Therapeutic Endoscopic Ultrasound and Endoscopic Ultrasound-Endoscopic Retrograde Cholangiopancreatography Interventions

Rishad Khan, MD[a], Ryan Law, DO[b,*]

KEYWORDS

- Endoscopic ultrasound • Biliary obstruction • Pancreatic fluid collection
- Gastric outlet obstruction • Lumen-apposing metal stent

KEY POINTS

- Therapeutic endoscopic ultrasound (EUS) allows for access to biliary and pancreatic ducts, the gallbladder, fluid collections, and adjacent luminal structures.
- EUS-guided rendezvous, antegrade stenting, and direct biliary drainage techniques can be used when there is an inaccessible papilla or a previously failed endoscopic retrograde cholangiopancreatography.
- EUS-guided gallbladder drainage provides internal drainage for patients with cholecystitis who are high-risk surgical candidates.
- EUS-guided drainage remains the standard of care for symptomatic and infected pancreatic fluid collections and is often utilized concomitantly with percutaneous drainage and, less commonly, surgical debridement.
- EUS-guided luminal anastomosis creation has allowed for transpapillary intervention in patients with surgically altered gastrointestinal anatomy and for palliation of gastric outlet obstruction.

Video content accompanies this article at http://www.gastro.theclinics.com.

[a] Division of Gastroenterology and Hepatology, Department of Medicine, University of Toronto, Toronto, Canada; [b] Division of Gastroenterology, Department of Medicine, Mayo Clinic, 200 1st Street Southwest, Rochester, MN 55905-0002, USA
* Corresponding author. Mayo Clinic, 200 1st Street Southwest, Rochester, MN 55905.
E-mail address: dr.ryanlaw@gmail.com

Gastroenterol Clin N Am 53 (2024) 683–707
https://doi.org/10.1016/j.gtc.2024.08.016 gastro.theclinics.com
0889-8553/24/

INTRODUCTION

Therapeutic endoscopic ultrasound (EUS) encompasses an expanding array of procedures to manage a range of benign and malignant conditions of the pancreaticobiliary and luminal gastrointestinal (GI) tract. Traditionally a diagnostic modality, the advent of therapeutic channel, linear-array echoendoscopes with improved image quality and Doppler capabilities, and dedicated tools and devices have allowed for EUS-guided access to biliary and pancreatic ducts, the gallbladder, fluid collections, and adjacent luminal structures. In this review, we will cover 3 overarching areas.

1. EUS-guided access and antegrade stenting
   a. Rendezvous of pancreatic and biliary ducts (endoscopic ultrasound-guided rendezvous technique [EUS-RV])
   b. Antegrade stenting
2. Direct EUS-guided drainage
   a. Bile duct drainage (endoscopic ultrasound-guided bile duct drainage either bile duct or biliary [EUS-BD])
   b. Pancreatic duct drainage (endoscopic ultrasound-guided pancreatic duct drainage [EUS-PD])
   c. Gallbladder drainage (endoscopic ultrasound-guided gallbladder drainage [EUS-GBD])
   d. Pancreatic fluid collection management (endoscopic ultrasound-guided pancreatic fluid collection [EUS-PFC])
3. EUS-guided luminal anastomosis
   a. Transgastric and transenteric luminal anastomosis creation (EUS-directed transgastric ERCP [EDGE] and EUS-direct transenteric ERCP [EDEE])
   b. Gastroenterostomy (endoscopic ultrasound-guided gastroenterostomy [EUS-GE])

We will discuss our approach, including indications and contraindications, patient preparation, procedural equipment, and technical steps. We will also cover adverse events (AEs) and salvage procedures, clinical outcomes, and follow-up care.

GENERAL CONSIDERATIONS

Patient Preparation

Therapeutic EUS procedures require careful patient selection, planning, and knowledge of salvage options given their relatively high rate of AEs. All procedures should be performed by experienced endoscopists, in hospitals with surgical and interventional radiology backup, and with fluoroscopy available.

Procedural decisions should be made in a multidisciplinary setting with hepatopancreatobiliary surgery and interventional radiology teams. Percutaneous alternatives to an interventional EUS procedure should be considered when patients are unable to tolerate sedation or have target organ (eg, gallbladder) perforation. While indications vary by procedure and individual patient characteristics (**Table 1**), general contraindications to therapeutic EUS include an inability to tolerate sedation, significant and uncorrectable coagulopathy, large volume ascites, and intervening vasculature between the EUS transducer and the target. As these procedures are considered high risk for bleeding,[1] we interrupt therapeutic anticoagulation and convert dual antiplatelet therapy to aspirin monotherapy when possible. We provide a single dose of broad-spectrum antibiotics for all patients undergoing therapeutic EUS procedures, similar to surgical and interventional radiology practice.[2,3]

Table 1
Indications and contraindications for therapeutic endoscopic ultrasound procedures

Procedure	Indications	Specific Contraindications
EUS-rendezvous and antegrade drainage	Inaccessible papilla, failed cannulation	Tumor infiltration at site of puncture, luminal obstruction, and nondilated target ducts
EUS-PD	Symptomatic pancreatic duct obstruction with inaccessible papilla or failed cannulation	Luminal obstruction, nondilated main pancreatic duct
EUS-CDS	Distal MBO with inaccessible papilla or failed cannulation	Nondilated CBD, tumor infiltration at site of puncture, and requirement to preserve native bilioenteric anatomy
EUS-HGS	Distal MBO with inaccessible papilla or failed cannulation, drainage of left hepatic system to complement ERCP for hilar obstruction	Nondilated target bile duct, tumor infiltration at site of puncture, and requirement to preserve native bilioenteric anatomy
EUS-GBD	Acute cholecystitis in high-surgical risk patients, internal gallbladder drainage to enable removal of percutaneous cholecystostomy tube, MBO with patent cystic duct if ERCP and EUS-guided biliary drainage is not possible or fails	Gallbladder perforation, biliary peritonitis, and requirement to preserve native gallbladder anatomy
EUS-PFC	Symptomatic or infected pancreatic fluid collections	Untreated vascular pseudoaneurysm within the PFC
EUS-GE	Malignant GOO when surgical resection of the tumor is not planned, benign GOO while awaiting definitive therapy, and afferent loop syndrome	Significant malignant ascites, diffuse peritoneal carcinomatosis, and malignant infiltration of gastric wall
EDGE/EDEE	Patients with biliary disease and prior RYGB, RYHJ, pancreatoduodenectomy, or Billroth II gastrectomy	Patient preference to avoid reconnection of the gastric pouch and excluded stomach

Abbreviations: CBD, common bile duct; CDS, choledochoduodenostomy; EDGE, EUS-directed transgastric ERCP; EDEE, EUS-direct transenteric ERCP; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; GE, gastroenterostomy; GOO, gastric outlet obstruction; GBD, gallbladder drainage; HGS, hepaticogastrostomy; MBO, malignant biliary obstruction; MPD, main pancreatic duct; PD, pancreatic drainage; PFC, pancreatic fluid collection; RYGB, Roux-en-Y gastric bypass; RYHJ, Roux-en-Y hepaticojejunostomy.

Equipment

EUS access generally involves (1) a wire-guided technique with needle puncture, guidewire passage, and tract dilation with self-expanding metal stent (SEMS) or plastic stent placement, (2) a wire-guided technique with an electrocautery-enhanced lumen apposing metal stents (EC-LAMS),[4,5] and (3) a direct or "freehand" technique[6] with a LAMS. We use 0.018 to 0.035 in guidewires, 19 or 22 G needles, normal saline with a water-soluble contrast medium, and a range of dilation devices and stents (**Table 2**). We prefer 0.025 or 0.035 in guidewires that have sufficient rigidity to streamline device passage and are insulated from the electrical current generated by EC-LAMS or cystotomes. Smaller caliber guidewires should be available in clinical scenarios when the target structure is small (eg, intrahepatic bile duct, main pancreatic duct [MPD]).

ENDOSCOPIC ULTRASOUND-GUIDED RENDEZVOUS TECHNIQUE AND ENDOSCOPIC ULTRASOUND-GUIDED ANTEGRADE STENTING

Endoscopic retrograde cholangiopancreatography (ERCP) remains the standard of care for biliary and pancreatic duct drainage. EUS-RV or EUS-guided antegrade stenting are alternative ways to allow for transpapillary biliary and pancreatic duct drainage.

Indications and Patient Selection

Indications for biliary EUS-RV and antegrade drainage include an inaccessible papilla or failed biliary cannulation. We pursue transpapillary drainage for benign cases and malignant cases with potential downstream surgery as this maintains the native anatomy of the biliary tree.[7] For unresectable malignant cases with failed ERCP, we instead consider EUS-guided choledochoduodenostomy (CDS), hepaticogastrostomy (HGS), or GBD.[7] Indications for pancreatic EUS-RV, antegrade stenting, and transmural drainage include symptomatic pancreatic duct obstruction after failed ERCP or surgically altered anatomy preventing papillary access in patients who have prohibitively high surgical risk.

Contraindications to biliary and pancreatic EUS-RV and antegrade drainage are tumor infiltrations at the site of puncture and inadequately dilated target ducts. EUS-guided pancreatic intervention is relatively contraindicated if there is a large pancreatic duct stone causing complete MPD obstruction, as this is better managed with surgery or shock wave lithotripsy.[8] EUS-guided pancreatic duct interventions should be done in expert centers given their technical complexity and associated morbidity.[9]

Approach

We perform biliary EUS-RV from the duodenal bulb in a long position to access the mid-common bile duct (CBD) or the proximal stomach to access the left intrahepatic duct.[10] The selected approach is based on target duct dilation, endoscope stability, feasibility of antegrade trajectory for guidewire passage, and the location of the lesion (eg, distal CBD vs hilar). For EUS-guided antegrade drainage, we use a transgastric approach to access the left hepatic duct system.

- Position the echoendoscope in the duodenal bulb or proximal stomach.
- Puncture the CBD or left hepatic duct system using a 19 or 22 G needle.
- When targeting the left hepatic ducts, puncture the duct at a depth of 2 to 3 cm from the liver capsule so that the liver parenchyma may contain potential bile leaks.[11]
- Aspirate bile to confirm adequate positioning and inject contrast to obtain a cholangiogram.

Table 2
Dilation devices and stents used for endoscopic ultrasound-guided procedures

Procedure	Dilator	Plastic Stents	SEMS	LAMS
EUS-PD	4–6 mm biliary balloon dilator 4–6 Fr rigid dilator 6–10 F cautery-tipped catheter	Straight plastic stents for antegrade drainage or pancreaticogastrostomy Caliber: 7, 8.5, or 10 Fr Length: 5–10 cm DPPS for ring drainage Caliber: 7, 8.5, or 10 Fr Length: 7–18 cm	—	—
EUS-CDS	4–6 mm biliary balloon dilator 6–10 Fr cautery-tipped catheter	—	FCSEMS or PCSEMS Caliber: 8–10 mm Length: 6 cm	Caliber: 6–10 mm Length: 8–10 mm
EUS-HGS	4–6 mm biliary balloon dilator 6–10 Fr cautery-tipped catheter	Single-pigtail (if available) Caliber: 8 Fr Length: 20 cm	FCSEMS or PCSEMS Caliber: 8–10 mm Length: 8–10 cm	—
EUS-GBD	—	DPPS for coaxial placement through LAMS Caliber: 7, 8.5, or 10 Fr Length: 3–5 cm	—	Caliber: 8–15 mm Length: 8–10 mm
EUS-PFC	4–6 mm biliary balloon dilator 4–6 Fr rigid dilator 6–10 Fr cautery-tipped catheter	DPPS for primary drainage or coaxial placement through LAMS Caliber: 7, 8.5, or 10 Fr Length: 3–7 cm	—	Caliber: 15–20 mm Length: 10 mm
EUS-GE	—	—	—	Caliber: 15–20 mm Length: 10 mm
EDGE/EDEE	—	—	—	Caliber: 15–20 mm Length: 10 mm

Abbreviations: CDS, choledochoduodenostomy; EDGE, EUS-directed transgastric ERCP; EDEE, EUS-direct transenteric ERCP; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; GE, gastroenterostomy; GBD, gallbladder drainage; HGS, hepaticogastrostomy; PD, pancreatic drainage; PFC, pancreatic fluid collection.

- Advance the guidewire through the papilla/anastomosis and coil it within the duodenum.
- If there is difficulty with guidewire manipulation, consider alternative guidewires or catheter accessories.
- For biliary EUS-RV
  - Withdraw the echoendoscope maintaining the rendezvous guidewire position.
  - Advance a duodenoscope and attempt cannulation either alongside the rendezvous guidewire where it exits the papilla/anastomosis, or grasp the tip of the curled guidewire with a forceps biopsy and pull it through the entirety of the working channel of the duodenoscope.
  - Proceed with ERCP.
- For EUS-guided biliary antegrade drainage
  - Dilate the hepaticogastrostomy tract over the guidewire using a 4 to 6 mm biliary dilating balloon or a small caliber, cautery-tipped catheter (eg, 6–8 F).
  - Dilate the hepaticogastrostomy tract and any biliary strictures with a 4 to 6 mm balloon dilator to for ease of passage of the stent catheter.
  - Once the stent is across the papilla/anastomosis and in ideal position, deploy the stent of choice. SEMS choice between uncovered SEMS (UCSEMS), partially covered SEMS (PCSEMS), and fully covered SEMS (FCSEMS) depends upon the procedural indication.

For pancreatic interventions, we prefer EUS-RV over antegrade stenting and transmural drainage as it allows for physiologic drainage of pancreatic fluid, an improved ability to manage pancreatic stones and strictures using a retrograde approach, and avoidance of thermal or mechanical dilation.[12] We opt for transmural drainage if we are unable to traverse a pancreatic duct obstruction. For all EUS-RV and antegrade stenting procedures, we provide a single dose of a rectal nonsteroidal anti-inflammatory medication.

- For all pancreatic duct interventions, the echoendoscope is positioned in the gastric body to visualize the MPD. Rarely, these procedures are carried out using a transduodenal or transjejunal route.[13] Ideally, the MPD diameter should be $\geq$4 mm.
- Puncture the MPD with a 19 or 22 G needle.
- Inject contrast to obtain a pancreaticogram.
- Advance a guidewire across the papilla/anastomosis and coil it within the small bowel.
- If difficulty is encountered when advancing the guidewire into the small bowel, dilate the pancreaticogastrostomy tract to 4 mm using balloon or rigid catheter dilators to allow passage of a sphincterotome. A sphincterotome may enhance the ability to manipulate the guidewire into position. Avoid cautery-enhanced dilation to prevent thermal pancreatic injury, if possible.[12,14]
- For pancreatic EUS-RV:
  - Proceed with echoendoscope removal and rendezvous technique as described earlier.
- For pancreatic antegrade drainage and transmural drainage:
  - Dilate the pancreaticogastrostomy tract to 4 mm with balloon or rigid catheter dilators.
  - Deploy straight plastic stents, with diameter choice determined by MPD diameter, to cross the papilla/anastomosis into the small bowel for antegrade drainage, or transmurally to create a pancreaticogastrostomy.
  - If feasible, consider “ring drainage,” or creation of a gastropancreaticoenterostomy, where a double plastic pigtail stent is used with the distal pigtail crossing

the papilla/anastomosis in the small bowel in an antegrade manner, and the proximal pigtail positioned in the stomach (Video 1). This configuration is more secure and has a lower risk of stent migration and pancreatic leak.[12,15]

Salvage Procedures

Salvage for biliary antegrade drainage and, to a lesser extent, EUS-RV is needed if there is misdeployment of the stent across the papilla/anastomosis or an inability to traverse an obstruction, as this may lead to a bile leak. In such cases, we consider EUS-guided hepaticogastrostomy (EUS-HGS) through the already existing tract or percutaneous biliary drainage (PTBD).

Salvage procedures may be necessary for pancreatic drainage procedures if there is distal migration of a plastic stent into the MPD after a pancreaticogastrostomy tract has been created. When the wire remains in place in the MPD, we attempt to recapture the stent by threading a snare over the wire. When this is not feasible, we monitor the patient closely for the development of peripancreatic fluid collections and offer transgastric drainage if the collections become infected or symptomatic.

Clinical Outcomes and Adverse Events

Biliary EUS-RV has reported technical success rates of 73% to 98% and AE rates of 3% to 23%.[16] Data for EUS-antegrade drainage are scant, with limited cases series reporting technical success rates of 57% to 81% and poorly described AE rates.[17] AEs include pancreatitis, cholangitis, bleeding, perforation, and bile leak with biliary peritonitis.[16]

Given the technical complexity and relatively low volume of pancreatic EUS interventions, evidence is limited to a small number of observational studies. In expert centers, success rates for pancreatic EUS-RV have been reported to be as low as 48%. Antegrade and transmural drainage have relatively high success rates of 89% to 93%.[15,18] Pancreatic EUS interventions are among the highest risk interventional EUS procedures with approximate AE rates of 15%.[19] AEs include pancreatitis, infected peripancreatic fluid collections, and perforation.

Follow-up

Patient follow-up after EUS-RV and antegrade drainage procedures is similar to patient follow-up after biliary and pancreatic ERCP and is covered elsewhere in this issue. For patients with transmural pancreatic drainage, we generally follow them clinically and perform stent exchanges if needed, based on symptom recurrence with radiographic or endoscopic evidence of stent dysfunction.

DIRECT ENDOSCOPIC ULTRASOUND-GUIDED DRAINAGE

Endoscopic Ultrasound-guided Biliary Drainage

EUS-BD has emerged as a useful second-line option for bile duct drainage after failed ERCP and as a potential primary therapy for distal malignant bile duct obstruction (MBO).[20,21] EUS-BD is achieved primarily through EUS-CDS and EUS-HGS. The choice of technique depends on provider preference, the nature of the pathology (benign vs malignant), location (distal vs hilar), and potential for future surgical management.

Indications and patient selection

EUS-CDS is indicated for malignant or benign biliary obstruction after failed ERCP or as primary therapy for distal MBO. EUS-HGS is indicated for malignant or benign biliary obstruction after failed ERCP or as complementary therapy to ERCP and/or PTBD for left bile duct dilation in hilar (Bismuth IIIb or IV) obstruction.[8] EUS-BD is contraindicated when the target bile duct is insufficiently dilated or there is tumor infiltration at the site of puncture and avoided if the patient's surgical team prefers to preserve the native bilioenteric anatomy.

Approach

The echoendoscope is positioned in the duodenal bulb when performing CDS and in the proximal stomach when performing HGS. Both procedures result in creation of a bilioenteric anastomosis.

Most endoscopists primarily use a freehand approach with a smaller caliber EC-LAMS (6, 8, or 10 mm) for CDS,[22] though a wire-guided technique with FCSEMS can be equally successful. The first puncture is critical, as it can lead to rapid biliary decompression and make subsequent attempts challenging.

- Position the echoendoscope such that the distance between the duodenal bulb and the CBD is 10 mm or less with a CBD diameter of $\geq$12 mm.[21]
- Deploy the distal flange of the EC-LAMS under fluoroscopic and sonographic guidance.
- Retract the catheter to create apposition and deploy the proximal flange in the echoendoscope channel before releasing the stent. Alternatively, the catheter can be retracted until a black marking is seen endoscopically, after which the proximal flange can be deployed.
- If bile duct space is small or collapses after puncture, there are 2 approaches. One is to advance a guidewire toward the liver such that the proximal flange is deployed at an oblique or perpendicular angle to the bile duct. Another option is to adjust the endoscope while partially deploying the distal flange in a stepwise manner.
- After EC-LAMS placement, we routinely place coaxial double pigtail stents as there may be obstruction secondary to the distal flange abutting against the wall of a now decompressed bile duct. Other experts, however, do not routinely put in coaxial double pigtail plastic stents (DPPS). Both approaches are likely acceptable if it is not clear whether plastic stent placement within an EC-LAMS improves outcomes.[23]

For the wire-guided technique, we use 8 to 10 mm diameter FCSEMS or PCSEMS. We favor FCSEMS that have antimigratory properties and that do not foreshorten during deployment or a PCSEMS that has antimigratory distal flanges and a pull-back delivery catheter that does not require tract dilation.[24,25]

- After appropriate positioning, puncture the bile duct with a 19 or 22 G needle.
- Aspirate bile or inject contrast to confirm positioning.
- Advance the guidewire (toward the liver if possible) and retract the needle.
- If using an FCSEMS, dilate the tract with a 6 Fr cautery-tipped catheter followed by a balloon dilator to 4 mm while applying traction on the guidewire.[26] Then deploy the FCSEMS over the guidewire.
- If using the PCSEMS with a pull-back delivery catheter, deploy without tract dilation.

For HGS, we use a transgastric approach. If right-sided drainage is required and there is a safe window from the duodenum, hepaticoduodenostomy using a similar technique can also be considered.[27] We use 8 to 10 mm diameter and 8 to 10 cm length FCSEMS. If available, another consideration is a PCSEMS with an inner uncovered part that does not obstruct bile duct branches and outer covered parts that may reduce the risk of bile leak.[28] We avoid DPPS as they are difficult to place and avoid

UCSEMS due to a high risk of bile leak.[29] We do not have experience with a previously reported single pigtail stent designed for EUS-HGS.[30]

- As mentioned earlier for biliary EUS-guided antegrade drainage, identify the dilated left hepatic bile ducts from the proximal stomach, puncture with a 19 or 22 G needle at a depth of 2 to 3 cm from the liver capsule, confirm positioning using bile aspiration and a cholangiogram, and advance a guidewire deep into the biliary system.
- Dilate the tract using 4 to 6 mm balloon dilator alone or with a cautery-tipped catheter first followed by balloon dilation.
- Deploy the SEMS inside the working channel while applying tension on the delivery catheter and retracting the endoscope so 2 to 3 cm of the stent extends into the gastric lumen, to reduce the risk of migration.[31]

Salvage procedures

For EUS-CDS, if the LAMS is misdeployed without bile duct puncture, the luminal defect can be closed with clips, and CDS can be reattempted. If the bile duct is punctured with a guidewire in place, we attempt to place an FCSEMS through the LAMS. If there is no guidewire in place, rapid decompression due to bile leak make repeat CDS challenging. In these cases, we close the luminal defect and attempt management of the bile duct leak with transpapillary drainage (using EUS-RV or antegrade drainage). When endoscopic salvage fails, we close the luminal defect and refer the patient for emergent PTBD.

Salvage during EUS-HGS is required when the proximal end of the stent is malpositioned. If the proximal end is buried in the gastric wall, we adjust its position with grasping forceps. If the proximal end is in the peritoneum with a guidewire in place, we place a bridging FCSEMS. If there is no guidewire in place, we attempt to regain access to the misdeployed stent with a second puncture through the gastric wall with subsequent placement of a bridging FCSEMS. If these procedures fail, the patient requires urgent decompression with PTBD for the management of iatrogenic bile leak and consideration of surgical revision of the stent.

Clinical outcomes and adverse events

EUS-CDS has overall excellent success rates. Two recent high-quality randomized trials have reported technical success and clinical success rates of greater than 90% with LAMS and 3 day AE rates of 12% and 17%, respectively.[20,21] Rates of stent dysfunction (due to obstruction or migration) were 5% to 9%.[20,21] Pooled outcomes between LAMS and SEMS have been similar.[32] While we typically use LAMS given the fewer total steps, stent choice may be informed by endoscopist experience, equipment availability, and cost.

EUS-CDS and HGS have similar technical success, clinical success, and AE rates in a recent meta-analysis.[33] As such, we make procedural decisions between these 2 options based on the indication and location of the obstruction. For hilar lesions, a combination of ERCP, PTBD, and or EUS-HGS may be required. When left biliary system drainage is needed, EUS-HGS is potentially advantageous over PTBD as it can be completed in the same session as ERCP and has no external drain. Additionally, EUS-BD may have lower AE rates compared to PTBD.[34,35] For right-sided biliary drainage, PTBD is preferred over EUS-guided drainage after ERCP fails given the technical complexity of a hepaticoduodenostomy.

Follow-up

As most EUS-CDS and HGS are done for malignant indications, we typically leave stents in place permanently. If there is LAMS occlusion after EUS-CDS due to food impaction that cannot be removed endoscopically or from compression against the bile duct wall, we place double plastic pigtail stents.[36] If there is stent migration without bile leak and an intact fistulous tract, we remove the LAMS and place a new SEMS or plastic stent through the fistulous tract.[37] Options for obstructed EUS-HGS stents include the placement of coaxial SEMS through the occluded stent or radiofrequency ablation of the stent lumen.[29] When EUS-HGS is done for benign indications, further biliary intervention, such as cholangioscopy and lithotripsy, can be performed through a mature tract after 2 to 4 weeks. After management of the underlying benign biliary condition, FCSEMS can be removed or exchanged for DPPS every 6 months.

Endoscopic Ultrasound-guided Gallbladder Drainage

EUS-GBD has emerged as a valuable alternative percutaneous gallbladder drainage (PT-GBD) and endoscopic transpapillary gallbladder drainage (ET-GBD) for patients requiring nonsurgical gallbladder decompression. Though PT-GBD is more widely available, it is limited by drain-associated discomfort, the requirement for tube changes, and high rates of recurrent cholecystitis if the drain is removed.[38] Transpapillary drainage is similarly limited by lower clinical success rates and risk of pancreatitis.[39] EUS-GBD, now done mainly with EC-LAMS,[40] has been associated with improved technical and clinical success, low risk of AE, the ability to perform peroral therapeutic cholecystoscopy, and fewer reinterventions.[41]

Indications and patient selection

Indications for EUS-GBD include acute cholecystitis in patients with high surgical risk,[42] internal gallbladder drainage to enable the removal of percutaneous cholecystostomy drains in patients who are not candidates for cholecystectomy,[43] and malignant biliary obstruction (MBO) where ERCP or EUS-BD is not possible and the cystic duct is patent.[44] Contraindications specific to EUS-GBD are gallbladder perforation and biliary peritonitis.

ET-GBD should be considered when there is significant coagulopathy or antithrombotic medication use, large volume ascites, or another indication for ERCP such as cholangitis or choledocholithiasis. An additional consideration is the future operative candidacy of the patient. While cholecystectomy and fistula repair is feasible after EUS-GBD,[45] endoscopists and surgeons should discuss whether ET-GBD is preferred in order to preserve the native gallbladder anatomy.

Approach

When feasible, we utilize transduodenal EUS-GBD using a direct technique (Video 2).[6]

- Position the echoendoscope so the distance between the duodenal bulb and the gallbladder lumen is 10 mm or less. The duodenal bulb approach is associated with a lower risk of stent obstruction and migration compared to a transgastric approach.[46,47] The transgastric approach may be more appropriate if there is duodenal obstruction, improved gallbladder apposition or endoscope position from the antrum, and if future cholecystectomy is planned as surgical access to the antrum may be more technically feasible than the duodenal bulb.
- If peroral cholecystoscopy is anticipated, consider a larger caliber EC-LAMS (15 mm).
- Preload the EC-LAMS with a guidewire, puncture the gallbladder, and coil the guidewire in the gallbladder lumen.
- Deploy the proximal and then distal flanges as described earlier.

- When a transgastric approach is used, there is substantial cholelithiasis, or concern about LAMS migration or obstruction, consider coaxial placement of two 7 Fr plastic double pigtail stents. This may reduce the risk of stent migration, obstruction, and contralateral gallbladder wall injury.[48,49]

If we encounter difficult echoendoscope positioning, anatomic gallbladder abnormalities (eg, significant cholelithiasis or fibrosis), or an existing percutaneous tube, we utilize a wire-guided technique.

- After appropriate positioning, puncture the gallbladder with a 19 or 22 G needle.
- Aspirate bile or inject contrast to confirm position.
- Coil a guidewire in the gallbladder and retract the needle.
- As mentioned earlier, deploy the EC-LAMS and coaxial double pigtail stents, if needed.

Though EUS-GBD has been performed using conventional drainage (eg, needle puncture, guidewire insertion, tract dilation, and placement of plastic or biliary SEMS),[50,51] we generally avoid this due to an increased risk of bile leakage, contralateral wall injury, stent occlusion, and stent migration.[52,53]

Salvage procedures
If the stent is misdeployed and the gallbladder is intact,[54] the duodenal or gastric defect can be closed with through-the-scope or over-the-scope clips, or endoscope suturing. In cases where the gallbladder is punctured and there is a guidewire in place, we attempt endoscopic salvage by placing an FCSEMS through the LAMS.[55] If there is gallbladder puncture without a guidewire in place, we immediately close the duodenal or gastric defect and refer the patient for emergent percutaneous or surgical gallbladder decompression.[29]

Clinical outcomes and adverse events
Recent meta-analyses on EUS-GBD have reported excellent technical and clinical success of greater than 90% and greater than 80%, respectively.[56–58] Pooled overall (early and delayed) AE rates range from 12% to 34%[41,59] an estimated 2% perforation risk, 4% to 7% stent obstruction and recurrent cholecystitis, and 4% migration risk.[52,60] EUS-GBD has comparable technical and clinical success to PT-GBD and lower AE rates, reintervention rates, and postprocedural pain scores.[58,60] Compared to ET-GBD, EUS-GBD has higher clinical and technical success rates, similar AE rates, and lower reintervention rates.[39,61]

Follow-up
For patients with ongoing cholelithiasis after EUS-GBD for cholecystitis, we perform peroral cholecystoscopy to achieve stone clearance as this may reduce the burden of future gallstone disease. While there are data suggesting long-term LAMS patency of greater than 80%,[52] we generally remove the LAMS and maintain the fistulous tract with plastic double pigtail stents.[4,62] For patients with limited life expectancy, advanced malignancy or frailty, or who are unwilling to undergo additional procedures, we leave the LAMS in place permanently.

Endoscopic Ultrasound-guided Pancreatic Fluid Collection Drainage

EUS-guided drainage is a first-line option for the management of symptomatic or infected PFCs including pancreatic pseudocysts, walled-off necrosis (WON), and postsurgical collections.[63] The first case of PFC drainage done entirely through a therapeutic channel echoendoscope was described in 1996.[64] We make decisions regarding optimal PFC drainage based on size, location, amount of solid necrosis, and presence of infection. For WON, EUS-guided drainage can be supplemented by percutaneous drainage and surgical debridement.[63]

Indications and patient selection

EUS-guided drainage is indicated for infected or sterile symptomatic pseudocysts, WON, and postsurgical collections. We generally wait 4 weeks after the onset of acute pancreatitis as this approach is associated with improved in-hospital outcomes and fewer invasive interventions.[65,66] We always obtain cross-sectional imaging prior to the procedure to delineate the amount of liquid versus solid necrotic material and to identify the presence of pseudoaneurysms within the collection.[67] As endoscopic decompression of the fluid collection can induce pseudoaneurysm rupture and life-threatening hemorrhage, we request percutaneous vascular intervention prior to proceeding with endoscopic drainage when pseudoaneurysms are present.[68]

Approach

We primarily use a direct technique for EC-LAMS as this involves fewer steps and allows for immediate necrosectomy, if needed. If LAMS deployment is high risk due to a small cavity size or adjacent vessels, we use a wire-guided technique with DPPS. Meta-analyses and a randomized trial on WON management using LAMS versus DPPS have suggested similar rates of clinical efficacy, AE rates, and number of required procedures.[69,70]

Wire-guided technique:

- Position the echoendoscope in the stomach or duodenum to visualize the collection, puncture with a 19 G needle and coil a 0.035 guidewire in the collection.
- Advance a 6 to 8 mm balloon dilator over the guidewire and dilate the tract. If there is resistance when advancing the balloon dilator, use rigid dilators or a cautery-tipped catheter first.
- Place a second guidewire inside the collection, and place two 7Fr DPPS (one over each wire).
- For pseudocysts and postsurgical collections, obtain cross-sectional imaging 4 to 6 weeks after stent insertion. If there is radiographic resolution of the collection, remove the DPPS.
- If DPPS are inserted for WON, wait 2 to 4 weeks for tract maturation before proceeding with further dilation to 15 mm and direct endoscopic necrosectomy with a therapeutic channel gastroscope.

Direct drainage with LAMS (**Fig. 1**A–C)

- Position the echoendoscope in the stomach or duodenum and deploy the EC-LAMS.
- If immediate necrosectomy is warranted, balloon-dilate the tract to 15 mm to allow for the passage of a therapeutic channel gastroscope.
- When possible, remove the LAMS within 3 to 4 weeks. A longer dwell time is associated with an increased risk of bleeding and buried stent.[70]
- If the LAMS needs to be in place for a longer period, such as when there is a disrupted MPD or numerous necrosectomies anticipated, place a coaxial DPPS (**Fig. 1**D). Placement of a DPPS through the LAMS may help maintain stent patency, prevent migration due to anchoring, and reduce trauma to the wall of the cavity and associated bleeding.[71]
- If there is MPD disruption, the fistulous tract may be kept patent after LAMS removal by placing DPPS. This approach is associated with lower rates of PFC recurrence.[72]

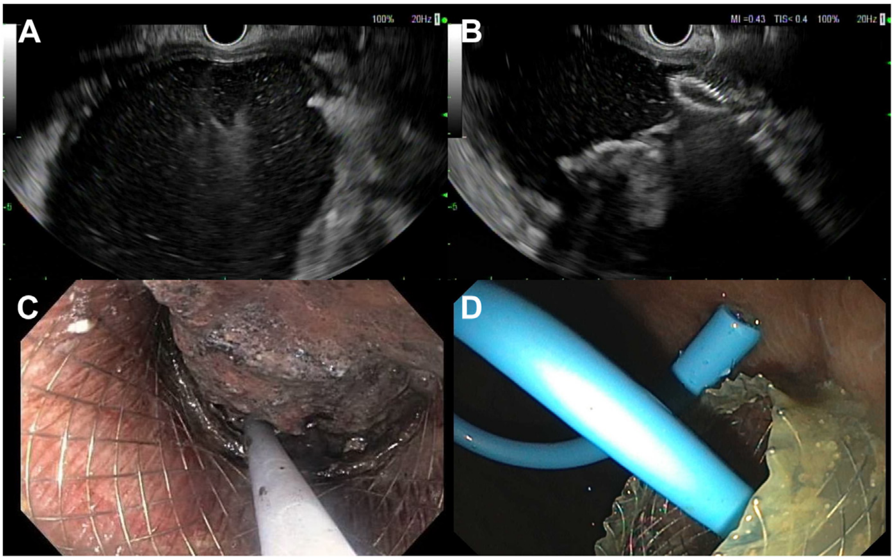

Fig. 1. EUS-guided pancreatic walled off necrosis drainage. (*A*) A large necrotic pancreatic collection is identified. (*B*) The distal flange of an electrocautery-enhanced lumen apposing metal stent (EC-LAMS) is deployed inside the collection. (*C*) A forward viewing gastroscope is used to enter the collection through the previously placed EC-LAMS to perform direct endoscopic necrosectomy with a snare. (*D*) A double-pigtail plastic stent is deployed with the distal pigtail inside the collection and the proximal pigtail in the stomach. This may help maintain EC-LAMS patency, prevent migration due to anchoring, and decrease bleeding from the cavity wall due to trauma from the EC-LAMS flange.

Salvage procedures

Stent misdeployment for PFC management usually involves either misdeployment of the distal flange outside the PFC into the peritoneum or misdeployment of the proximal flange and migration of the entire stent into the PFC. For distal flange misdeployment, over-the-wire deployment of a new stent through the fistulous tract can be done with LAMS, FCSEMS, or plastic stents.[73] If the stent has migrated into the PFC, a new LAMS can be placed through the fistulous tract while leaving the misdeployed stent within the collection. Once the tract is mature, the misdeployed stent can be retrieved from the PFC cavity.[74]

Clinical outcomes and adverse events

EUS-guided drainage of symptomatic pseudocysts has clinical success rates of greater than 90% and recurrence rates of less than 10%.[75,76] Endoscopic management of WON in contemporary studies has clinical success rates greater than 80 to 90%.[77,78] Data from randomized trials suggest shortened length of hospital stay and lower rates of multiorgan failure and enterocutaneous fistula formation with endoscopic versus surgical management.[79]

AE rates for EUS-PFC drainage vary by technique and type of stent used. Common AE for EUS-guided drainage of WON includes bleeding (10%–11%), infection (5%), perforation (1%–5%), and pancreatic fistula development (3%–4%).[78,79]

Follow-up

We make decisions around the necessity and timing of necrosectomy based on collection size, location, and percentage of necrotic tissue.[80] Factors shown to be associated with the need for necrosectomy include collection size greater than 10 cm, more than 30% solid necrotic tissue, and extension into the paracolic gutters.[80]

When necrosectomy is required, we use a combination of irrigation, suction, through-the-scope devices such as snares and baskets. We continue to assess patients clinically and radiographically and perform necrosectomy every 1 to 2 weeks until resolution of the collection. In cases with massive necrosis burden, necrosectomy can be performed multiple times per week.

Patients may require percutaneous drainage and surgical debridement in addition to endoscopic therapy. We consider percutaneous drainage up front as part of a combined approach for collections that extend into the pelvis or paracolic gutters. For nonresolving collections, surgical approaches include either video-assisted retroperitoneal debridement or open necrosectomy.[63]

ENDOSCOPIC ULTRASOUND-GUIDED LUMINAL ANASTAMOSIS

Anastomoses can be created between adjacent parts of the GI lumen by placing an EC-LAMS under EUS guidance. EUS-GE is used to treat gastric outlet obstruction (GOO)[81] and EDGE/EDEE is used to enable ERCP in patients with prior Roux-en-Y gastric bypass (RYGB), Roux-en-Y hepaticojejunostomy (RYHJ), pancreaticoduodenectomy, or Billroth II gastrectomy surgery.[82]

Endoscopic Ultrasound-guided Gastroenterostomy

EUS-GE is performed by using an EC-LAMS to create an anastomosis between the stomach and an adjacent loop of duodenum or jejunum. Over several days, the fistulous tract matures into a secure anastomosis. EUS-GE has improved durability compared to luminal stenting and lower AE risks compared to surgical gastrojejunostomy.[83]

Indications and patient selection

The primary indication for EUS-GE is malignant GOO, commonly due to gastric, duodenal, ampullary, CBD, or pancreatic cancer.[8] EUS-GE has been used for benign GOO[84] with the understanding that the LAMS should be removed once the cause of the benign obstruction has been treated and for afferent loop syndrome as an alternative to surgery and PTBD.[85]

Relative contraindications are significant malignant ascites and diffuse peritoneal carcinomatosis.[8] EUS-GE in these settings may have limited benefit as treatment of GOO can reveal additional downstream sites of obstruction.[86] Another relative contraindication is diffuse malignant infiltration of the gastric wall. Puncturing through thickened malignant tissue may require more cautery and carry a higher risk of bleeding.[87] Finally, if patients have a life expectancy of 3 months or less, we consider enteral stenting instead of EUS-GE given a lower AE risk and reasonable enteral stent patency within the first 3 months.[88]

Approach

Prior to the procedure, we place patients on a clear liquid diet (for partial obstruction) or nothing by mouth (for complete obstruction) for 2 to 3 days to minimize the amount of solid food we encounter during the procedure. EUS-GE is now largely performed using a wireless endoscopic simplified technique (WEST) and through balloon-occluded gastrojejunostomy EUS-guided double-balloon-occluded gastroenterostomy bypass (EPASS).[89,90] With both techniques, it is critical to identify and adequately dilate a loop of distal duodenum or jejunum such that it is 10 mm or less from the gastric wall. While several other techniques have been described, these have largely fallen out of favor due to multiple additional steps and the associated potential for stent misdeployment.[91]

WEST (Video 3)

- Advance a forward viewing endoscope or echoendoscope through the site of the obstruction or at the proximal end of the obstruction if it is impassable.
- Pass a long guidewire and coil it within the jejunum.
- Pass a nasobiliary (7–10 F) tube down the working channel of the scope and over the guidewire into the small bowel.
- Withdraw the endoscope or echoendoscope leaving the guidewire and nasobiliary drain in place. After scope removal, the guidewire can be removed.
- Inject normal saline with contrast and methylene blue (250–500 mL) through the nasojejunal tube to distend the small bowel loop. Contrast enables for delineation of small bowel anatomy. Methylene blue helps confirm correct LAMS placement when reflux of blue fluid is seen after stent deployment.
- If passage of the nasojejunal tube past the obstruction is unsuccessful, the fluid can be injected via a gastroscope proximal to the obstruction and allowed to passively fill the small bowel loop.
- Advance an echoendoscope into position within the stomach to visualize the distended loops of small bowel.
- Identify an optimal target for EUS-GE creation. Scan the area for interposed vascular structures.
- Give an intravenous bolus of glucagon (2–4 mg) to induce bowel paralysis prior to cautery entry.
- While depressing the cautery pedal on the electrosurgical generator, advance the EC-LAMS catheter across the gastric and small bowel well in a controlled manner.
- Deploy the distal flange of an EC-LAMS (15 or 20 mm), advance a preloaded guidewire into the jejunum, and then deploy the proximal flange using intrachannel release technique as described earlier. While the flanges are often deployed without a guidewire, the presence of a guidewire is critical to salvaging stent misdeployment, if necessary.
- After adequate positioning of the LAMS, dilation of the tract can be considered using a balloon dilator to 15 or 20 mm for 15 and 20 mm diameter LAMS, respectively.

Balloon-occluded gastrojejunostomy (EPASS)

- As mentioned earlier, advance a stiff guidewire past the obstruction and coil it within the jejunum.
- The gastroscope or echoendoscope is then removed leaving the guidewire in place.
- Advance the double-balloon occluding catheter past the obstruction, with the balloons positioned proximal and distal to the target small bowel site.
  - The double-balloon occluding catheter originally used for EPASS is not available outside of Asia.[90] In North American settings, a double-balloon device was initially fashioned using vascular balloon catheters set 10 cm apart, which could each be inflated up to 46 mm in diameter.[92]
  - More recently, a through-the-scope double-balloon catheter has been developed (DUBX, Naja; Chess Medical, Montreal, Quebec, Canada) and approved for use in the United States.[93] This catheter has 2 balloons that can be inflated

to 50 mm and are 12 cm apart. Additionally, it has a detachable working hub that allows for the catheter to be exchanged through the endoscope working channel and thus remain in place in the small bowel during removal of the forward viewing gastroscope or echoendoscope. This catheter also contains an infusion port that allows injection of fluid into the space between the 2 balloons.

- Inflate both balloons to 40 mm and then inject dilute contrast and methylene blue to dilate the target loop of small bowel.
- Once the target loop is adequately dilated, deploy the EC-LAMS with or without a guidewire as described earlier.

Salvage procedures

Stent misdeployment is not uncommon for EUS-GE and has been reported to occur in 9% of cases,[94] though these rates are likely decreasing with more widespread use of the WEST and balloon-occluded GE techniques. Misdeployment is categorized as type I (proximal flange in stomach, distal flange in peritoneum, no enterotomy), type II (proximal flange in stomach, distal flange in peritoneum after enterotomy), type III (proximal flange in peritoneum with gastrotomy, distal flange in small bowel), and type IV (proximal flange in stomach, distal flange in colon).[94] Type I misdeployment can be managed by removing the LAMS and closing the gastrotomy with endoscopic clips followed by reattempt of EUS-GE at a different site.

For type II and III misdeployment, the presence of a guidewire in the small bowel is critical. If a guidewire is present, a new LAMS or SEMS can be used to bridge the defect.[95] If a guidewire is not present, a forward viewing gastroscope can be used to enter the peritoneum through the proximal flange of the LAMS (in type II misdeployment) or the gastrotomy (in type III misdeployment) and identify the enterotomy or misdeployed LAMS, respectively. A cannula and guidewire can then be advanced into the small bowel to secure access, followed by SEMS deployment. This attempted rescue is technically demanding and may fail, resulting in a need for urgent surgical rescue.

Type IV misdeployment is usually recognized late when patient either experiences postprandial diarrhea or passes undigested food contents in their stool. This can be managed with the removal of the LAMS and endoscopic closure of the gastric and colonic defects after maturation of the fistulous tract.[94]

Clinical outcomes and adverse events

EUS-GE carries a high periprocedural AE rate of 11% to 12%,[83,96] which includes stent misdeployment and associated perforation, bleeding, aspiration of gastric contents, and erosion of the small bowel wall from contact with the distal flange of the LAMS. EUS-GE has higher clinical success rates and lower reintervention rate compared to enteral stenting[83] and a lower AE profile compared to surgical gastrojejunostomy.[83,96]

Follow-up

Given the novelty of this technique, long-term data are only now emerging. Stent dysfunction can occur due to food obstruction and tissue ingrowth. These events can generally be managed endoscopically by removing the food, placement of a new stent across the existing LAMS, or removing and replacing the LAMS.[83] For malignant disease, we leave stents in place permanently and provide expectant management. For benign disease, we follow patients for resolution of their benign GOO and then remove the LAMS to induce spontaneous tract closure.

Endoscopic Ultrasound-guided Transgastric and Transenteric Endoscopic Retrograde Cholangiopancreatography

Patients with prior RYGB, RYHJ, pancreaticoduodenectomy, or Billroth II gastrectomy with biliary disease have traditionally undergone laparoscopy-assisted ERCP (LA-ERCP) or balloon enteroscopy-assisted ERCP (BA-ERCP). EDGE and EDEE offer less invasive alternatives to LA-ERCP and have considerably higher success rates than BA-ERCP.[97]

Indications and patient selection

EDGE and EDEE are indicated when ERCP is planned for patients with prior RYGB and non-RYGB bypass (RYHJ, pancreatoduodenectomy, and Billroth II gastrectomy). For patients with non-RYGB, we generally attempt BA-ERCP first given the relatively shorter afferent limb (compared to RYGB). For patients with a gallbladder in place and planned cholecystectomy, we opt for LA-ERCP as this can be done during the same operation as a cholecystectomy.

EDGE is contraindicated if the patient wishes to avoid reconnecting the gastric pouch and excluded stomach. It is relatively contraindicated if patients have had sleeve gastrectomy prior to RYGB given the limited space in gastric remnant. If there is future surgical intervention planned, options for biliary intervention should be discussed with the surgical team prior to further altering the patient's enteric anatomy.

Approach

EDGE and EDEE involve creating an anastomosis either between the stomach and excluded stomach or between the small bowel and adjacent small bowel limb, respectively, using an EC-LAMS. A duodenoscope or forward-viewing scope can then be passed through the anastomosis to perform conventional ERCP. As with EUS-GE, adequate dilation of the target organ is critical to prevent stent misdeployment (**Fig. 2**).

- Position the echoendoscope in the native stomach, gastric pouch, or small bowel and visualize the target lumen (excluded stomach or small bowel).
- Puncture the target lumen with a 19 G needle and instill dilute contrast with methylene blue until the target lumen is adequately distended, typically 250 to 500 mL. Though we generally use a direct puncture, other methods to distend the target lumen have been described, including saline infusion through a nasobiliary drain, balloon-enteroscope, or percutaneous drain.[82]
- Deploy an EC-LAMS as described earlier for EUS-GE with or without wire guidance. A 20 or 15 mm diameter LAMS can be used, though the latter may have a higher risk of intraprocedural migration.[98]
- If possible, delay transgastric or transenteric ERCP for at least 7 days to allow the fistulous tract to mature.
- If same session ERCP is required for an emergent indication such as cholangitis, dilate the LAMS to at least 15 mm and consider using clips or endoscopic suturing to anchor the stent in place prior to transmural intervention.[99]

Salvage procedures

In addition to the 4 types of misdeployments described earlier for EUS-GE, stent dislodgement may occur during ERCP and result in a free perforation. Salvage techniques for stent misdeployment and dislodgement are similar to those used for EUS-GE as earlier.

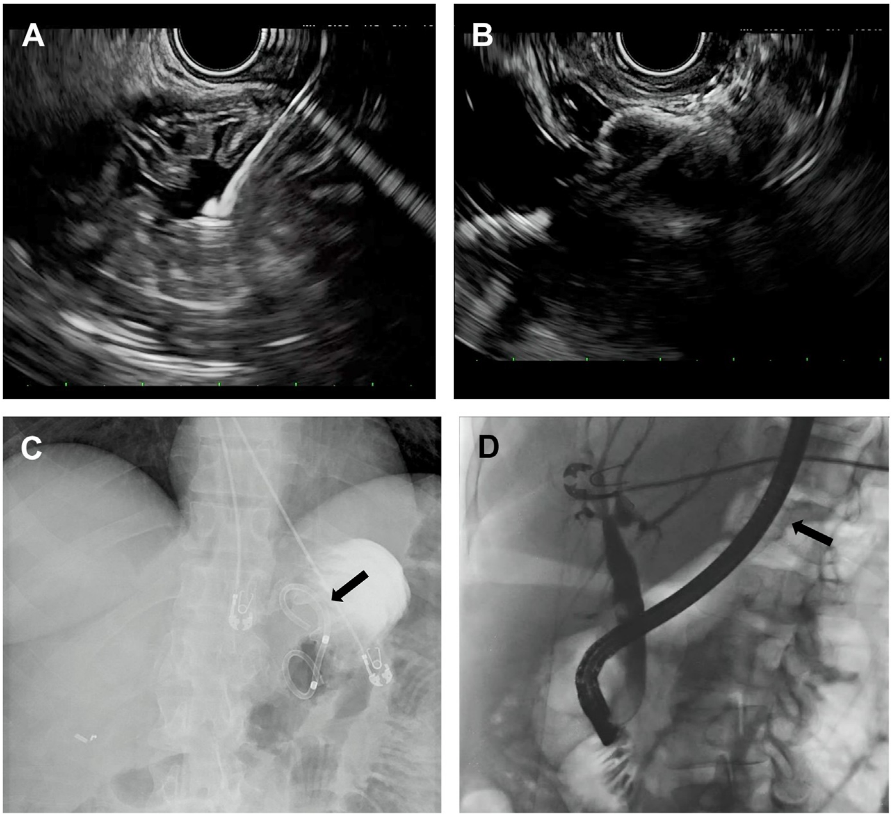

Fig. 2. Endoscopic ultrasound-directed transgastric ERCP (EDGE). (*A*) With an echoendoscope positioned in the gastric pouch of a patient with prior Roux-en-Y gastric bypass, a 19 G needle is used to puncture the excluded stomach. (*B*) The distal flange of an electrocautery-enhanced lumen apposing metal stent (EC-LAMS) is deployed in the excluded stomach. (*C*) An EC-LAMS (*black arrow*) with an anchoring double pigtail plastic stent is seen connecting the gastric pouch to the excluded stomach. (*D*) A duodenoscope is used to access the papilla through the EC-LAMS (*black arrow*) and excluded stomach to perform ERCP.

Clinical outcomes and adverse events

Pooled outcomes from meta-analysis of EDGE and EDEE have reported technical success rates of greater than 95%.[97] AE rates are approximately 17% to 18% and include stent dislodgement during subsequent ERCP, postprocedural abdominal pain, bleeding, persistent fistula despite LAMS removal, and post-EDGE weight gain.[97] EDGE and EDEE have similar success rates and AE rates with shorter procedure times compared to LA-ERCP, and higher success rates and AE rates compared to BA-ERCP.[97]

Follow-up

After the biliary issue is resolved, we remove the LAMS. Despite removal, a large and persistent fistula may lead to weight gain. Fistula persistence seems to be associated a longer LAMS dwell time[98] and can be managed endoscopically using through-the-scope or over-the-scope clips, endoscopic suturing, or argon coagulation applied to the tract.[98]

CONSIDERATIONS FOR SALVAGE PROCEDURES

Salvage options for stent misdeployment are detailed earlier for each procedure. The objective of all salvage procedures is to re-establish access to the ductal or luminal target, if possible. When this is not possible, the goal is to secure closure of any defects and attain access or drainage through percutaneous or surgical means. In the vast majority of cases, we admit patients to hospital, administer broad-spectrum antibiotics, manage pneumoperitoneum with needle decompression, if needed, and request surgical and/or interventional radiology consultation as indicated.[8]

SUMMARY

Therapeutic EUS is an innovative and rapidly developing field that allows for internal access to pancreaticobiliary and adjacent luminal structures. While these procedures are demanding and require significant expertise, they can have excellent clinical outcomes and provide valuable treatment options for patients.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.gtc.2024.08.016.

REFERENCES

1. Veitch AM, Radaelli F, Alikhan R, et al. Endoscopy in patients on antiplatelet or anticoagulant therapy: British Society of Gastroenterology (BSG) and European Society of Gastrointestinal Endoscopy (ESGE) guideline update. Endoscopy 2021;53(09):947–69.
2. Venkatesan AM, Kundu S, Sacks D, et al. Practice guideline for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Intervent Radiol 2010;21(11):1611–30.
3. Berríos-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for disease control and prevention guideline for the prevention of surgical site infection, 2017. JAMA Surgery 2017;152(8):784–91.
4. Teoh AYB, Leung CH, Tam PTH, et al. EUS-guided gallbladder drainage versus laparoscopic cholecystectomy for acute cholecystitis: a propensity score analysis with 1-year follow-up data. Gastrointest Endosc 2021;93(3):577–83.
5. Teoh A, Perez-Miranda M, Kunda R, et al. Outcomes of an international multicenter registry on EUS-guided gallbladder drainage in patients at high risk for cholecystectomy. Endosc Int Open 2019;7(08):E964–73.
6. Teoh AYB, Binmoeller KF, Lau JYW. Single-step EUS-guided puncture and delivery of a lumen-apposing stent for gallbladder drainage using a novel cautery-tipped stent delivery system. Gastrointest Endosc 2014;80(6):1171.
7. Jearth V. Current paradigm of endoscopic ultrasound in biliary and pancreatic duct drainage: an update. Aog 2023. https://doi.org/10.20524/aog.2023.0854.
8. Van Der Merwe SW, Van Wanrooij RL, Bronswijk M, et al. Therapeutic endoscopic ultrasound: European society of gastrointestinal endoscopy (ESGE) guideline. Endoscopy 2022;54(02):185–205.
9. Chandan S, Mohan BP, Khan SR, et al. Efficacy and safety of endoscopic ultrasound-guided pancreatic duct drainage (EUS-PDD): a systematic review and meta-analysis of 714 patients. Endosc Int Open 2020;8(11):E1664–72.
10. Tsuchiya T, Itoi T, Sofuni A, et al. Endoscopic ultrasonography-guided rendezvous technique. Dig Endosc 2016;28:96–101.

11. Yamamoto Y, Ogura T, Nishioka N, et al. Risk factors for adverse events associated with bile leak during EUS-guided hepaticogastrostomy. Endoscopic Ultrasound 2020;9(2):110–5.
12. Fujii LL, Topazian MD, Dayyeh BKA, et al. EUS-guided pancreatic duct intervention: outcomes of a single tertiary-care referral center experience. Gastrointest Endosc 2013;78(6):854–64.
13. Imoto A, Ogura T, Higuchi K. Endoscopic ultrasound-guided pancreatic duct drainage: techniques and literature review of transmural stenting. Clinical Endoscopy 2020;53(5):525.
14. Krafft MR, Nasr JY. Anterograde endoscopic ultrasound-guided pancreatic duct drainage: a technical review. Dig Dis Sci 2019;64:1770–81.
15. Chen Y-I, Levy MJ, Moreels TG, et al. An international multicenter study comparing EUS-guided pancreatic duct drainage with enteroscopy-assisted endoscopic retrograde pancreatography after Whipple surgery. Gastrointest Endosc 2017;85(1):170–7.
16. Klair JS, Zafar Y, Ashat M, et al. Effectiveness and safety of EUS rendezvous after failed biliary cannulation with ERCP: a systematic review and proportion meta-analysis. J Clin Gastroenterol 2023;57(2):211–7.
17. Hedjoudje A, Sportes A, Grabar S, et al. Outcomes of endoscopic ultrasound-guided biliary drainage: a systematic review and meta-analysis. United European Gastroenterology Journal 2019;7(1):60–8.
18. François E, Kahaleh M, Giovannini M, et al. EUS-guided pancreaticogastrostomy. Gastrointest Endosc 2002;56(1):128–33.
19. Basiliya K, Veldhuijzen G, Gerges C, et al. Endoscopic retrograde pancreatography-guided versus endoscopic ultrasound-guided technique for pancreatic duct cannulation in patients with pancreaticojejunostomy stenosis: a systematic literature review. Endoscopy 2021;53(03):266–76.
20. Teoh AYB, Napoleon B, Kunda R, et al. EUS-guided choledocho-duodenostomy using lumen apposing stent versus ERCP with covered metallic stents in patients with unresectable malignant distal biliary obstruction: a multicenter randomized controlled trial (DRA-MBO Trial). Gastroenterology 2023;165(2):473–82.
21. Chen Y-I, Sahai A, Donatelli G, et al. Endoscopic ultrasound-guided biliary drainage of first intent with a lumen-apposing metal stent vs endoscopic retrograde cholangiopancreatography in malignant distal biliary obstruction: a multicenter randomized controlled study (ELEMENT Trial). Gastroenterology 2023;165(5):1249–61.
22. Anderloni A, Fugazza A, Troncone E, et al. Single-stage EUS-guided choledochoduodenostomy using a lumen-apposing metal stent for malignant distal biliary obstruction. Gastrointest Endosc 2019;89(1):69–76.
23. Garcia-Sumalla A, Loras C, Guarner-Argente C, et al. Is a coaxial plastic stent within a lumen-apposing metal stent useful for the management of distal malignant biliary obstruction? Surg Endosc 2021;35:4873–81.
24. Bang JY, Navaneethan U, Hasan M, et al. Stent placement by EUS or ERCP for primary biliary decompression in pancreatic cancer: a randomized trial (with videos). Gastrointest Endosc 2018;88(1):9–17.
25. Itonaga M, Kitano M, Hatamaru K, et al. Endoscopic ultrasound-guided choledochoduodenostomy using a thin stent delivery system in patients with unresectable malignant distal biliary obstruction: a prospective multicenter study. Dig Endosc 2019;31(3):291–8.

26. Kawakubo K, Isayama H, Kato H, et al. Multicenter retrospective study of endoscopic ultrasound-guided biliary drainage for malignant biliary obstruction in J apan. J Hepato-Biliary-Pancreatic Sci 2014;21(5):328–34.
27. Cho SH, Song TJ, Oh D, et al. Endoscopic ultrasound-guided hepaticoduodenostomy versus percutaneous drainage for right intrahepatic duct dilatation in malignant hilar obstruction. J Gastroenterol Hepatol 2024;39(3):552–9.
28. De Cassan C, Bories E, Pesenti C, et al. Use of partially covered and uncovered metallic prosthesis for endoscopic ultrasound-guided hepaticogastrostomy: results of a retrospective monocentric study. Endoscopic Ultrasound 2017;6(5):329–35.
29. Van Wanrooij RL, Bronswijk M, Kunda R, et al. Therapeutic endoscopic ultrasound: European Society of Gastrointestinal Endoscopy (ESGE) technical review. Endoscopy 2022;54(03):310–32.
30. Umeda J, Itoi T, Tsuchiya T, et al. A newly designed plastic stent for EUS-guided hepaticogastrostomy: a prospective preliminary feasibility study (with videos). Gastrointest Endosc 2015;82(2):390–6.
31. Miyano A, Ogura T, Yamamoto K, et al. Clinical impact of the intra-scope channel stent release technique in preventing stent migration during EUS-guided hepaticogastrostomy. J Gastrointest Surg 2018;22(7):1312–8.
32. Amato A, Sinagra E, Celsa C, et al. Efficacy of lumen-apposing metal stents or self-expandable metal stents for endoscopic ultrasound-guided choledochoduodenostomy: a systematic review and meta-analysis. Endoscopy 2021;53(10):1037–47.
33. Yamazaki H, Yamashita Y, Shimokawa T, et al. Endoscopic ultrasound-guided hepaticogastrostomy versus choledochoduodenostomy for malignant biliary obstruction: a meta-analysis. DEN Open 2024;4(1):e274.
34. Sharaiha RZ, Khan MA, Kamal F, et al. Efficacy and safety of EUS-guided biliary drainage in comparison with percutaneous biliary drainage when ERCP fails: a systematic review and meta-analysis. Gastrointest Endosc 2017;85(5):904–14.
35. Lee TH, Choi J-H, Park DH, et al. Similar efficacies of endoscopic ultrasound–guided transmural and percutaneous drainage for malignant distal biliary obstruction. Clin Gastroenterol Hepatol 2016;14(7):1011–9.
36. Manno M, Vavassori S, Deiana S, et al. Rescue endoscopic therapy after malfunctioning choledochoduodenostomy in patient with malignant distal biliary obstruction. Endoscopy 2020;52(04):E144–5.
37. Tsuchiya T, Teoh AYB, Itoi T, et al. Long-term outcomes of EUS-guided choledochoduodenostomy using a lumen-apposing metal stent for malignant distal biliary obstruction: a prospective multicenter study. Gastrointest Endosc 2018;87(4):1138–46.
38. Pisano M, Allievi N, Gurusamy K, et al. World Society of Emergency Surgery updated guidelines for the diagnosis and treatment of acute calculus cholecystitis. World J Emerg Surg 2020;15(1):1–26.
39. Krishnamoorthi R, Jayaraj M, Thoguluva Chandrasekar V, et al. EUS-guided versus endoscopic transpapillary gallbladder drainage in high-risk surgical patients with acute cholecystitis: a systematic review and meta-analysis. Surg Endosc 2020;34:1904–13.
40. Irani S, Baron TH, Grimm IS, et al. EUS-guided gallbladder drainage with a lumen-apposing metal stent (with video). Gastrointest Endosc 2015;82(6):1110–5.
41. Hemerly MC, de Moura DTH, do Monte Junior ES, et al. Endoscopic ultrasound (EUS)-guided cholecystostomy versus percutaneous cholecystostomy (PTC) in

the management of acute cholecystitis in patients unfit for surgery: a systematic review and meta-analysis. Surg Endosc 2023;37(4):2421–38.
42. Mori Y, Itoi T, Baron TH, et al. Tokyo Guidelines 2018: management strategies for gallbladder drainage in patients with acute cholecystitis (with videos). J Hepato-Biliary-Pancreatic Sci 2018;25(1):87–95.
43. Law R, Grimm IS, Stavas JM, et al. Conversion of percutaneous cholecystostomy to internal transmural gallbladder drainage using an endoscopic ultrasound–guided, lumen-apposing metal stent. Clin Gastroenterol Hepatol 2016;14(3):476–80.
44. Imai H, Kitano M, Omoto S, et al. EUS-guided gallbladder drainage for rescue treatment of malignant distal biliary obstruction after unsuccessful ERCP. Gastrointest Endosc 2016;84(1):147–51.
45. Tyberg A, Duarte-Chavez R, Shahid HM, et al. Endoscopic ultrasound-guided gallbladder drainage versus percutaneous drainage in patients with acute cholecystitis undergoing elective cholecystectomy. Clin Transl Gastroenterol 2023;14(6):e00593.
46. Perez-Miranda M. Technical considerations in EUS-guided gallbladder drainage. Endoscopic Ultrasound 2018;7(2):79.
47. Dollhopf M, Larghi A, Will U, et al. EUS-guided gallbladder drainage in patients with acute cholecystitis and high surgical risk using an electrocautery-enhanced lumen-apposing metal stent device. Gastrointest Endosc 2017;86(4):636–43.
48. James TW, Krafft M, Croglio M, et al. EUS-guided gallbladder drainage in patients with cirrhosis: results of a multicenter retrospective study. Endosc Int Open 2019;7(09):E1099–104.
49. Cho SH, Oh D, Song TJ, et al. Comparison of the effectiveness and safety of lumen-apposing metal stents and anti-migrating tubular self-expandable metal stents for EUS-guided gallbladder drainage in high surgical risk patients with acute cholecystitis. Gastrointest Endosc 2020;91(3):543–50.
50. Kwan V, Eisendrath P, Antaki F, et al. EUS-guided cholecystenterostomy: a new technique (with videos). Gastrointest Endosc 2007;66(3):582–6.
51. Baron TH, Topazian MD. Endoscopic transduodenal drainage of the gallbladder: implications for endoluminal treatment of gallbladder disease. Gastrointest Endosc 2007;65(4):735–7.
52. Choi J-H, Lee SS, Choi JH, et al. Long-term outcomes after endoscopic ultrasonography-guided gallbladder drainage for acute cholecystitis. Endoscopy 2014;656–61.
53. Kamata K, Takenaka M, Kitano M, et al. Endoscopic ultrasound-guided gallbladder drainage for acute cholecystitis: long-term outcomes after removal of a self-expandable metal stent. World J Gastroenterol 2017;23(4):661.
54. Rana SS. Endoscopic ultrasound-guided gallbladder drainage: a technical review. Ann Gastroenterol 2021;34(2):142.
55. Yang MJ, Hwang JC, Yoo BM, et al. Tips for dealing with common beginner's mistakes made during endoscopic ultrasound-guided gallbladder drainage. Dig Dis 2020;38(6):542–6.
56. Osman KT, Abdelfattah AM, Elbadawi ME, et al. Outcomes of EUS-guided gallbladder drainage in malignant distal biliary obstruction: a systematic review and meta-analysis. iGIE 2023;2(3):324–32.
57. Kamal F, Khan MA, Lee-Smith W, et al. Efficacy and safety of EUS-guided gallbladder drainage for rescue treatment of malignant biliary obstruction: a systematic review and meta-analysis. Endoscopic Ultrasound 2023;12(1):8.

58. Boregowda U, Chen M, Saligram S. Endoscopic ultrasound-guided gallbladder drainage versus percutaneous gallbladder drainage for acute cholecystitis: a systematic review and meta-analysis. Diagnostics 2023;13(4):657.
59. Hayat U, Al Shabeeb R, Perez P, et al. Safety and adverse events of endoscopic ultrasound-guided gallbladder drainage using lumen-apposing metal stents and percutaneous cholecystostomy tubes: a systematic review and meta-analysis. Gastrointest Endosc 2023;99(3):444–8.e1.
60. Teoh AY, Kitano M, Itoi T, et al. Endosonography-guided gallbladder drainage versus percutaneous cholecystostomy in very high-risk surgical patients with acute cholecystitis: an international randomised multicentre controlled superiority trial (DRAC 1). Gut 2020;69(6):1085–91.
61. Siddiqui A, Kunda R, Tyberg A, et al. Three-way comparative study of endoscopic ultrasound-guided transmural gallbladder drainage using lumen-apposing metal stents versus endoscopic transpapillary drainage versus percutaneous cholecystostomy for gallbladder drainage in high-risk surgical patients with acute cholecystitis: clinical outcomes and success in an International, Multicenter Study. Surg Endosc 2019;33:1260–70.
62. Chan SM, Teoh AYB, Yip HC, et al. Feasibility of per-oral cholecystoscopy and advanced gallbladder interventions after EUS-guided gallbladder stenting (with video). Gastrointest Endosc 2017;85(6):1225–32.
63. Arvanitakis M, Dumonceau J-M, Albert J, et al. Endoscopic management of acute necrotizing pancreatitis: European Society of Gastrointestinal Endoscopy (ESGE) evidence-based multidisciplinary guidelines. Endoscopy 2018;50(05):524–46.
64. Wiersema MJ. Endosonography-guided cystoduodenostomy with a therapeutic ultrasound endoscope. Gastrointest Endosc 1996;44(5):614–7.
65. Van Santvoort HC, Bakker OJ, Bollen TL, et al. A conservative and minimally invasive approach to necrotizing pancreatitis improves outcome. Gastroenterology 2011;141(4):1254–63.
66. Boxhoorn L, van Dijk SM, van Grinsven J, et al. Immediate versus postponed intervention for infected necrotizing pancreatitis. N Engl J Med 2021;385(15):1372–81.
67. Marshall GT, Howell DA, Hansen BL, et al. Multidisciplinary approach to pseudoaneurysms complicating pancreatic pseudocysts: impact of pretreatment diagnosis. Arch Surg 1996;131(3):278–83.
68. Bhasin DK, Rana SS, Sharma V, et al. Non-surgical management of pancreatic pseudocysts associated with arterial pseudoaneurysm. Pancreatology 2013;13(3):250–3.
69. Chandrasekhara V, Barthet M, Devière J, et al. Safety and efficacy of lumen-apposing metal stents versus plastic stents to treat walled-off pancreatic necrosis: systematic review and meta-analysis. Endosc Int Open 2020;8(11):E1639–53.
70. Bang JY, Navaneethan U, Hasan MK, et al. Non-superiority of lumen-apposing metal stents over plastic stents for drainage of walled-off necrosis in a randomised trial. Gut 2019;68(7):1200–9.
71. Vanek P, Falt P, Vitek P, et al. EUS-guided transluminal drainage using lumen-apposing metal stents with or without coaxial plastic stents for treatment of walled-off necrotizing pancreatitis: a prospective bicentric randomized controlled trial. Gastrointest Endosc 2023;97(6):1070–80.
72. Bang JY, Wilcox CM, Navaneethan U, et al. Impact of disconnected pancreatic duct syndrome on the endoscopic management of pancreatic fluid collections. Ann Surg 2018;267(3):561–8.

73. Armellini E, Metelli F, Anderloni A, et al. Lumen-apposing-metal stent misdeployment in endoscopic ultrasound-guided drainages: a systematic review focusing on issues and rescue management. World J Gastroenterol 2023;29(21):3341.
74. Ladd AM, Bashashati M, Contreras A, et al. Endoscopic pancreatic necrosectomy in the United States-Mexico border: a cross sectional study. World J Gastrointest Endosc 2020;12(5):149.
75. Ramouz A, Shafiei S, Ali-Hasan-Al-Saegh S, et al. Systematic review and meta-analysis of endoscopic ultrasound drainage for the management of fluid collections after pancreas surgery. Surg Endosc 2022;36(6):3708–20.
76. Szakó L, Mátrai P, Hegyi P, et al. Endoscopic and surgical drainage for pancreatic fluid collections are better than percutaneous drainage: meta-analysis. Pancreatology 2020;20(1):132–41.
77. Boxhoorn L, Fritzsche JA, Fockens P, et al. Clinical outcome of endoscopic treatment for symptomatic sterile walled-off necrosis. Endoscopy 2021;53(02):136–44.
78. Bang JY, Wilcox CM, Navaneethan U, et al. Treatment of walled-off necrosis using lumen-apposing metal stent versus plastic stents: a systematic review and meta-analysis of data from randomized trials. Endoscopy 2023;56(3):184–95.
79. Bang JY, Wilcox CM, Arnoletti JP, et al. Superiority of endoscopic interventions over minimally invasive surgery for infected necrotizing pancreatitis: meta-analysis of randomized trials. Dig Endosc 2020;32(3):298–308.
80. Chandrasekhara V, Elhanafi S, Storm AC, et al. Predicting the need for step-up therapy after EUS-guided drainage of pancreatic fluid collections with lumen-apposing metal stents. Clin Gastroenterol Hepatol 2021;19(10):2192–8.
81. Khashab MA, Baron TH, Binmoeller KF, et al. EUS-guided gastroenterostomy: a new promising technique in evolution. Gastrointest Endosc 2015;81(5):1234–6.
82. Ichkhanian Y, Yang J, James TW, et al. EUS-directed transenteric ERCP in non–Roux-en-Y gastric bypass surgical anatomy patients (with video). Gastrointest Endosc 2020;91(5):1188–94.
83. Benchaya JA, Chen Y-I, Martel M, et al. EUS-guided gastroenterostomy vs. surgical gastrojejunostomy and enteral stenting for malignant gastric outlet obstruction: a meta-analysis. Endosc Int Open 2023;11(7):E660–72.
84. James TW, Greenberg S, Grimm IS, et al. EUS-guided gastroenteric anastomosis as a bridge to definitive treatment in benign gastric outlet obstruction. Gastrointest Endosc 2020;91(3):537–42.
85. Ikeuchi N, Itoi T, Tsuchiya T, et al. One-step EUS-guided gastrojejunostomy with use of lumen-apposing metal stent for afferent loop syndrome treatment. Gastrointest Endosc 2015;82(1):166.
86. Bronswijk M, Vanella G, Van Malenstein H, et al. Laparoscopic versus EUS-guided gastroenterostomy for gastric outlet obstruction: an international multicenter propensity score–matched comparison (with video). Gastrointest Endosc 2021;94(3):526–36.
87. Carbajo AY, Kahaleh M, Tyberg A. Clinical review of EUS-guided gastroenterostomy (EUS-GE). J Clin Gastroenterol 2020;54(1):1–7.
88. Jeurnink SM, Steyerberg EW, van Hooft JE, et al. Surgical gastrojejunostomy or endoscopic stent placement for the palliation of malignant gastric outlet obstruction (SUSTENT study): a multicenter randomized trial. Gastrointest Endosc 2010;71(3):490–9.
89. Bronswijk M, Vanella G, Petrone MC, et al. EUS-guided gastroenterostomy: less is more! The wireless EUS-guided gastroenterostomy simplified technique. VideoGIE 2020;5(9):442.

90. Itoi T, Itokawa F, Uraoka T, et al. Novel EUS-guided gastrojejunostomy technique using a new double-balloon enteric tube and lumen-apposing metal stent (with videos). Gastrointest Endosc 2013;78(6):934–9.
91. Marrache MK, Itani MI, Farha J, et al. Endoscopic gastrointestinal anastomosis: a review of established techniques. Gastrointest Endosc 2021;93(1):34–46.
92. Miller CS, Chen Y-I, Chavez YH, et al. Double-balloon endoscopic ultrasound-guided gastroenterostomy: simplifying a complex technique towards widespread use. Endoscopy 2020;52(02):151–2.
93. Chen Y-I, Menard C, Khashab M, et al. EUS-guided gastroenterostomy using a novel through-the-scope exchangeable dual-balloon enteroclysis catheter: a potentially secure and scalable approach. VideoGIE 2023;8(12):500–2.
94. Ghandour B, Bejjani M, Irani SS, et al. Classification, outcomes, and management of misdeployed stents during EUS-guided gastroenterostomy. Gastrointest Endosc 2022;95(1):80–9.
95. Tyberg A, Zerbo S, Barthet M, et al. A novel technique for salvaging a dislodged lumen-apposing metal stent during creation of an endoscopic gastrojejunostomy. Gastrointest Endosc 2016;83(1):254.
96. Iqbal U, Khara HS, Hu Y, et al. EUS-guided gastroenterostomy for the management of gastric outlet obstruction: a systematic review and meta-analysis. Endoscopic Ultrasound 2020;9(1):16–23.
97. Dhindsa BS, Dhaliwal A, Mohan BP, et al. EDGE in Roux-en-Y gastric bypass: How does it compare to laparoscopy-assisted and balloon enteroscopy ERCP: a systematic review and meta-analysis. Endosc Int Open 2020;8(02):E163–71.
98. Runge TM, Chiang AL, Kowalski TE, et al. Endoscopic ultrasound-directed transgastric ERCP (EDGE): a retrospective multicenter study. Endoscopy 2021;53(06):611–8.
99. Shinn B, Boortalary T, Raijman I, et al. Maximizing success in single-session EUS-directed transgastric ERCP: a retrospective cohort study to identify predictive factors of stent migration. Gastrointest Endosc 2021;94(4):727–32.