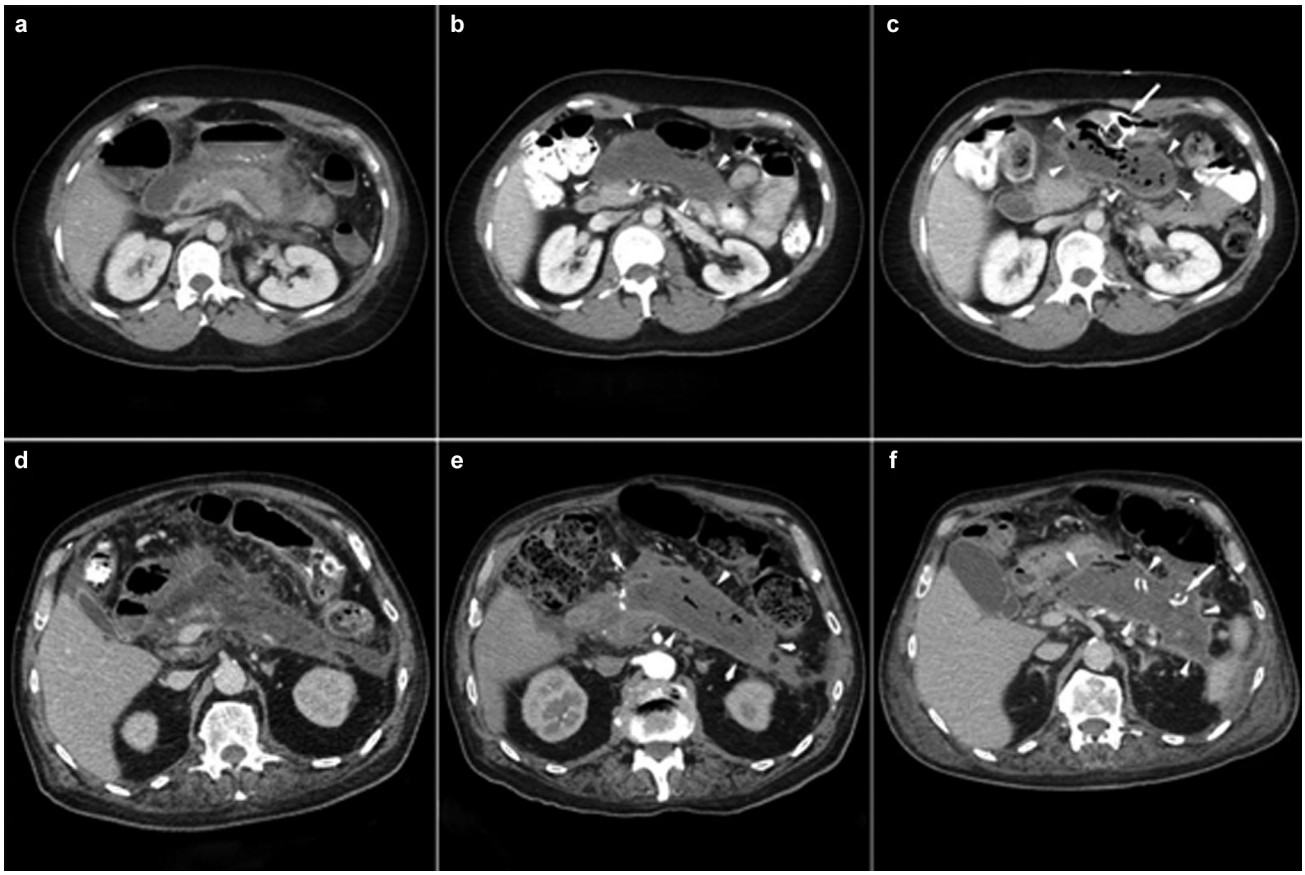

Fig. 3 (**a–c**) A 50-year-old female presented with pain and fever after laparoscopic cholecystectomy. (**a**) The pancreas is intact and enhancing; acute interstitial edematous pancreatitis was diagnosed. Amorphous fluid surrounding the pancreas without a well-defined wall is known as an acute peripancreatic fluid collection. (**b**) Two months later, this evolved into an encapsulated fluid collection without much internal debris, known as a pancreatic pseudocyst (outlined by white arrowheads). (**c**) She underwent successful lumen-apposing metal stent endoscopic drainage (AXIOS stent indicated by the white arrow). (**d–f**) A 76-year-old male presented with abdominal pain. (**d**) Nonenhancement of part of the pancreas with (peri) pancreatic debris without a defined wall, known as an acute necrotic collection. (**e**) Two months later, there is a wall encapsulating the internal debris and air suspicious of superimposed infection, known as walled-off necrosis (outlined by white arrowheads). (**f**) Necrotic region (white arrowheads) successfully with prolonged large-bore percutaneous drainage (white arrow) via a lateral approach.

collection (APFC) or a pseudocyst depending on chronicity, containing fluid only. NP may lead to an acute necrotic collection (ANC) or walled-off necrosis (WON) depending on chronicity.[23,27]

Any of these collections can become infected, but infection is more common with necrosis, occurring in 20 to 40% of patients. For ANC, 6% will get infected, and 38% will progress to WON after 4 weeks, with the rest resolving. Of those progressing to WON, 21% will get infected, 59% will resolve, and the rest will develop chronic sterile collections.[29] Most patients with sterile necrosis can be managed nonoperatively unless symptomatic, in which case a 4-week or longer timeframe is recommended for intervention.[30] However, patients with infected necrosis require intervention, which may be percutaneous, endoscopic, or open surgical.[31]

Nonpancreatic sites of infection tend to occur earlier than pancreatic or peripancreatic infections and should be treated based on cultures if present.[32] Aspiration to confirm infection of a pancreatitis-associated collection is not advocated as standard practice because clinical (persistent fever and rising inflammatory markers) and imaging signs (gas in the collection on CT) are accurate predictors, and there is a significant risk of false-negative results with FNA, and the risk of infecting a previously sterile collection.[30,31,33,34]

Intervention for infection in pancreatic fluid collections should follow a step-up management protocol. The first step is broad-spectrum antibiotics.[30,31] If the patient deteriorates despite antibiotics, drainage is indicated. Ideally, invasive intervention should be delayed until at least 4 weeks after the onset of pancreatitis to allow collections to become walled-off,[30,31,34–37] though this may not be possible if clinical deterioration occurs.[35,37]

There are multiple guidelines published on the subject, with some variability in recommendations on the approach to drainage.[30,31,34–37] The common theme is the preference for drainage after 4 weeks to allow for encapsulation. Mortality after transmural endoscopic drainage (ED) was shown to decrease as the time from hospital admission increased (014 days: 56%; 14–29 days: 26%; >29 days: 15%; $p < 0.001$).[38] A meta-analysis comparing four studies in which surgery was held off until 30 days after presentation demonstrated a fourfold decrease in mortality.[36]

A recent meta-analysis of 11 retrospective studies (1990–2022) evaluated 775 patients with early interventions and

725 patients with delayed interventions. Early intervention patients tended to be complicated by OF. The studies included endoscopic, percutaneous, and surgical interventions as the initial procedure, and although the adverse event rates were comparable ($p = 0.38$), mortality was significantly higher ($p < 0.01$) with early interventions.[39] Another meta-analysis found significantly increased mortality in NP with OF.[40] Additionally, the clinical practice of treating acute pancreatitis has evolved recently, and now includes recommendations for early enteral feeding, avoidance of prophylactic antibiotics, resuscitation, a consistently more conservative approach to infected necrosis with delayed intervention (whether endoscopic or surgical), management of biliary pancreatitis, and abdominal compartment syndrome.[31,37,41] The details of all these treatment recommendations are beyond the scope of this review, and older studies may not reflect these improved management strategies.[37]

The POINTER Trial, a randomized control trial (RCT) published in 2021, compared immediate versus postponed intervention for infected NP, randomized subjects immediately upon diagnosis of infected necrotic pancreatic fluid collection, and hypothesized that early drainage patients would have better outcomes. Interventions included percutaneous or ED. If unsuccessful, drains were upsized, followed by either endoscopic necrosectomy or videoscopic-assisted retroperitoneal debridement. The study demonstrated that 39% of the delayed drainage group resolved with antibiotics alone and did not require drainage. Those who had procedures had similar complications, but the delayed drainage group had significantly fewer interventions.[42] This further supports delayed intervention whenever possible, as advocated by multiple guidelines.

However, early drainage may be appropriate in certain situations. An RCT evaluated on-demand drainage versus standard drainage in ANC with persistent OF.[43] The authors reported a preliminary trend toward decreased mortality, complications, and OF in the early drainage group. These trials suggest early intervention is not as detrimental as previously thought and should be considered in cases of persistent sepsis and OF. Similar findings were reported in another recent RCT.[44]

Ultimately, management of fluid collections in pancreatitis patients requires a multidisciplinary approach and should take into account local expertise and individual patient circumstances. Delayed intervention is preferred, whenever possible, with early drainage indicated when clinically necessary, following the step-up approach. As an adjunct, abdominal paracentesis performed at the time of percutaneous drainage (PCD) has shown benefits in reducing all-cause mortality and length of stay, without increasing infection or OF.[45]

Where advanced endoscopy is available, dual-modality drainage (DMD) should be considered in patients with favorable anatomy (►**Fig. 4**). This allows for irrigation of the collection through the PCD and egresses through the ED. This approach aids in the debridement of WON[46] and early removal of the PCD, which may decrease the risk of pancreatic fistula formation.[46,47] The newer lumen-opposing metal stent (LAMS) placed endoscopically, being larger caliber, allows for better egress of debris, leading to improved outcomes.[47,48] One study comparing DMD to PCD demonstrated improved outcomes in the DMD cohort, with shorter length of stay, shorter time to PCD removal with no pancreatic fistula formation, fewer CTs, fewer ERCPs, and no need for surgical necrosectomy.[48]

Irrigation Technique Variations for Percutaneous Catheters

While it is standard practice to flush PCDs with normal saline solution (NSS) for any infected collection, flushing large collections with necrotic debris can be challenging. One group published a flushing protocol using two adjacent catheters to allow for flushing into one and drainage from the other. Eight out of ten patients did not require necrosectomy.[49] Another group published a study with the placement of two adjacent catheters through a larger tube for flushing into one and drainage from the other, with debridement via scope versus a single PCD with open debridement. They demonstrated lower mortality, major complications, and new-onset OF in the double-catheter cohort.[50] A third group published an RCT comparing large-volume lavage with warmed NSS through a single catheter, followed by dependent drainage (DD) the rest of the day, to standard DD alone. The lavage group received 250 mL of NSS over 1 to 2 hours, with volume escalation over 3 to 4 days if the catheter returned at least 70% of the volume. This was done for 2 weeks and resulted in a significant reversal of OF.[51] Instillation of antibiotic solutions into PCDs has not been published but has shown some benefit with earlier clearing of cultures in ED versus systemic antibiotics,[52] warranting further investigation.

Two recent studies published by the same group reported on adding necrolytic agents through a PCD in WON. The first compared two doses of streptokinase to NSS flushing in a retrospective analysis. Reversal of sepsis was higher in the streptokinase group, with lower mortality and the need for necrosectomy. The higher dose of streptokinase (150,000 IU diluted in 100 mL of NSS infused over 60 minutes) resulted in lower rates of necrosectomy, bleeding, and mortality compared with the 50,000-IU dose.[53] The second study compared the lower dose of streptokinase to hydrogen peroxide (3% diluted to 100 mL with NSS) flushing, finding lower bleeding rate, mortality, the need for surgery, and length of stay in the streptokinase group, though not statistically significant.[54]

Predicting Response to Percutaneous Catheter Drainage in Acute Pancreatitis

To predict outcomes of PCD in infected pancreatic collections secondary to AP, studies have analyzed inflammatory markers. A prospective study in 2019 found lower pre-PCD levels of CRP and IL-6 in patients who improved following PCD ($p = 0.013$). Significant decreases in CRP, IL-6, and IL-10 on postoperative day (POD) 3 ($p = 0.01$) and further decreases of CRP and IL-6 on POD 7 ($p = 0.01$) correlated with outcomes.[55] Monitoring CRP and IL-6 may identify patients not responding to PCD, indicating the need to escalate treatment. The Dutch Pancreatitis Study Group analyzed factors predicting drainage success (i.e., survival without

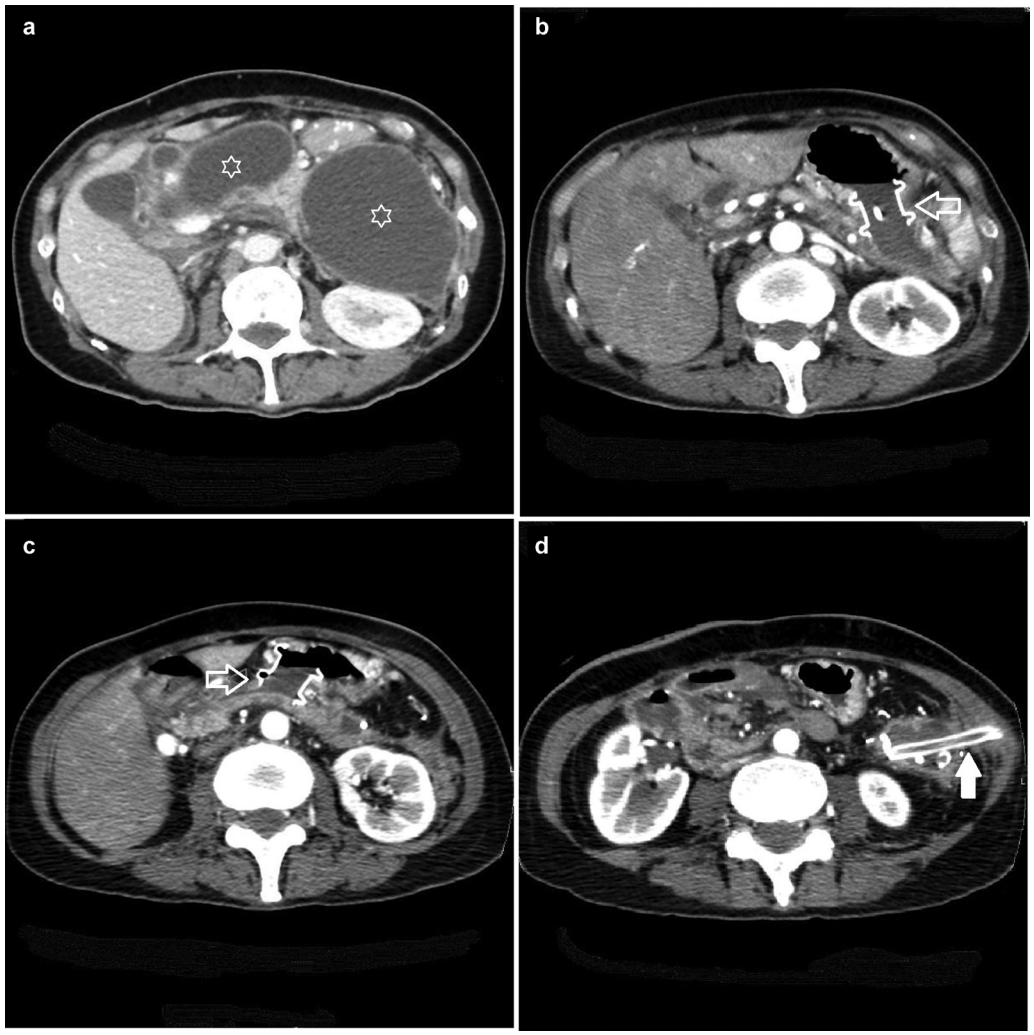

Fig. 4 (**a–d**) Patient with walled-off necrosis (WON) in a bilobed configuration producing significant compressive symptoms. (**a**) Preintervention WON (stars). (**b–d**) Images taken 2.5 weeks after dual-modality drainage with the placement of a percutaneous drain (closed arrow) and two large transgastric lumen-opposing metal stents (LAMS) (open arrows), showing significant resolution. Note the obvious connection of the WON/LAMS to the main PD due to mid-body necrosis (**c,** arrowhead).

necrosectomy) in a prospective study. Percutaneous drainage was performed in 113 patients and ED in 17 patients. Male sex, multiple OF, increased amount of necrosis, and heterogeneity of the collection were associated with reduced success.[56] A 2022 retrospective study examined 21 factors predicting successful PCD. Patients with BMI greater than 25, multiple OF, and Bedside Index for Severity in Acute Pancreatitis (BISAP) score $\geq$4 were less likely to have successful outcomes.[57]

Postoperative Pancreatic Fluid Collections

Despite advancements, pancreatic resection still has high complication rates, including fistula, leak, and abscess, leading to significant morbidity.[58–60] The International Study Group of Pancreatic Fistula defines a clinically relevant fistula as any measurable volume of output with an amylase level more than three times the upper limit of normal serum amylase for more than 3 days associated with clinical symptoms.[61] The mechanisms for leakage after pancreatic surgery differ based on the operation performed. Pancreaticoduodenectomy (Whipple procedure) leaks typically occur at the pancreatic-intestinal anastomosis or traumatized gland surface. Risk factors include small duct size, soft gland texture, nonductal adenocarcinoma, and greater than 1 L intraoperative blood loss.[62] For distal pancreatectomy, the proposed mechanism is increased in intraductal pressure due to functional obstruction at the sphincter of Oddi, possibly related to postoperative narcotic use.[63] The incidence of postoperative fistula is higher for central versus distal pancreatectomy.[64] PCD has been shown to be safe and effective for postoperative pancreatic fluid collections (POPFC), and high technical success rates are reported (►**Fig. 5**).[65,66]

Percutaneous Catheter Drainage Technique

PCD placement is generally performed under CT or US guidance. Multiple approaches were described by Lee et al in 1998, but the retroperitoneal approach is preferred to avoid peritoneal cavity contamination and bowel injury and to facilitate future VARDS if needed for AP patients (►**Fig. 6**).[67] This approach is best performed under CT.

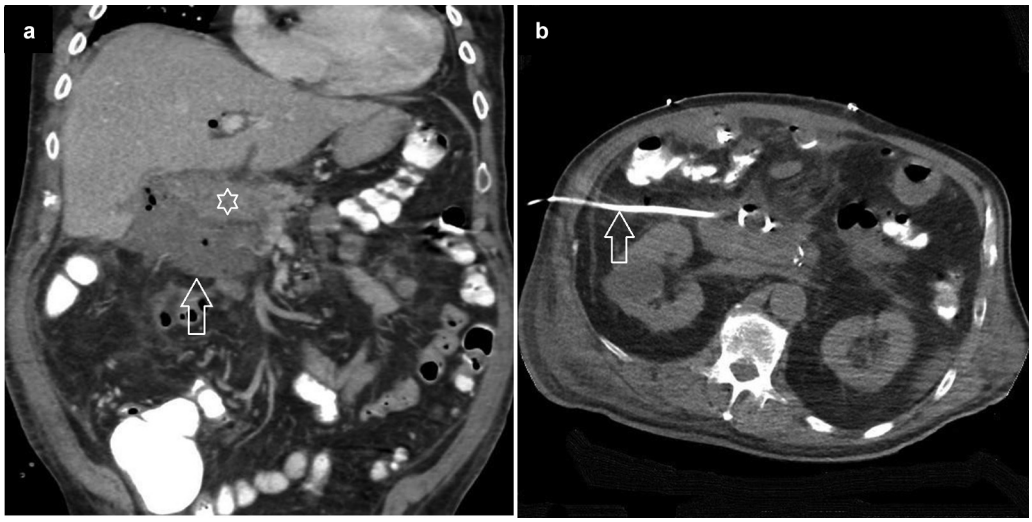

Fig. 5 Patient post pancreaticoduodenectomy with leakage at the pancreatic-intestinal anastomosis. (**a**) Coronal CT demonstrating a collection (arrow) inferior to the pancreas (star). (**b**) Axial CT demonstrating successful drain placement (arrow), avoiding the liver, colon, and right kidney.

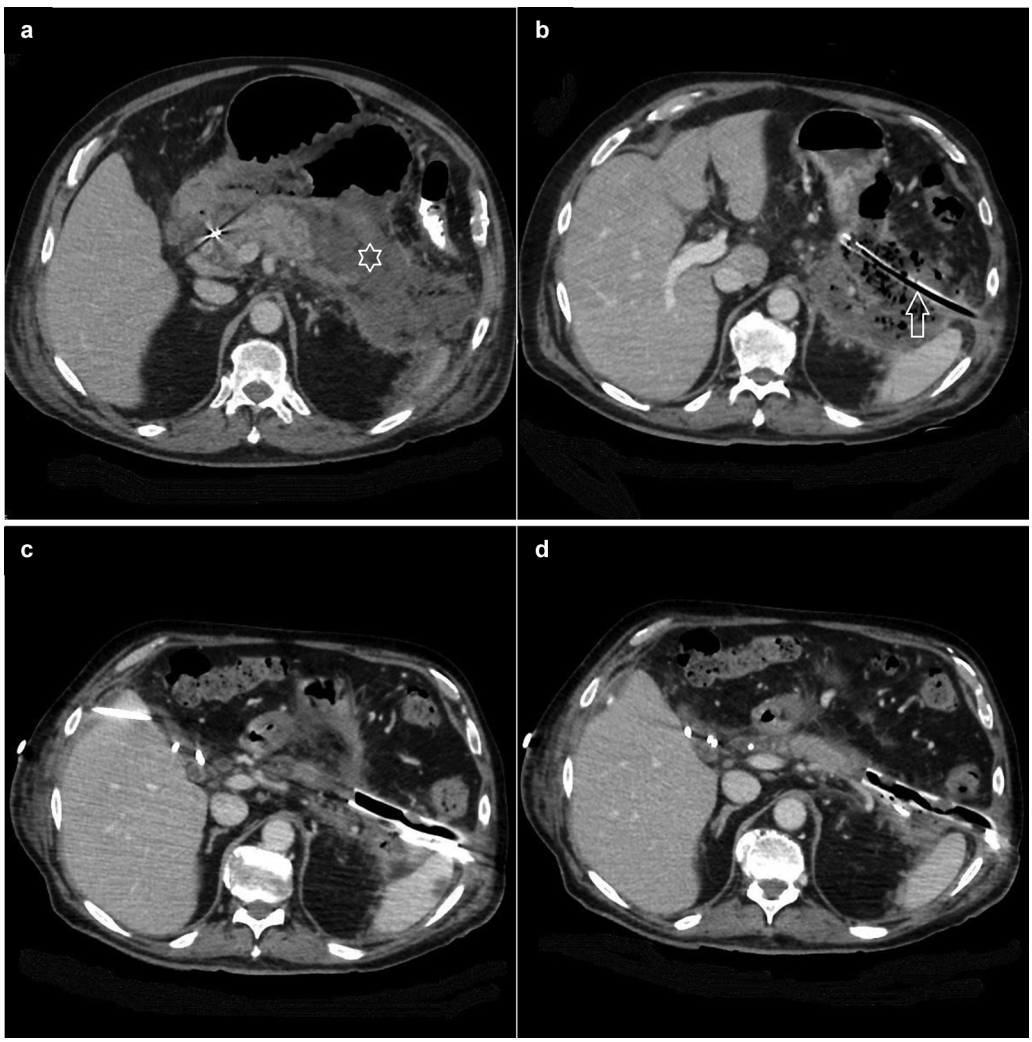

Fig. 6 Management in a patient who may require future videoscopic-assisted retroperitoneal debridement. (**a**) Preprocedure WON (star). (**b**) Preferred retroperitoneal drain tract (arrow). (**c, d**) After upsizing and additional catheter placement for the two-catheter flushing technique (block arrows).

Transperitoneal approaches are acceptable for superficial collections and may be performed under US guidance, even at the bedside in ICU patients.[68] Transgastric access is considered safe if no other approach is feasible (►**Fig. 7**).[67] Transhepatic approach may also be used when no other route is available,[67] though many such collections are accessible by ED. Seldinger and trocar techniques are both acceptable for large and superficial collections drained under US guidance, but the Seldinger technique is the mainstay under CT and for deeper collections. Placement of an 8- or 10-Fr catheter is usually adequate for POPFC or simple AP collections.[69] While older studies showed no outcome differences between <12- and >12-Fr catheters,[70,71] a more recent study did show better outcomes with larger initial catheter placement, with shorter ICU stays and fewer readmissions.[72]

Outcomes of Percutaneous Drainage

A recent study reported PCD success rates of 80% for APFC and pseudocysts (PP), 75% for WON, and 50% for ANCs. Post-PCD surgery was needed in 50% of ANCs and 25% of WON, with 20% of APFC/PP requiring surgical or endoscopic treatment.[73] A 2023 meta-analysis reviewed 17 articles involving 1,170 patients. Ten articles focused on POPFC, and the rest on WON or PP collections. The meta-analysis compared endoscopic versus PCD outcomes.[74] Technical success rates were similar, but clinical success favored ED over PCD for WON ($p = 0.0005$), which was not observed in the POPFC studies. The rates of adverse events were similar between ED and PCD in POPFC, but higher for PCD in the WON group. The pooled data also showed shorter hospital stays, decreased mortality, and reduced reinterventions for ED versus PCD.[74]

Disconnected pancreatic duct syndrome (DPDS) occurs in 20 to 40% of NP patients[75] and is defined as complete duct transection due to tissue necrosis, resulting in leakage of secretions from the viable distal pancreatic remnant into a peripancreatic fluid collection, ascites, or a fistula. This entity is one of the most important treatment challenges in this population,[76] and PCD alone has a high failure rate.[77,78] There is one series of low-output fistulae (<200 mL daily) that reported a 97% success rate of

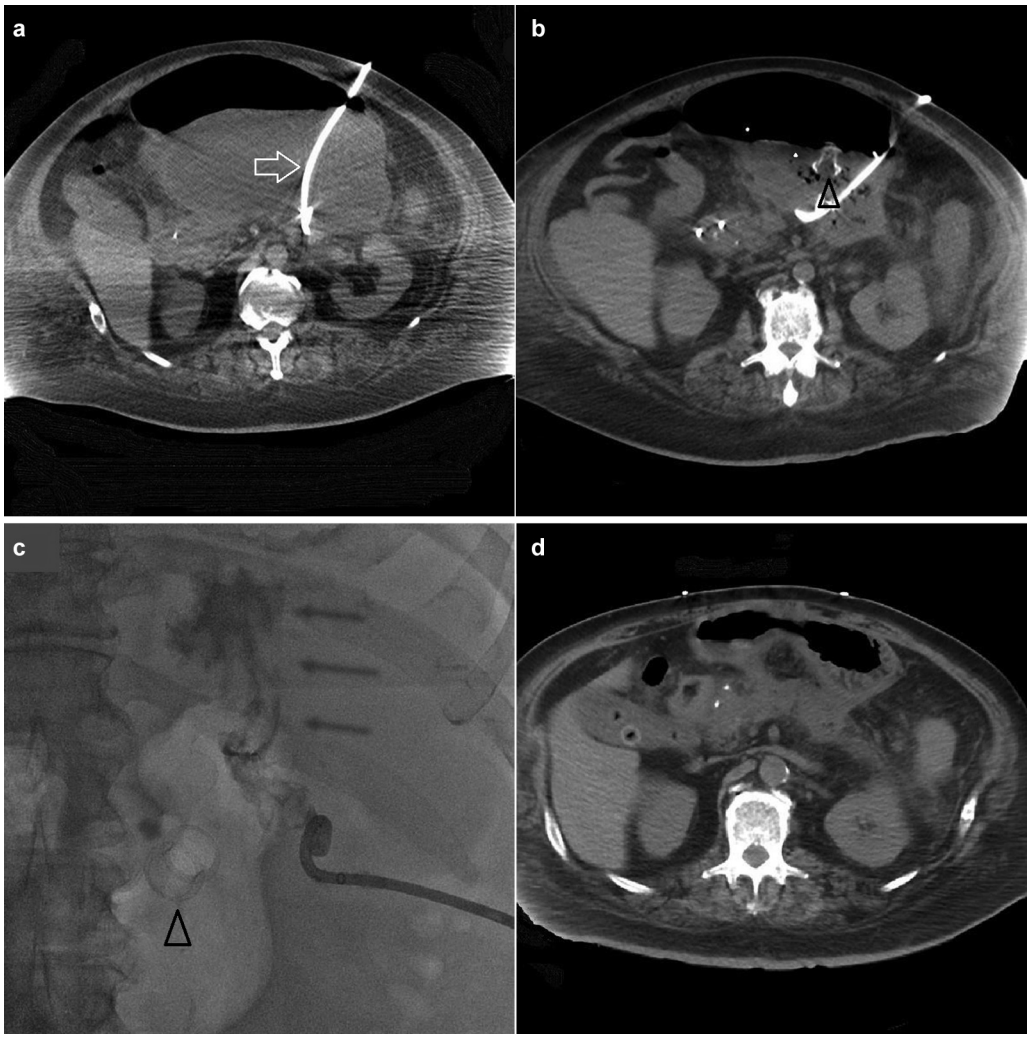

Fig. 7 (**a**) Percutaneous transgastric drainage (arrow) of an infected APFC at 3 weeks' duration. (**b**) Addition of an endoscopic LAMS after 4 weeks (arrowhead), with the collection now considered a pseudocyst with a mature wall. (**c**) Tube check of IR drain demonstrating retraction of the catheter into the stomach with contrast outlining rugae (line arrows) and LAMS appearance under fluoroscopy (arrowhead). (**d**) CT appearance after LAMS removal.

spontaneous closure with prolonged drainage.[79] According to a meta-analysis published in 2021, transmural ED with stenting had a 91 to 92% success rate for the treatment of DPDS.[80] Transpapillary drainage is not as effective for DPDS but can be effective for partial disruptions if the stent can bridge the disruption.[81,82] It is of note that the diagnosis of DPDS occurred between 56 days and 7.5 months. The same meta-analysis reported an 87% success rate for surgical resection within 3.9 to 6.1 months. Diagnosis of DPDS is the first step, but cannot be determined prior to 2 weeks into AP. It can be made via CECT (portal phase), MRCP (best with the administration of secretin), or ERCP, the gold standard (►**Fig. 8**).[81–83] These findings highlight the need for multidisciplinary treatment of these patients, especially for AP patients.

Complications of Percutaneous Catheter Drainage

As with all PCD catheter placements, catheter displacement, blockage, and leakage are common but underreported.[84,85] Other minor complications include suture erosion, skin irritation, and breakdown from dressings. Careful attention to skin care is necessary.[84,85] Catheter tip fractures have also been reported. Every attempt should be made for the retrieval of fractured pieces (►**Fig. 9**).[85] It is important to check the IFU of drainage catheters, as some are not indicated for abdominal collections and are prone to this complication.

Inadvertent bowel or organ transgression is possible with any PCD, as are bowel fistulae which can occur due to constant pressure of the drain on the bowel.[86] Additionally, AP-related collections can cause fistulae secondary to pressure erosion or even vessel thrombosis of vessels causing areas of ischemia.[87] These should not be considered complications of drainage procedures, but part of the disease process itself. If these fistulae are well controlled and there is no sign of peritonitis, a conservative approach with graded withdrawal of the catheter is often successful.[88] One complication specific to collections draining pancreatic enzymes is the formation of a pancreatic-cutaneous fistula, which may occur in up to 32% of cases; however, the risk is reduced with DMD.[48]

Again, as with any PCD placement, there is always a risk of bleeding related to the transgression of a blood vessel in the tract. Additionally, in the case of pancreatitis-related collections, patients may develop bleeding or pseudoaneurysms related to the disease process or pressure erosion from the

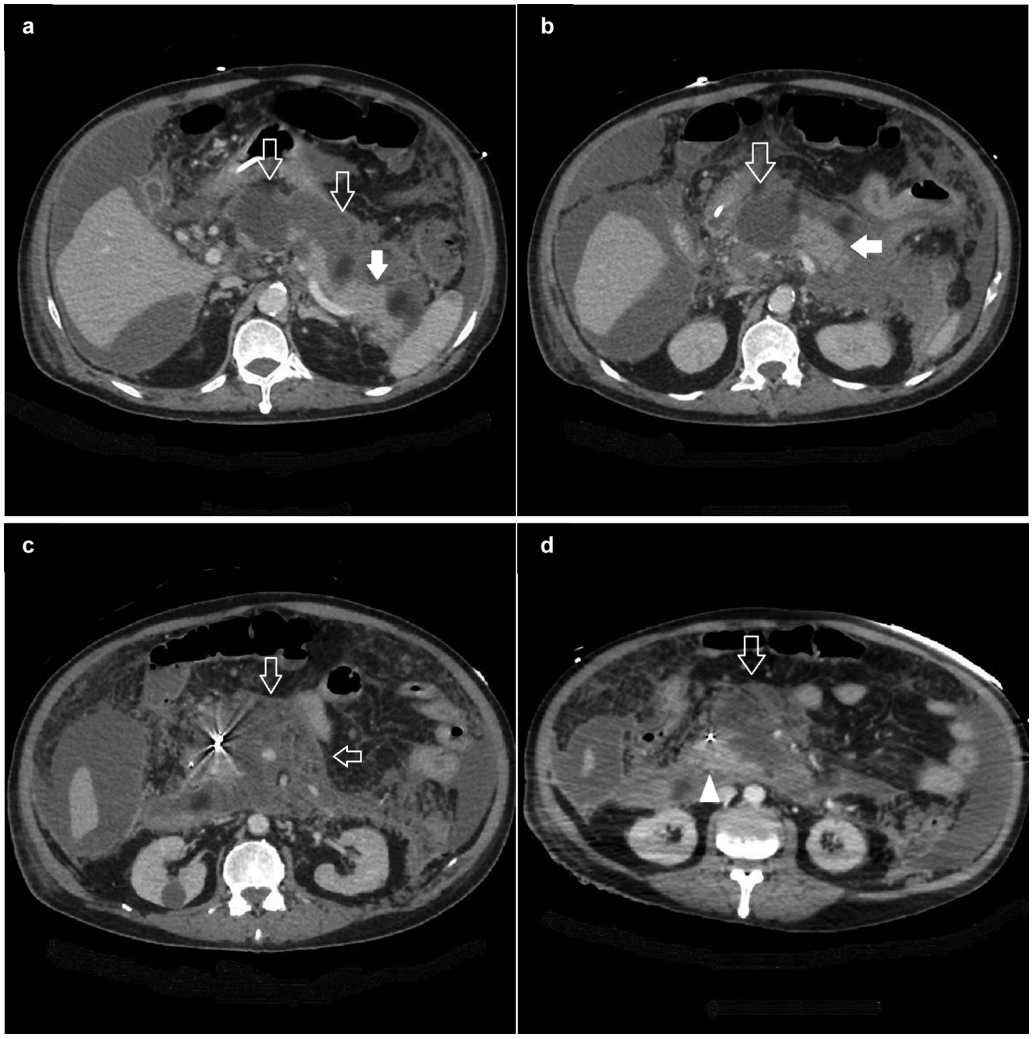

Fig. 8 (**a–d**) Disconnected pancreatic duct syndrome with necrosis of the proximal pancreatic body (open arrows), viable pancreatic body/tail enhancement (solid arrows), and viable pancreatic head enhancement (arrowheads). Embolization coils in the GDA after embolization of a bleeding pseudoaneurysm (**c**).

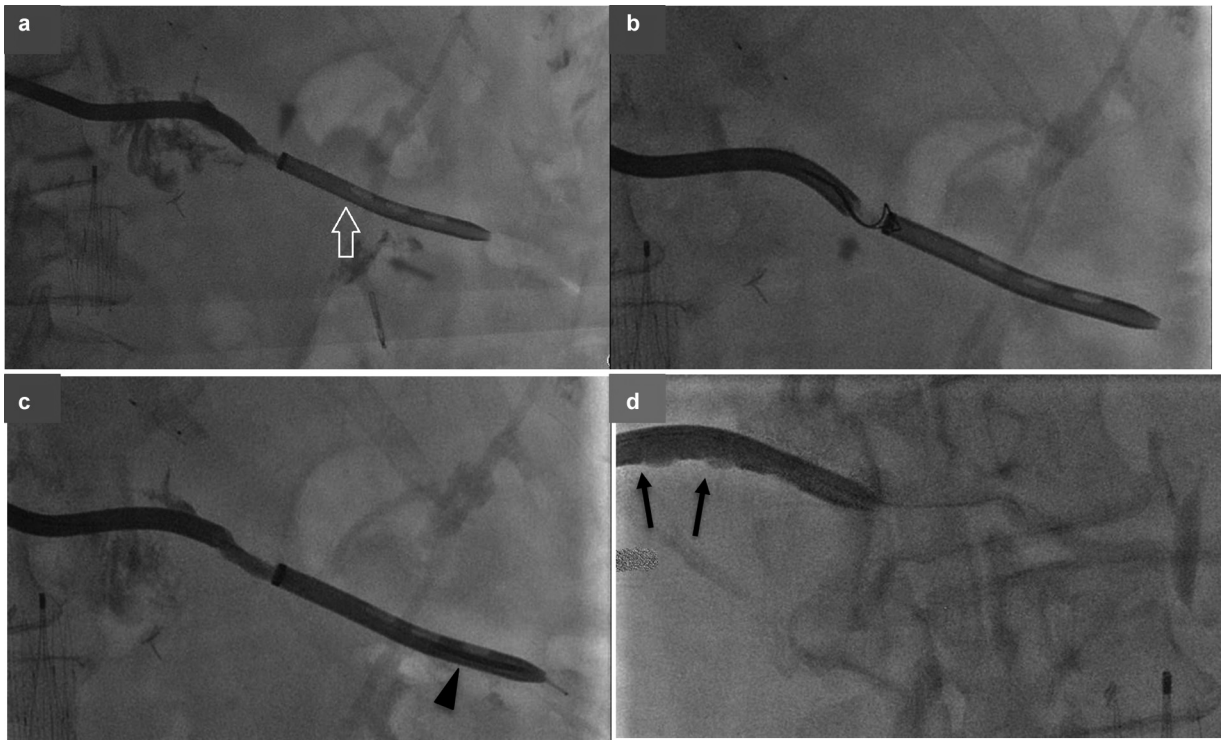

Fig. 9 Drainage catheter tip fracture in a patient post-pancreaticoduodenectomy with leak. Due to equipment shortages, a replacement catheter not intended for abdominal use developed a tip fracture. (**a**) Injection of the fractured catheter (arrow) showing two fistulas to the small bowel. (**b**) A failed attempt to snare (arrow) the fractured tip due to the small size of the tract. (**c**) Successful catheterization and wire placement (arrowhead). (**d**) Successful removal of the fractured tip by inflating a 9-mm angioplasty balloon inside it. The balloon can be seen bulging through the side holes in the tip (arrows).

drain. Any significant bleeding warrants investigation with CTA and endovascular treatment with embolization after resuscitation. In extreme situations, temporary capping of the catheter may provide a tamponade effect until definitive treatment with embolization or surgery (if hemostasis is not successfully obtained with embolization).[85,89]

Conclusion

The management of patients with pancreatic abnormalities is evolving. Best outcomes are achieved through multidisciplinary teams well-versed in treatment options and guidelines that direct the appropriate use of each. Some variability is expected depending on local expertise and the availability of advanced techniques.

Conflict of Interest
The authors have identified no conflict of interest.

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