Narrative Review

Endoscopic Ultrasound-Guided Pancreatic Fluid Collection Drainage and Pancreatic Ductal Drainage

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ABSTRACT

Peripancreatic fluid collections (PFCs) are common complications associated with acute and chronic pancreatitis. Symptomatic PFCs need drainage, and endoscopic ultrasound (EUS) is the current standard of care. Various factors like the size, location, presence of debris in the collection, and general condition of the patient drive the choice of technique for EUS-guided transmural PFC drainage. While plastic stents were initially used, specially designed lumen-apposing and biflanged metal stents have revolutionized therapy for pancreatic necrotic collections. Minimally invasive approach in the form of endoscopic necrosectomy is now established as part of the step-up approach for performing debridement. PFCs are also often associated with disconnected pancreatic duct, which is a difficult situation to manage with evolving evidence. Pancreatic ductal obstruction due to strictures and stones represent indications for endoscopic intervention with stent placement to reduce ductal hypertension. EUS-guided pancreatic duct drainage represents an alternative in patients where endoscopic retrograde cholangiopancreatography fails or is not feasible. Either transmural or transpapillary approaches have been described. In this review, we discuss the role of EUS in drainage of PFCs along with technical tips for the same. We also discuss in detail technical steps and accessories and provide a critical appraisal on evidence for EUS-guided pancreatic duct drainage.

Keywords: Endosonography; Endoscopic retrograde cholangiopancreatography; Stent; Lumen-apposing metal stents; Pancreatic duct.

Introduction

Peripancreatic fluid collections (PFCs) are common local complications of acute pancreatitis, occurring in up to 40% of cases, more so in those with moderately-severe and severe pancreatitis and those with pancreatic necrosis.[1] The Revised Atlanta Classification subdivides PFCs into 4 subtypes based on the content and maturity of the wall.[2] Collections that occur within 4 weeks with fluid represent acute peri-PFC and after 4 weeks with maturation of wall represent pseudocysts. Patients with necrotizing pancreatitis develop acute necrotic collections within 4 weeks and walled-off pancreatic necrosis (WON) after 4 weeks. These contain pancreatic or peripancreatic necrotic debris. Pseudocysts occur more often in background of chronic pancreatitis (~40%) than in acute pancreatitis (~10%-15%).[3] Acute collections most often do not need drainage; however, symptomatic pseudocysts and WON need drainage. Surgical drainage was primary modality till 1980s when endoscopic drainage achieved by directly puncturing the cyst bulging into the gastric lumen became popular making the process minimally invasive.[4] Collections without an obvious bulge and those which were further away from the lumen were not easily accessible endoscopically. In addition, there was an increased risk of vascular injury due to inadvertent vessel rupture.[5] Wiersema[6] reported the first endoscopic ultrasound (EUS)-guided cyst drainage via trans duodenal route in 1996. Subsequently comparative

Abbreviations used in this paper: BFMS, biflanged metal stent; CT, computed tomography; DEN, direct endoscopic necrosectomy; DPDS, disconnected pancreatic duct syndrome; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; MRCP, magnetic resonance cholangiopancreatography; LAMS, lumen apposing metal stent; MRI, magnetic resonance imaging; NCD, nasocystic drain; PD, pancreatic duct; PDD, pancreatic duct drainage; PFC, peripancreatic fluid collections; PPI, proton pump inhibitor; RCT, randomized controlled trial; RV, rendezvous; WON, walled-off pancreatic necrosis.

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What You Need to Know

Background

Peripancreatic fluid collection and pancreatic duct obstruction due to stenosis, stones, or both, or duct disconnection, have important clinical consequences.

Findings

The advent of therapeutic endoscopic ultrasound (EUS) has expanded the role of endotherapy, with failures being successfully managed by EUS-guided interventional therapy.

Implications for Patient Care

EUS-guided transmural drainage is standard of care for symptomatic peripancreatic fluid collection located near the stomach/duodenum.

EUS-guided pancreatic duct drainage is an effective alternative when endoscopic retrograde cholangiopancreatography is unsuccessful or not feasible.

studies showed that EUS was technically safe and efficacious.[7,8] Over the years with development of better echoendoscopes and accessories, EUS has become the primary modality of drainage.[9]

Indications and Timing of Drainage

PFCs associated with symptoms of infection, pain, jaundice, and gastric outlet obstruction need to be drained.[10] In a previous study, PFCs with a diameter of <7.5 cm size and volume of <250 mL and no internal debris showed spontaneous resolution in most patients over 5 months.[11] Unlike acute interstitial pancreatitis, PFCs in chronic pancreatitis and acute necrotizing pancreatitis follow a different course. Pseudocysts in chronic pancreatitis often require drainage due to increased ductal pressure and rarely resolve spontaneously. Asymptomatic WON may resolve on their own in 30% of cases within 6.2 ± 3.4 months, with 30% developing complications within 3.2 ± 1.3 months.[12]

Endoscopic drainage is deferred till 4 weeks after the episode of acute pancreatitis to ensure formation of cyst wall and solid contents to liquefy to achieve optimal drainage.[13] Early endoscopic drainage (<4 weeks) is possible but carries a risk of incomplete drainage and complications due to insufficient wall formation. Early intervention is typically needed for infection or significant necrosis causing systemic inflammation. The POINTER trial comparing early vs delayed intervention for infected necrotizing pancreatitis found fewer interventions and necrosectomies in the delayed group, with similar complication rates. Additionally, 39% of patients in the delayed group required no intervention.[14] In a systematic review of 11 studies comparing early vs delayed endoscopic intervention in necrotizing pancreatitis, while the rate of adverse events was similar, mortality was higher in those undergoing early intervention (odds ratio [OR], 1.70).[15] There was lower rate of clinical success in patients with early intervention and higher need for necrosectomy and surgical intervention. In another systematic review of 6 studies, early intervention was associated with longer hospitalization with similar technical and clinical success and adverse events.[16]

Technical Considerations for EUS-Guided Drainage of PFCs

Initial Assessment

Preprocedural cross-sectional imaging helps assess the cyst wall maturity, size of the cyst, location in relation to the stomach and duodenum, amount of necrosis, ductal disruptions, and vascular anomalies including venous collaterals and pseudoaneurysms. In patients with WON and pseudoaneurysms, embolization is recommended before considering drainage.[17] While magnetic resonance imaging (MRI) is better at quantifying necrosis and evaluation of ductal anatomy, computed tomography (CT) is better for assessing vascular abnormalities in addition to size and relations of fluid collections.[18] Some CT scan features that are more likely to suggest that a collection is a WON are presence of irregular wall, disruption of pancreas parenchyma with collection occurring contiguous to the pancreas, and large size with extension into paracolic gutter.[19] Imaging often dictates the initial plan of therapy between endoscopic, percutaneous, and surgical drainage for patients with PFCs. Baroud et al[20] described the QNI (Quadrant, Necrosis, Infection) classification based on quadrant in which PFC was present, amount of necrosis, and presence of infection to risk stratify WON into 2 groups. In the group with WON involving ≥3 quadrants, 2 quadrants with ≥30% necrosis, or 1 quadrant with >60% necrosis and infection, the need for necrosectomy, hospital stay, readmission rate, and mortality was higher.[20] In patients with infected necrosis, broad-spectrum antibiotics with good pancreatic parenchymal penetration like carbapenems or quinolones should be started.[21] Proton pump inhibitors (PPIs) are discontinued in patients undergoing drainage of WON. A retrospective study of 272 patients found that those off from PPIs required fewer necrosectomy sessions compared with those on PPIs.[22]

Technical Steps of EUS-Guided Drainage of PFCs

EUS-guided cystogastrostomy/cystoduodenostomy is typically done under general anesthesia with endotracheal intubation to reduce the risk of aspiration, after correcting coagulopathy or stopping anticoagulants (Figures 1-3). The procedure is usually performed in the left lateral position to optimize drainage of lesser sac cysts. Standard steps include cyst puncture, guide wire insertion, tract dilation, and stent placement.[10] Before puncture, it is crucial to find an avascular window with close apposition to

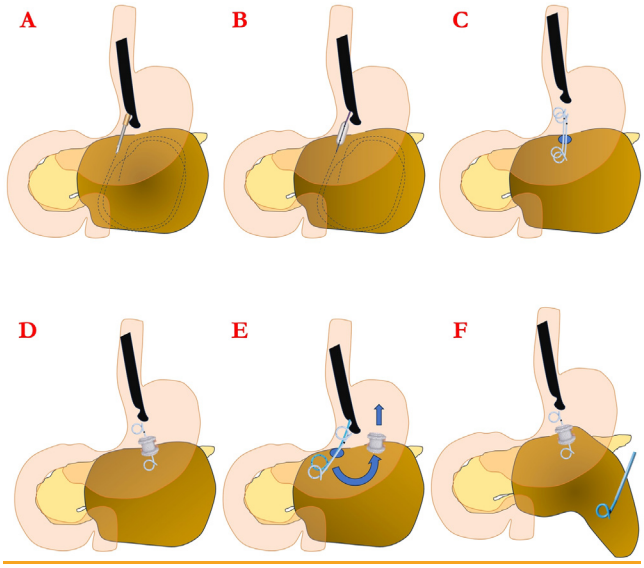


Figure 1. EUS-guided cystogastrostomy. (A) Puncture of cyst with 19-gauge needle, guide wire passed. (B) Dilation of tract with balloon dilator. (C) Double pigtail plastic stents placed across tract. (D) LAMS placement in WON with coaxial plastic stent. (E) Multigated drainage approach: LAMS at 1 site and plastic stent and nasocystic drain at another. (F) Combined endoscopic and percutaneous drainage in WON extending into the paracolic gutter.

the gastric wall (<1 cm). A 19-gague fine-needle aspiration needle is used for cyst puncture, followed by aspiration of cyst contents for microbiological analysis. A 0.025- or 0.035-inch guide wire is inserted into the cyst to form 2 coils. The tract is then dilated with a 6-F cystotome, avoiding noncoaxial catheters like precut sphincterotomes due to complication risks. For plastic stent placement, the tract is dilated to 10-15 mm, followed by placement of 2 guide wires and double pigtail stents. Balloon dilation should be done carefully for approximately 1 minute. In a transduodenal approach, dilation is limited to 6-8 mm due to space constraints and the duodenal wall's thinness. While 2 stents are typically placed, a single stent may be sufficient for PFCs with minimal debris.[23]

Metal stents are preferred by most endosonologists in patients with significant debris due to its ease of placement, aiding drainage of solid debris from the cyst more easily and to facilitate subsequent sessions of endoscopic necrosectomy.[24] Metal stents can either be biflanged metal stents (BFMSs) or lumen-apposing metal stents (LAMSs). Table 1 summarizes the different types of stents used for EUS-guided PFC drainage.[25] Cautery-enhanced LAMS simplify the procedure by reducing steps and the need for accessory exchanges, thus lowering the risk of complications. Key considerations for LAMS placement include cyst size, deployment runway, and the presence of significant debris that may require necrosectomy. For metal stent placement, the distal flange should be deployed under endosonography guidance, followed by release of the proximal flange inside the endoscope channel, and then pushing the stent out under vision. This technique ensures proper apposition to the cyst wall and minimizes maldeployment risk. A coaxial plastic stent is placed to anchor the metal stent and prevent clogging from food and debris, maintaining the lumen's patency. In cases with substantial debris, a 7-F nasocystic catheter may be inserted for cyst lavage.

Choosing the Right Technique and Stent for the Right Patient

While optimal drainage of pseudocysts can be achieved with plastic stents alone, the choice of stent between plastic and metal has always been a matter of debate in patients with WON. Previous retrospective series have shown that metal stents perform better in

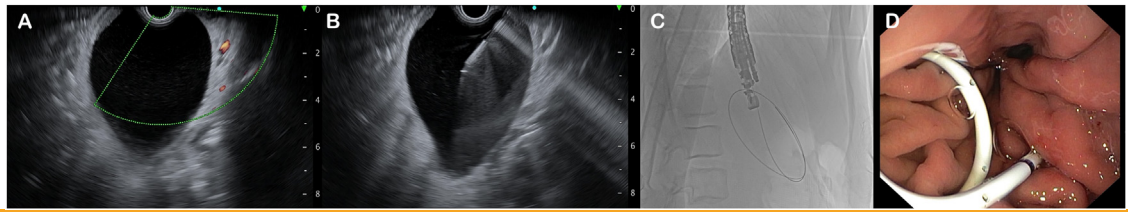


Figure 2. Placement of plastic stent into pseudocyst. (A) Avascular window identified for puncture. (B) Puncture into cyst with 19-gauge fine-needle aspiration needle. (C) Guide wire placed in cyst via fluoroscopy. (D) Single plastic stent placed for drainage.

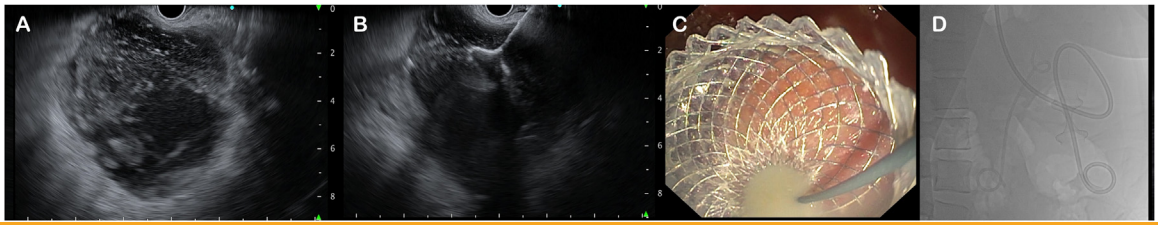
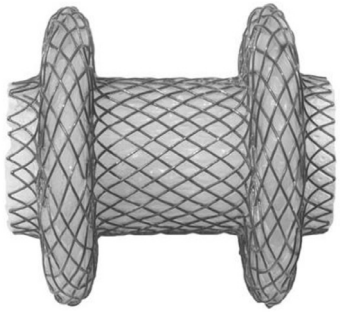
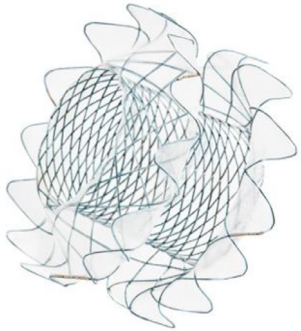
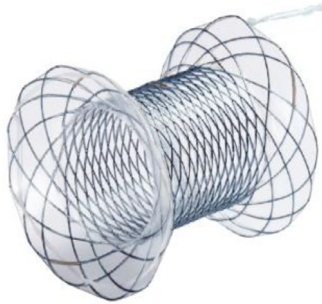


Figure 3. Placement of LAMS into infected WON. (A) WON identified in lesser sac on EUS. (B) Puncture with Hot Axios catheter and distal flange deployment. (C) Proximal flange and pus drainage after deployment. (D) Nasocystic drainage catheter placement across stent.

Table 1. Comparison of LAMS and BFMS

	Axios (Boston Scientific)	Spaxus (Taewoong)	Nagi (Taewoong)
Characteristics			
Type of stent	LAMS	LAMS	BFMS
Saddle length, mm	8, 10, and 15	20	20 and 30
Diameter, mm	8, 10, 15, and 20	8, 10, and 16	10, 12, 14, and 16
Cautery-enhanced tip	Available	Available	Available (although predominantly used as cold device)
Lumen-apposing capability	Highest	High	Poor
Delivery system	4-step delivery device—endoscopist controlled	Coaxial system like standard biliary metal stents	Coaxial system like standard biliary metal stents
Ability to recapture	Difficult, especially with larger-size LAMS	Recapturable during deployment	Recapturable during deployment

Modified with permission from Sundaram et al.[25]

Table 2. Different RCTs Comparing Plastic and Metal Stents for EUS Drainage of PFC

Study	No. of patients	Technical success	Clinical success	No. of necrosectomies	Median hospital stay (d)	Adverse events
Bang et al,[28] 2019	60 (29 DPS, 31 LAMS)	100% DPS, 100% LAMS (P = 1.0)	96.6% DPS, 93.5% LAMS (P = 0.99)	3 DPS, 2 LAMS (P = 0.192)	12.2 in DPS, 6.2 in LAMS (P = 0.129)	**6.9% DPS, 32.3% LAMS (P = 0.014)**
Boxhoorn et al,[29] 2023	104 (51 DPS, 53 LAMS) (included from 2 RCTs for infected necrosis)	–	–	1.8 DPS, 2.4 LAMS (P = NS)	53 in DPS, 43 in LAMS (P = NS)	Only bleeding reported: 22% DPS, 17% LAMS (P = NS)
Karstensen et al,[30] 2023	42 (22 in DPS, 20 in LAMS)	100% DPS; 95% LAMS (P = 0.48)	95.5% DPS; 94.7% LAMS (P = 1.0)	2.2 DPS, 3.2 LAMS (P = 0.42)	43 DPS, 58 LAMS (P = 0.71)	4/22 DPS, 1/20 LAMS (P = 0.35)
Kakadiya et al,[31] 2023	48 (24 in DPS, 24 in LAMS)	100% DPS, 100% LAMS (P = NS)	95.8% DPS, 91.6% LAMS (P = 1.0)	2.2 DPS, 2.8 LAMS (P = 0.097)	5 DPS, 8.5 LAMS (P = 0.11)	No difference in major adverse events
Koduri et al,[32] 2024	92 (46 DPS, 46 BFMS)	100% DPS, 100% BFMS (P = 1.0)	89.1% DPS, 89.1% BFMS (P = 1.0) **Reintervention-free clinical success: 43.5% DPS, 67.4% BFMS (P = 0.021)**	**1 DPS, 0 B.M. (P = 0.028)**	**9.09 DPS, 7.04 B. M. (P = 0.03)**	9.8% DPS, 8.8% BFMS (P = NS)
Gornals et al,[33] 2024	64 (31 DPS, 33 LAMS)	91% DPS, 100% LAMS (P = 0.11)	45% DPS, 63% LAMS in 4 wk (short term) (P = 0.218) 73% DPS, 88% LAMS in 4 mo (long term) (P = 0.291)	2 DPS, 2 LAMS (P = 0.97)	38 DPS, 34 LAMS (P = 0.82)	45% DPS, 36% LAMS (P = 0.61)

DPS, double pigtail stent; NS, not significant.
Bold values are difference in statistically significant.

terms of clinical success with need for fewer reinterventions.[26,27] Six randomized controlled trials (RCTs) have assessed the safety and efficacy of plastic vs metal stents in drainage of WON[28–33] (Table 2). Bang et al[28] in their randomized trial showed that procedure duration was shorter for patients undergoing drainage using metal stents, while technical success and clinical success were similar with higher rate of adverse events with LAMS (Hot Axios, Boston Scientific). In another randomized trial in infected pancreatic necrosis, from the Netherlands, the need for necrosectomy was similar with similar rate of adverse events.[29] These results were replicated in another trial from Denmark.[30] Kakadiya et al[31] in their randomized trial of 48 patients showed that rate of treatment success was similar in both groups (83.3% in plastic group and 87.5% in metal stent group) with similar rate of adverse events.[31] In another recent RCT of 92 patients by Koduri et al,[32] BFMS (Nagi Stent, Taewoong Medical) showed higher reintervention-free clinical success (67.4% vs 43.5%) compared with plastic stents, with shorter hospital stay and lesser reinterventions, with similar overall clinical success and adverse events. Gornals et al,[33] in a Spanish multicenter randomized trial of 78 patients, showed that while clinical success in short and long terms, days of hospitalization, and adverse events did not differ between plastic and metal stents, LAMS was associated with lesser time duration for the procedure.[33] The findings of this RCT were similar to a recent systematic review by Bang et al,[34] wherein only procedure time was different between plastic and metal stents with no difference in clinical outcomes. In patients with WON, although BFMS or LAMS seem more pragmatic, clinical outcomes do not vary significantly. The Orlando protocol alludes to this approach of using LAMS with selective use of plastic stents to ensure optimal drainage of collection and ease of necrosectomy in patients in whom it is likely to be required.[35]

Choice of metal stent between BFMS and LAMS is largely based on the endoscopist's discretion. In a previous retrospective comparison between LAMS (Hot Axios, Boston Scientific) and BFMS (Nagi Stent, Taewoong Medical), technical success and clinical success were similar in both groups.[36] While median number of procedures to WON resolution were fewer in BFMS, stent occlusion due to debris (10.2% vs 5.9%) and rate of migration (7.3% vs 1.6%) was higher. In a recent retrospective study comparing cautery-enhanced LAMS (Hot Axios [Boston Scientific] and Hot Spaxus [Taewoong Medical]), Hot Axios was associated with higher overall rate of adverse events (9.8% vs 3.0%) and higher bleeding events needing transfusion or intervention (6.8% vs 1.5%).[37] This may be due to the

atraumatic design for the Hot Spaxus. Larger prospective randomized trials are needed to clarify the choice between different available metal stents.

The multigated drainage technique involves placing a nasocystic drainage (NCD) catheter through one site and stents through another. The NCD aids in lavage, while the stents ensure optimal drainage. A study by Varadarajulu et al[38] showed better cyst resolution with the multigated technique (97% vs 53%).[38] However, second puncture and NCD placement can be challenging due to rapid cyst decompression. This technique is useful in large collections and those with multiple septations, debris, or inadequate drainage from a single site. Dual modality drainage, combining EUS and percutaneous routes, is recommended for large collections with paracolic extension.[39]

Adjuncts to Endoscopic Drainage of PFCs

In addition to stent placement, a NCD catheter for irrigation can be used in WON with significant debris. A study by Siddiqui et al[40] showed that adding an NCD along with a plastic stent reduced stent occlusion rates and improved short-term success by 3 times. Lavage through the NCD with saline or diluted hydrogen peroxide (H_2O_2) (2:1-10:1) can help loosen debris, aiding necrosectomy. The clinical efficacy of H_2O_2 is 92%, with a 19% adverse event rate.[41] However, complications arise when using undiluted H_2O_2, leading to bleeding, ileus, and obscured vision during procedures due to bubbling.

Coaxial plastic stent placement is preferred across BFMS or LAMS to prevent stent clogging by solid debris, block large food boluses from entering the cyst, and reduce the risk of delayed bleeding caused by LAMS abrasion of the cyst wall. A randomized trial by Vanek et al[42] found that coaxial plastic stents reduce the rate of adverse events (20% with plastic stent vs 51% without), primarily due to prevention of stent occlusion. However, a systematic review of 8 studies with 460 patients found no significant difference in overall adverse event rates between those with and without the coaxial stent.[43] There is a lack of large prospective studies on the role of coaxial plastic stents following cystogastrostomy with BFMS or LAMS.

Endoscopic Necrosectomy After PFC Drainage

Almost one-fourth of patients with WON need additional intervention after initial cyst drainage with BFMS in the form of direct endoscopic necrosectomy (DEN) few days after drainage.[44] This ensures the liquid contents are drained, allowing easier removal of solid debris. For patients with plastic stents, the tract needs to be dilated to at least 15 mm for endoscope passage, while those with LAMS or BFMS can have the endoscope passed directly through the stent. After endoscope passage, debris is removed using accessories like snares, grasping forceps, or baskets.[45] The ideal timing for DEN is often debated. Immediate DEN after dilation of LAMS may lead to stent dislodgment, perforation and increased risk of bleeding.[46] Delayed DEN was associated with higher reinterventions and longer hospital stay in a previous retrospective study.[47] In an RCT by Bang et al,[48] immediate DEN at time of index procedure was associated with lower number of reinterventions with similar rate of adverse events.[48] Considering only one-fourth of patients need additional intervention after PFC drainage, more studies are needed to define those who are likely to benefit from upfront necrosectomy. Various new dedicated devices like Endo-Rotor and Xcavator (over-the-scope grasper) are now available for DEN.[49] Large-scale randomized trials are needed prior to validate their use in routine clinical settings.

Follow-up After PFC Drainage

In patients with LAMS or BFMS, removal is planned at 3-4 weeks, to prevent risk of bleeding that occurs as the cyst cavity collapses and possibility of buried LAMS with inability to remove the stent.[50] However, with respect to removal of LAMS, a previous Italian study showed no difference in complications between early and delayed (>4 weeks) of LAMS.[51] Assessment of residual collection and ductal anatomy with CT or magnetic resonance cholangiopancreatography (MRCP) is better at this point after drainage of collection. In a recent study by Bofill et al,[52] MRCP prior to removal of LAMS was associated with lower risk of recurrence as it guides strategy to keep indwelling plastic stent in situ.[52] In patients with ductal disruption with leak, there may be refilling of the collection. Transpapillary pancreatic duct (PD) stent placement should be considered in patients where there is high risk of refilling like patients with obstructive chronic pancreatitis, post–distal pancreatectomy collections and those with nonresolving PFCs.[53]

Necrosis of the central portion of the pancreatic parenchyma leads to disconnected PD syndrome (DPDS), which may be evident on MRCP. Presence of viable parenchyma on either end of the disconnected segment is a must for DPDS.[54] DPDS is seen in 46.3% patients in a retrospective series of 361 patients.[55] In another series of 256 patients treated with EUS-guided transmural drainage (TMD), DPDS was seen in 73.4% patients.[56] Dhir et al[57] showed different patterns of ductal disruption and disconnection as seen on endoscopic retrograde cholangiopancreatography (ERCP) after WON drainage with BFMS and their subsequent removal. In patients with the disconnection in neck and body with communication of proximal duct with collection, the rate of recurrence was higher. Conventional recommendation is to keep a permanent indwelling double pigtail plastic stent in situ after drainage of WON in those with DPDS. In patients where coaxial plastic stent was not placed, it is often difficult to place a stent once the cyst cavity collapses. In those where a coaxial stent was placed, the LAMS or BFMS can be removed over the stent.

In a previous RCT of 104 patients by Chavan et al,[58] there was no statistical difference in rate of recurrence in

those with indwelling stent and those without (13% vs 25%) at 1 year with most recurrences (65%) being asymptomatic and needing no reintervention.[58] However, in 20% patients in indwelling stent group, plastic stent could not be placed into the cavity, and intention-to-treat analysis was done, likely undermining the benefit of plastic stents. Another study looked at long-term efficacy of indwelling plastic stents in 116 patients.[59] Late complications (17/116) were mostly related to stent abrading against mucosal surface leading to ulceration. PFC recurrence rate was 28%, with presence of chronic pancreatitis, stent migration and collection size (>6 cm) being independent predictors of recurrence. In another recent study, the rate of recurrence in 320 patients undergoing EUS-guided PFC drainage was 17.9%.[60] The rate of recurrence was lower in those with plastic stent in situ (10%) compared with those where removal was done (25.5%) or stent migration occurred (14%). While previous studies have shown that recurrences are largely asymptomatic, plastic stents reduce recurrences overall.

Managing Complications of EUS-Guided PFC Drainage

Complications occur in 10%-25% procedures with common complications being bleeding, stent migration and infection. Rarer complications include buried stent syndrome and pyloric occlusion.[61] Mitigation remains the best strategy when it comes to bleeding, which occurs in 7% of cases with significant bleeding in 1% cases.[62] Assessment of flow in the vicinity of the cyst to look for potential sources like pseudoaneurysms and venous collaterals is done. Persistent flow may be evident in cyst in case of bleeding from puncture site. Tamponade using a balloon or metal stent often helps to tackle this source. Bleeding may also occur during necrosectomy from smaller cavitatory vessels or larger retroperitoneal vessels. In case of significant bleeding uncontrolled by endoscopic modalities, best to consider interventional radiology–guided embolization. Migration is more common in patients with plastic stent placement.[63] Internal maldeployment of BFMS or LAMS can also occur. In these cases, it is prudent to avoid attempting removal in same setting. It is safer to establish optimal drainage using plastic or metal stents and removing the stent in subsequent setting after drainage of liquid contents. A previous Italian study developed a nomogram to predict risk of adverse events when draining PFCs using LAMS.[64] Injury to the main PD, using a multigate technique, need for percutaneous drainage, and presence of abnormal vessels were associated with higher risk of complications.

EUS-Guided Pancreatic Ductal Drainage

Symptomatic PD obstruction due to either stenosis or stones or both or duct disconnection results in upstream ductal hypertension with its clinical consequences of abdominal pain or recurrent pancreatitis.[65] Surgical drainage had been the conventional method of restoring the pancreatic flow in these patients, however with significant morbidity.[66] Over the years, ERCP has become the mainstay of management for symptomatic PD obstruction and surgery is reserved for patients who either have not responded to endotherapy or failed ERCP because of technical reasons.[67,68] ERCP may not be technically feasible in patients with disconnected duct syndrome, duodenal narrowing, and surgically altered anatomy. With use of EUS, we can access the PD away from the papilla and perform endoscopic drainage in situations when ERCP is not feasible using EUS-guided pancreatic ductal drainage (EUS-PDD).[69]

Indications for EUS-PDD

EUS-PDD is offered to patients with symptomatic PD obstruction planned for endoscopic decompression and failed or technically difficult ERCP.[70,71] In patients with normal anatomy and accessible papilla, EUS-PDD should be performed only after a failed ERCP, whereas in patients with inaccessible papilla due to duodenal obstruction or surgically altered anatomy, it can be offered as a first-line management option.[72] The failure of ERCP could be due to inability to cannulate the PD or achieve deep access because of complete disruption (DPDS) or complete occlusion secondary to stricture or obstructing large stone.[73] Before undertaking EUS-PDD, the surgical candidacy of patients should be carefully assessed as surgery has better long-term results than endoscopic decompressive treatment and EUS-PDD is associated with risk of potentially serious adverse effects.[74,75] Patients unfit or unwilling to undergo surgery may be offered EUS-PDD at expert centers with experienced surgical and radiologic backup. EUS-PDD has also been reported for palliation of obstructive pain in patients with inoperable malignant obstruction.[76]

Contraindications for EUS-PDD

EUS-PDD is a technically challenging procedure due to factors like the smaller diameter of the PD, fibrotic pancreas, unstable echoendoscope positioning, difficult wire manipulation, and fragile pancreatic tissue. It carries a risk of serious adverse effects, so careful evaluation of both patient-related and procedure-related factors is essential. EUS-PDD is contraindicated in patients with hemodynamic instability, severe thrombocytopenia (platelet count <50,000), or severe coagulopathy (international normalized ratio, >1.5).[71] Minimal dilation (<4 mm) is a relative contraindication. EUS-PDD is contraindicated in patients with blood vessels in the transmural puncture tract and those with multiple PD strictures.[71]

Technique of EUS-PDD

Types of EUS-PDD

EUS-PDD can be performed using either the rendezvous (RV) or anterograde/transluminal technique.[65] The

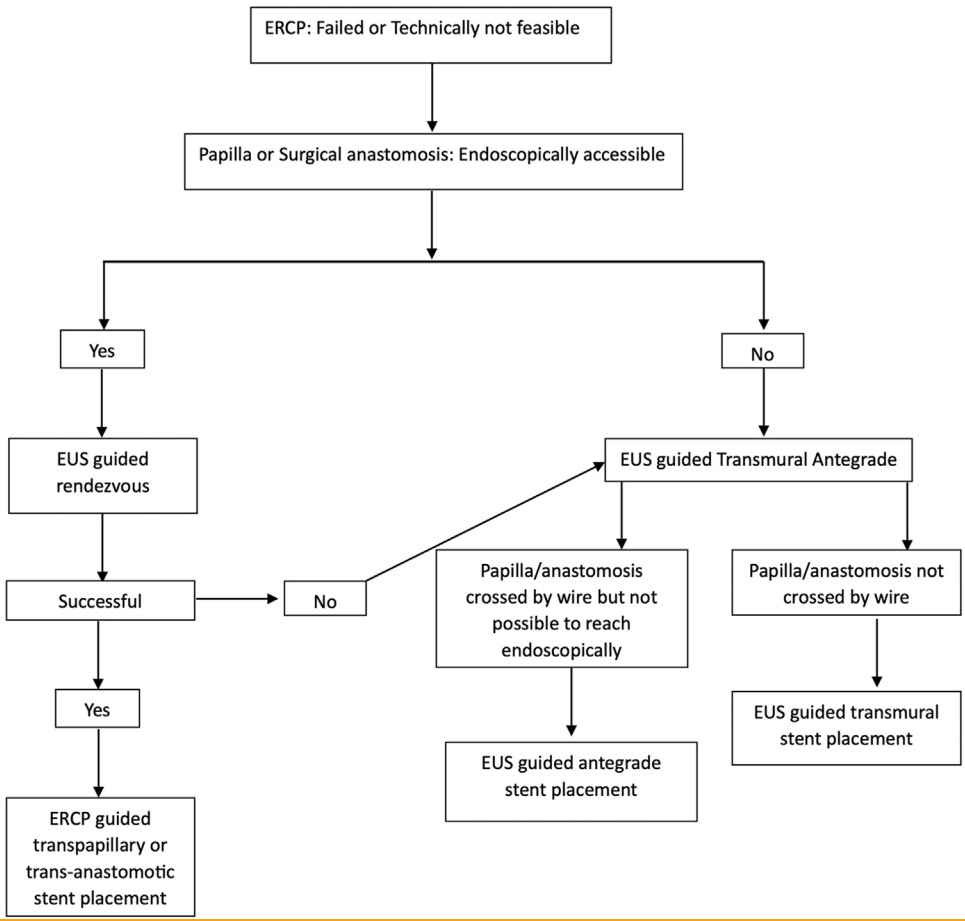


Figure 4. Algorithm for EUS-guided PD drainage.

anterograde technique includes pancreaticoenterostomy or transenteric antegrade stenting. For patients with an endoscopically accessible ampulla or PD anastomosis, EUS-RV should be considered first. EUS-TMD is recommended only for symptomatic patients with an inaccessible ampulla or anastomosis or when EUS-RV fails. The choice of technique depends on the patient's anatomy, the ability to access the ampulla or surgical anastomosis endoscopically, and successful guide wire negotiation from the transluminal puncture site into the bowel (Figure 4).

Preprocedural Assessment

Before EUS-PDD, an anatomical assessment of the PD is done using contrast-enhanced CT and/or MRCP. This includes evaluating the PD's diameter, configuration, presence of duct stricture or stones, intervening blood vessels in the needle puncture tract, and the distance between the pancreas and stomach. A considerable distance between the stomach and pancreas increases the risk of guide wire dislodgment and complications during device insertion. Coagulopathy should be corrected, and anticoagulants/antiplatelets modified as per guidelines for therapeutic endoscopic procedures. While the role of prophylactic antibiotics and rectal nonsteroidal anti-inflammatory drugs in EUS-PDD is not well-established, they are routinely used in our unit. Given the complexity, these procedures should be performed under monitored anesthesia care. EUS-PDD can be done in either the supine or prone position, with carbon dioxide insufflation.[77,78]

Site of Puncture

Selection of the proper site for PD puncture is the most critical step in EUS-guided PDD. Careful consideration should be given to the PD diameter, PD stricture distance from the site of PD puncture, the angle between the needle and PD, and the distance between the bowel lumen and main PD. The distance between PD and the bowel lumens should be the shortest, and the puncture site should be carefully evaluated by Doppler. The site of main PD (MPD) access can be located anywhere from the cardia of the stomach to the third portion of the duodenum.[79] It is advised that PD should be punctured at an oblique angle as it will facilitate guide wire as well as stent insertion.[80] The relationship between the vertebrae and PD stricture on the CT abdomen can help in selecting the best site for needle puncture. Puncture from the center of vertebrae usually results in a puncture of PD near the neck whereas the puncture from left side of vertebrae usually results in a puncture of PD in body.[65,71] In patients planned for an antegrade procedure,

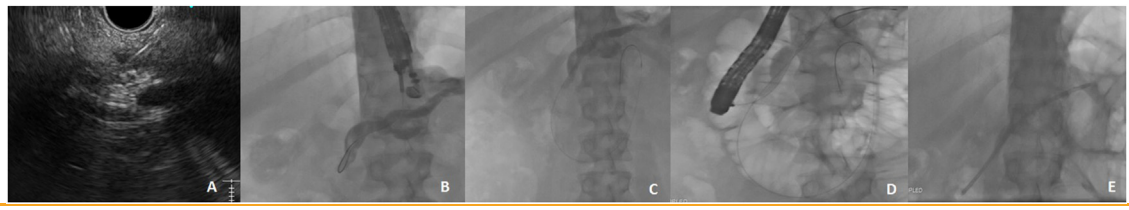


Figure 5. EUS-RV in chronic pancreatitis with failed ERCP. (A) EUS-guided puncture of PD. (B) Guide wire negotiated into duodenum. (C) Guide wire negotiated via minor papilla. (D) Minor papilla cannulated alongside guide wire. (E) Pancreatic stent placed post-minor papillotomy.

repuncture should be considered if the initial puncture has been made close to PD stricture.

Puncture of the PD

The choice of needle for EUS-PDD depends on the procedure's indication, the PD diameter, and surrounding parenchymal fibrosis. For patients requiring anterograde/transluminal drainage with a dilated PD (>5 mm), a 19-gauge needle is used, allowing for the use of a 0.035-inch or 0.025-inch guide wire. In cases with fibrotic pancreas where puncture with a 19-gauge needle is challenging, a 22-gauge needle with a 0.021-inch or 0.018-inch guide wire may be used. Small-caliber needles are preferred for EUS-guided pancreatography alone due to the lower risk of complications such as leakage, bleeding, or postprocedural pancreatitis.[81]

Duct Access With a Guide Wire

A 0.035-inch guide wire is stiffer, making interventions like stent insertion easier, but it can be difficult to insert into the PD or navigate tight strictures. A 0.018-inch guide wire is more flexible, aiding passage through tight strictures, but its floppy nature makes subsequent interventions, such as dilation and stent insertion, more challenging. We use a 0.025-inch wire (VisiGlide; Olympus Corp), which offers similar stiffness to the 0.035-inch guide wire while still allowing for better navigation of tight strictures. After confirming PD access endoscopically, contrast is injected to obtain a pancreatogram. The needle is then flushed with saline to facilitate guide wire movement. Careful manipulation of the wire is crucial, as pulling back the wire can lead to shearing, particularly with small-caliber needles.[81] Once the guide wire crosses the stricture, the course of the procedure depends upon whether the guide wire has crossed the endoscopically accessible papilla/anastomosis or not.

Guide Wire Crosses the Endoscopically Accessible Papilla/Anastomosis

The transpapillary RV approach is feasible in this situation (Figure 5). The guide wire is advanced deep into the small bowel across the papilla or anastomosis, forming multiple loops. The echoendoscope is then withdrawn with the guide wire in place. A duodenoscope or colonoscope is introduced, and the papilla/anastomosis is cannulated either alongside the guide wire or by retrieving it using a snare or grasping forceps into the endoscope's working channel. After cannulating the PD, further endotherapy, such as stricture dilation, stone extraction/lithotripsy, and stent placement, is performed. The critical step is grasping the guide wire, and as with all RV procedures, there is a risk of losing the guide wire. EUS-guided RV has been shown to be equally effective via both major and minor papillae.[82] It should also be remembered that if the wire manipulation into the duodenum is unsuccessful, injection of diluted methylene blue into the PD may help identify an obscure ampullary orifice.[83]

Unable to Cross the Endoscopically Accessible Papilla/Anastomosis or Papilla/Anastomosis Not Accessible Endoscopically: EUS-Guided Antegrade Stenting or Pancreaticoenterostomy

The critical step in antegrade stenting or pancreaticoenterostomy is transmural tract dilation, which involves dilating the gastric wall, pancreatic parenchyma, and PD wall (Figure 6). The extent of dilation depends on the size of the stent to be inserted. Cautery or noncautery dilating devices can be used, with coaxial devices such as graduated dilation catheters, balloon catheters, or cystotomes typically used. Mechanical dilators are generally preferred due to their higher success rates and absence of thermal injury risk, while cautery-based dilators are used when mechanical dilators fail.[81] A 6-F cystotome

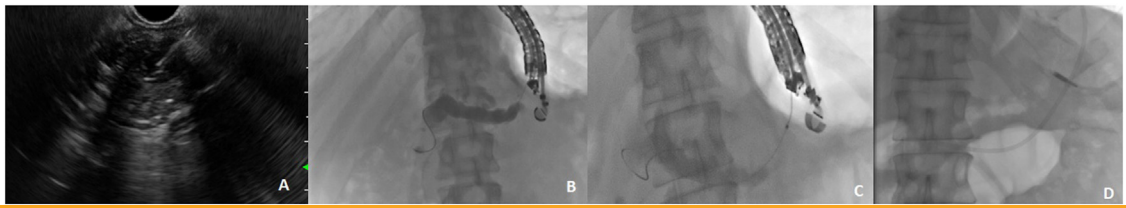


Figure 6. EUS pancreaticogastrostomy in chronic pancreatitis with failed ERCP and EUS-RV. (A) EUS-guided puncture of dilated PD. (B) EUS-RV failed due to stricture–stone complex. (C) Balloon dilation of transmural tract. (D) Transmural plastic stent placed, and hemoclip used to prevent migration.

(diathermic sheath) using a pure cutting current is a preferred cautery-based dilating device for dilating the tract with excellent success rates. However, the risk of both acute and late burn effects around the transmural tract can lead to serious complications including pancreatitis, duct leakage, bleeding, and perforation. Pure cutting current is used during the tract dilation as it results in easier passage through the tract and less current diffusion with lesser risk of delayed thermal injury.[84] It is important to remember that none of these dilating devices are ideal. Bougie dilators result in axial dilation force, which may cause separation of the tissue planes with advancement. Conversely, balloon dilators have radial dilating force, which may increase the risk of perforation, leaks, and bleeding.[79,85] An ultratapered mechanical dilator (180 cm long dilator with extremely tapered up to 2.5 F and designed for a 0.025-inch guide wire; ES dilator DC7R180S; Zeon Medical, Tokyo, Japan) has been developed for EUS-PDD, and a retrospective study demonstrated similar rates of dilation success (100% vs 90%; $P = 0.071$) with no bleeding in mechanical dilator group compared with a 6-F cautery dilator.[86] A 4-F angioplasty balloon catheter (Sterling, Boston Scientific, Marlborough, MA) loaded over a 0.018-inch guide wire has also been described for mechanical dilation of the transmural tract.[87,88]

After tract dilation, 1 or more straight 5- or 7-F plastic stents can be placed transmurally. If the guide wire can be negotiated across the papilla or anastomosis, gastropancreaticoenterostomy (ring drainage) is created. Double pigtail stents are preferred for ring drainage to reduce migration risk. Unlike conventional PD stents with side holes, EUS-guided PDD typically uses plastic stents without side holes to prevent leakage of pancreatic juice, especially when the stomach and pancreas are significantly separated. The transmural tract usually matures within a month, allowing for further interventions like stricture dilation, stone retrieval, stent revision, or pancreatoscopy. Fully covered self-expandable metal stents can also be used, offering advantages like easier insertion, larger diameter for the transmural tract, reduced bleeding risk due to tamponade, prolonged patency, and lower risk of PD leaks. However, there is a theoretical risk of side branch occlusion and new stricture formation, although studies on fully covered self-expandable metal stents in EUS-PDD have not reported these adverse effects.[89,90]

Choosing the correct size and length of the stent for EUS-PDD is crucial, as stent placement can be challenging. Longer stents with sufficient length in the bowel lumen are preferred to prevent inward migration into the PD. The stent diameter should be carefully selected based on the PD size and the dilated transmural tract diameter, as failure to insert the stent can result in PD leakage. To mitigate this risk, stents that can be removed while leaving the guide wire in the PD can be used. “All-in-1 stents” are plastic stents with a string between the stent and the delivery system, allowing the stent to be removed from the scope while keeping the guide wire in place if stent advancement fails.[81]

Outcomes of EUS-guided PDD

Technical Success

The technical success depends upon the operator expertise with expert centers reporting technical success rates ranging from 79% to 100%.[72,89,91-94] A systematic review of 16 studies (503 patients) yielded a pooled technical success rate of 81.4% (95% CI, 72-88.1; $I^2 = 74\%$).[78] The technical success was reported to be associated with type of PD drainage (transmural vs RV; log OR, 0.02; 95% CI, 0.004-0.0037) and the method used for dilation (log OR, 0.38; 95% CI, 1.45-0.69). Pooled analysis for TMD revealed technical success of 85.3% (95% CI, 73.6-92.3), whereas for RV technique, it was 76.9% (95% CI, 61-87.6; $I^2 = 52.57\%$). The meta-analysis also suggested that using balloon dilation for transmural tract dilation was associated with slightly better technical success compared with using cystotome. Another meta-analysis of 22 studies (714 patients) reported pooled technical success rate of 84.8% (95% CI, 79.1-89.2).[95] Interestingly, it has been reported that there are more chances of EUS-PDD failure if performed on the same day as failed ERCP.[94] This is possible because of anatomic factors, inflammation induced by ERCP attempts, or decreased commitment by the tired endoscopist in prolonged procedure time.

Clinical Success

The published clinical success of EUS-PDD ranges from 79% to 100%.[66,83,85-88] A systematic review of 16 studies (503 patients) yielded a pooled clinical success rate of 82.3% (95% CI, 73.1-88.8).[72] It also revealed that type of procedure (RV and transmural), duration of follow-up, and presence of patients with altered anatomy were associated with variance in the results. Another meta-analysis of 22 studies (714 patients) reported pooled clinical success rate of 89.2% (95% CI, 82.1-93.7). The clinical success after a follow-up time >12 months was 86.4% (95% CI, 71.9-94.1) and <12 months was 85.3% (95% CI, 70.3-93.5) respectively.[95] A recent retrospective study compared the outcomes of EUS-PDD or longitudinal pancreaticojejunostomy after failed ERCP in 21 patients (11 EUS-PDD, 10 surgical drainage).[96] There were no significant differences in mean Izbicki pain score (EUS-PDD, 13.6 ± 10.1 vs surgical drainage 10.7 ± 7.9, $P = 0.483$) or complete/partial pain relief (60%/30% vs 70%/30%; $P = 0.752$) at the end of 6-12 months follow-up. The rates of overall adverse events (27.3% vs 30.0%; $P = 0.893$) and readmission (63.6% vs 40.0%; $P = 0.290$) were similar with patients in the EUS-PDD group requiring more reinterventions (45.5% vs 0%; $P = 0.039$) compared with patients in the surgery group. This study demonstrated that EUS-PDD has a similar safety and efficacy profile as surgical drainage.

An international multinational study comparing EUS-PDD with enteroscopy-assisted endoscopic retrograde

pancreatography (e-ERP) after Whipple surgery reported technical success in 92.5% of procedures in the EUS-PDD group compared with 20% of procedures in the e-ERP group (OR, 49.3; $P < 0.001$).[93] Clinical success (per patient) was reported in 87.5% of procedures in the EUS-PDD group compared with 23.1% in the e-ERP group (OR, 23.3; $P < 0.001$). Although complications occurred more commonly in the EUS-PDD group (35% vs 2.9%; $P < 0.001$), they were rated as mild or moderate, and procedure time and length of stay were comparable between the groups.

Adverse Effects

EUS-PDD is associated with the risk of various complications reported including abdominal pain, pancreatitis, bleeding, perforation, peripancreatic abscess, shearing of the guide wire, pneumoperitoneum, pseudocyst, and pseudoaneurysm formation.[79] Various systematic reviews have reported pooled adverse effects ranging from 18% to 21%, with the most common adverse effect being pain, followed by postprocedural pancreatitis.[72,95,97] Stent-related adverse effects include migration and/or occlusion resulting in the recurrence of symptoms and/or pancreatitis. A systematic review of 16 studies yielded a pooled adverse event rate of 21.3% (95% CI, 16.8-26.7) with no mortality reported to the procedure.[72] The most common adverse event reported was a postprocedural pain rate of 15.9% (95% CI, 11.2%-22.2%) with significant heterogeneity ($I^2 = 53.04$) whereas pooled post−EUS-PDD pancreatitis rate was 5% (95% CI, 3.2-7.8) with no heterogeneity ($I^2 = 0$). Another meta-analysis of 22 studies reported a pooled rate of all adverse events of 18.1% (95% CI, 14.2-22.9).[95] The pooled rates of procedure-related complications were: mild 13% (95% CI, 8.3-19.9), moderate 9.9% (95% CI, 6.5-14.8), and severe 3.9% (95% CI, 2.5-5.9). Specific complications included acute pancreatitis of 6.6% (95% CI, 4.5-9.4), bleeding 4.1% (95% CI, 2.7-6.2), perforation/pneumoperitoneum 3.1% (95% CI, 1.9-5.0), pancreatic leak/PFC formation 2.3% (95% CI, 1.4−4.0), infection 2.8% (95% CI, 1.7-4.6), and nonspecific postprocedural abdominal pain requiring admission 13.9% (95% CI, 8.2-22.6). Stent migration/occlusion occurred in 21.3% (95% CI, 11.5-36.2), with a pooled reintervention rate of 15.2% (95% CI, 9.1-24.1).

Learning Curve for EUS-PDD

EUS-PDD, described in 2002, has seen limited evidence evolution compared with EUS-guided biliary interventions.[98] These procedures are rare, limiting training opportunities. Owing to their complexity, they have a steep learning curve. Tyberg et al[99] found that 80 minutes of procedure time is consistently reached after 27 cases, with mastery achieved after 40 cases, highlighting the need for significant experience.

Conclusions

Recent advancements in the management of PFCs and pancreatic ductal obstruction have led to improvements in techniques, technology, and training. While PFCs and pancreatic necrosis remain complex, more data are available on the role of endoscopic step-up therapy, including the use of adjunctive techniques like necrosectomy, to achieve optimal outcomes. EUS-PDD has evolved from a high-risk procedure for patients with failed ERCP and high surgical risk to a safe, minimally invasive alternative for those in whom ERCP failed or is not technically feasible.

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