Review Article

Therapeutic EUS: New tools, new devices, new applications

Barbara Braden, Vipin Gupta, Christoph Frank Dietrich[1]

Translational Gastroenterology Unit, Oxford University Hospitals NHS Foundation Trust, Oxford, UK, [1]Department of Medicine, Caritas-Krankenhaus, Uhlandstr, Bad Mergentheim, Germany

ABSTRACT

Linear echoendoscopes with large instrument channels enable EUS-guided interventions in organs and anatomical spaces in proximity to the gastrointestinal tract. Novel devices and tools designed for EUS-guided transluminal interventions allow various new applications and improve the efficacy and safety of these procedures. New-generation biopsy needles provide higher histology rates and require less passes. Specially designed stents and stent insertion devices enable intra- and extra-hepatic bile and pancreatic duct stenting as well as gallbladder drainage. Currently, EUS-guided biliary drainage in obstructive jaundice due to malignant distal bile duct obstruction is feasible and safe when ERCP has failed. It might replace ERCP as first choice intervention in future. EUS-guided transmural stenting is regarded as the preferred intervention in the management of symptomatic peripancreatic fluid collections. Creating a new anastomosis between different organs such as gastrojejunostomy has also become possible with lumen-apposing stents. EUS-guided creation of a gastrogastrostomy is a promising novel technique to access the excluded stomach to facilitate conventional ERCP in patients with Roux-en-Y gastric bypass anatomy. The role of EUS in tumor ablation and targeted angiotherapy is also constantly expanding. In this review, we report on the newest developments of therapeutic EUS within the past 4 years.

Key words: Biliary drainage, peripancreatic collection, Roux-en-Y gastric bypass anatomy, targeted angiotherapy

INTRODUCTION

Diagnostic EUS has progressed in the last decade by advances in imaging techniques and introducing novel methods of tissue characterization based on the vascular structure and tissue stiffness. Contrast enhanced EUS has gained similar importance in characterization of hepatic and pancreatic masses comparable to cross-sectional imaging contrast techniques. Elastography has added another dimension to tissue characterization by adding the measurement of the stiffness.

Despite these improvements in imaging information, the main indication of EUS has shifted to therapeutic interventions, a similar phenomenon we have observed for ERCP which is nowadays only performed for therapeutic indications.

Noninvasive conventional imaging techniques such as computed tomography, magnetic resonance, and positron emission tomography have also improved allowing high-resolution images and contrast

Access this article online

Quick Response Code:

Website: www.eusjournal.com

DOI: 10.4103/eus.eus_39_19

How to cite this article: Braden B, Gupta V, Dietrich CF. Therapeutic EUS: New tools, new devices, new applications. Endosc Ultrasound 2019;8:370-81.

Address for correspondence

Prof. Barbara Braden, Oxford University Hospitals NHS Foundation Trust, Oxford, UK. E-mail: braden@em.uni-frankfurt.de

Received: 2019-02-24; **Accepted:** 2019-06-02; **Published online:** 2019-08-09

application. Noninvasive imaging has replaced EUS as the first modality for indications such as tumor staging or the assessment of the distal bile duct for choledocholithiasis.[1,2] EUS still plays a role in the detection of distal bile duct stones when the magnetic resonance cholangiopancreatography was negative and the clinical suspicion remains as it has higher sensitivity.

On the other hand, the indications for endosonographic interventions are rapidly expanding. The instrument channel in curvilinear array echoendoscopes allows the use of various tools and devices (needles, forceps, stents, radiofrequency ablation [RFA], or microscopy probes) for transmural interventions. Beyond the EUS-guided drainage techniques in biliary and pancreatic disease, new techniques for tumor ablation or hemostasis have been developed. The development of lumen-apposing stents has enabled the option to create a new anastomosis between luminal organs.

The guidelines of the European Federation of Societies for Ultrasound in Medicine and Biology on interventional ultrasound have summarized the status quo in 2015,[3-5] but many innovations have been reported since.

METHODS

In this review, we have focussed on the most recent literature (2015–2019) on therapeutic EUS and give an overview on established and emerging therapeutic EUS interventions. We have searched PubMed using the following singular and combined search terms: <EUS>; <endoscopic ultrasound>; <drainage>; <cholecystostomy>; <bile duct>; <pancreatic duct>; <peripancreatic collection>; <walled-off necrosis>; <malignant biliary obstruction>; <Roux-en-y gastric bypass anatomy>; <Fundal varix>; <pseudoaneurysm>; <tumourablation>; <stent>; <coeliac block>; <neurolysis>; <anastomosis>; <tissue sampling>; <cytology>; <aspiration>; <biopsy>.

In the selection process, the authors favored randomized controlled multi-center studies over single-center randomized studies. If randomized studies were not available, controlled studies with large case numbers were cited, again preferring multi-center to single-center studies.

Tissue sampling

Apart from diagnostic sampling for tumor confirmation and classification, EUS-guided tissue acquisition is becoming also increasingly important for immunostaining, mutation analysis, and the prognosis of tumor behavior and therapy response allowing genetically based individualized risk stratification.[6]

FNA

There is ongoing debate on whether suction techniques and needle caliber affect the diagnostic yield in fine-needle aspiration (FNA). In a randomized controlled study including 352 patients with pancreatic masses, 22G or 25G needles performed equally well. Use of suction increased specimen bloodiness and the passes required.[7]

19G FNA needles performed equally well to 25G needles in a randomized multi-center study by Ramesh *et al*.[8] in 100 patients with pancreatic head mass lesions, although the 19G needle produced more tissue cores. However, for the transduodenal approach, the randomized multi-center study by Laquière *et al*. including 125 patients demonstrated less technical success due to more difficult sampling using the 19G needle compared to the 22G needle.[9]

In a multi-center study, the conventional suction technique has been compared to a new aspiration method with the slow withdrawal of the needle stylet to create a slight negative pressure. The diagnostic sensitivity or passes required did not differ between both suction methods.[10]

For biliary tumors, EUS-FNA performs better than ERCP with brush cytology and intraductal forceps biopsy in diagnosing malignant biliary strictures.[11] The superior sensitivity of EUS-FNA (73.6%) compared to ERCP brushings (56.5%) has also been confirmed in a multi-center study including 263 patients with suspected malignant biliary obstruction who underwent both procedures in the same session.[12]

FNB

A recent meta-analysis concluded that there is no significant difference in the diagnostic yield whether an FNA or fine-needle biopsy (FNB) (using reverse bevel needles) has been used as long as rapid onsite evaluation by cytopathologist is available. Otherwise, FNB showed better diagnostic adequacy, which was achieved in fewer passes.[13] A multicenter randomized controlled trial including 274 patients also confirmed no difference in diagnostic yield between FNA or biopsy needle with reverse bevel.[14]

New-generation biopsy needles

Novel biopsy needles have been introduced with a special tip design to cut and keep the tissue. The fork-tip Sharkcore™ (Medtronic) has two, the Acquire™ needle (Boston Scientific) three opposing bevels. The first studies with the SharkCore™ needles demonstrate better tissue rates sufficient for histology with fewer needle passes not only compared to FNA needles[15-18] but also compared to the older generation biopsy needles with reverse bevels.[19,20]

The Acquire™ biopsy needle also obtained better tissue results than the conventional end-cut type needle for FNA.[21,22]

Comparing both new biopsy needles directly, the fork-tip biopsy needle (SharkCore™) and the Franseen tip biopsy needle (Acquire™), in a randomized study design including 50 patients, Bang *et al.* found no significant difference and excellent histology yields of >90% in just one pass for both needle types.[23]

A comparative study by Abdelfatah *et al.* with 97 patients in each group reported higher diagnostic yield (77%) for the fork-tip needle compared to the Franseen-needle (63%, $P = 0.027$).[24]

Through the needle forceps biopsy

A new disposable microbiopsy forceps has been developed with a 0.8-mm diameter; this minute biopsy forceps can be advanced through a 19G needle. Use of this forceps biopsy has shown promising results for assessing pancreatic cysts by obtaining cystic wall tissue [Table 1].[25-29] In a pilot study, tissue could also be obtained using a through-the-needle microforceps from solid pancreatic tumors with a good safety profile.[30]

EUS-GUIDED PANCREATIC FLUID DRAINAGE

Pancreatic pseudocysts

Acute pancreatitis is often complicated by (peri)-pancreatic fluid collections. According to the revised Atlanta classification,[31] we distinguish between acute peripancreatic fluid collections in interstitial edematous pancreatitis and acute necrotic collection located intra- or peripancreatic in necrotizing pancreatitis during the first 4 weeks, while later on, pseudocysts can develop after interstitial edematous pancreatitis and walled-off necrosis after necrotizing events.

Most pancreatic pseudocysts resolve spontaneously, but symptomatic enlarged and infected pseudocysts require drainage. Plastic stents are preferred as lumen-apposing metal stents give no added advantage but increase the costs significantly.[32-34]

Walled-off necrosis

Conventional plastic stents are often of limited use in the treatment of walled-off necrosis because the narrow lumen might become occluded by the thick necrotic debris. The development of large diameter lumen-apposing fully covered self-expanding metal stents has overcome problems of draining fluids of high consistency and avoids leakage along the newly created tract.[35] The saddle-shaped stent has double-walled flanges on both ends to anchor

Table 1. Diagnostic yield and safety of through-the-needle microforceps biopsy in the evaluation of pancreatic cysts through EUS

Study	*n*	Technical success (%)	Diagnostic accuracy (%)	Adverse events	Comments
Mittal *et al.*[29]	27	100	88.9	None	-
Barresi *et al.*[25]	56	100	83.9	9 (16%)	Most common adverse event Limited intracystic hemorrhage - 7 (12.5%) All adverse events-mild
Shakhatreh *et al.*[26]	2	100	100	None	-
Kovacevic *et al.*[27]	31	87.1	71	3 (9.7%)	All adverse events - mild Two cases of mild infection and one mild pancreatitis
Yang *et al.*[28]	47	85.1	65	2 (4.2%)	One self-limited bleeding and one episode of mild pancreatitis
Nakai *et al.*[30]	17	100	100	None	-

Data is in frequency and percentages

the position. The complete silicone cover and self-expanding radial forces avoid leakage along the tract. The stents are removable.

Fully covered metal stents can be inserted into the walled-off necrosis [Figure 1] under EUS-guidance only and without the need for fluoroscopy,[36,37] but it might be helpful to have access to X-ray when complications occur.

There is ongoing debate on whether lumen-apposing stents are superior to drainage with multiple plastic stents in the treatment of walled-off necrosis. Although lumen-apposing metal stents are very costly, a cost-analysis revealed that they are cost-effective[38] due to less procedures, higher efficacy,[39,40] and shorter hospital stay.[40] In some studies, more bleeding events have been observed using metal stents compared to plastic stents[41-43] and the recommendation is to extract metal stents after 3–4 weeks[41,44] to avoid eroding into vessels and pseudoaneurysm in or surrounding the pancreatic cavity. This is also advised by the European Society of Gastroenterology and Endoscopy which summarized the evidence for the endoscopic management of necrotizing pancreatitis in new guidelines.[45]

The large diameter of the lumen-apposing metal stents not only allows better spontaneous drainage of debris but also enables direct endoscopic necrosectomy through the stent if clinically required [Figure 2]. A large multi-center study from the United States concluded that direct endoscopic necrosectomy at the time of transmural stent placement results in earlier resolution of complex walled-off necrosis and reduced number of endoscopic sessions.[46] On the other hand, it could be shown that from 205 symptomatic walled-off necrosis, 75% resolved with stenting alone, whereas the rest required step-up approach including deblocking of the stent, nasocystic tube irrigation or direct endoscopic necrosectomy. Endoscopic necrosectomy was required only in 9.2%.[47]

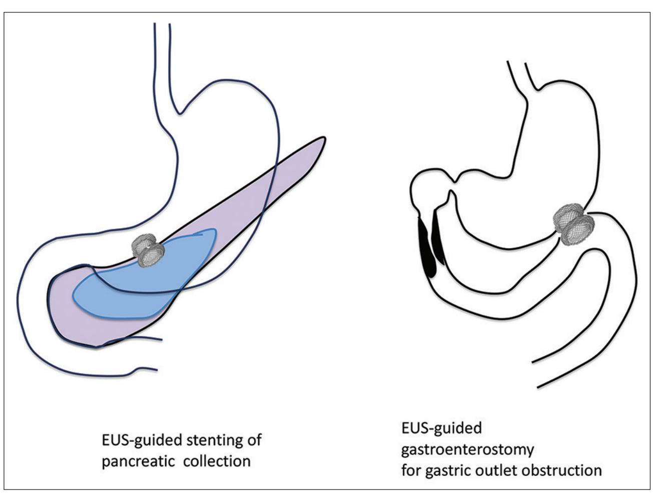

Figure 1. EUS-guided stent insertion for drainage of pancreatic fluid collections and EUS-guided insertion of a lumen-apposing stent to create a gastroenterostomy in gastric out let syndrome

EUS-guided drainage of infected pancreatic necrosis followed by endoscopic necrosectomy if required results in the less pancreatic fistula and shorter hospital stay than the surgical approach with percutaneous drainage followed by video-assisted retroperitoneal debridement if necessary.[48] Compared to open invasive surgical necrosectomy, EUS-guided endoscopic necrosectomy has clearly reduced the mortality in necrotizing pancreatitis.[49,50]

EUS-GUIDED BILIARY DRAINAGE

EUS-guided transmural biliary drainage (EUS-BD) has evolved as a helpful rescue tool after failed endoscopic retrograde cholangiography.[51-57] The biliary system can be accessed through the transgastric route into the intrahepatic ducts of the left liver lobe [Figure 3] or through the transduodenal route to the extrahepatic bile duct [Figure 4].

After accessing the bile duct from the duodenum or stomach, a guide wire can be advanced through the papilla to enable a rendez-vous technique and complete the BD in conventional ERCP techniques. Alternatively, plastic or metal stents (partially or fully covered) can be placed directly through the newly created tract to drain the bile. These stents can be placed antegrade transpapillary[58] or as transluminal stents creating a choledochoduodenostomy or hepaticogastrostomy.

The transhepatic or duodenal approach might be selected depending on the location of the malignant obstruction with similar technical success and safety.

Transgastric access to the intrahepatic system allows BD also in situations of gastric outlet obstruction or surgically altered anatomy (*e.g.*, Billroth II, Whipple or Roux-en-Y).

Compared to percutaneous transhepatic biliary drainage (PTCD), EUS-BD has several advantages: The patients suffer less peri-interventional pain and less adverse events when treated by EUS-guided BD; they need less re-interventions, have better cosmesis without

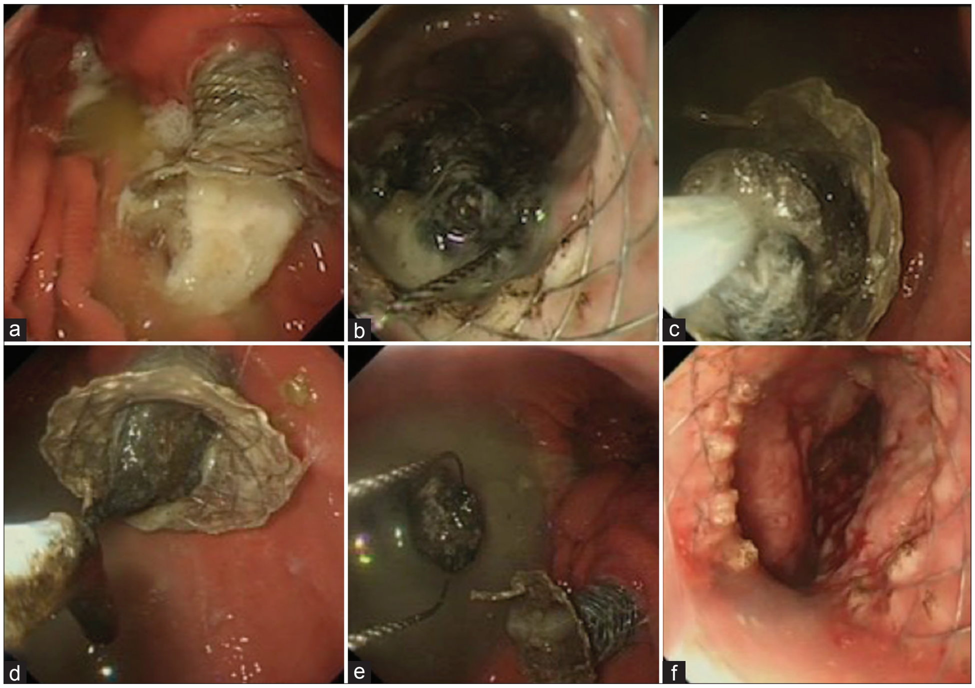

Figure 2. EUS-guided transmural insertion of fully covered metal stents with large diameter allows endoscopic access to the walled-off necrosis for endoscopic debridement. (a) Pus pours through the transgastric stent, (b-e) debris can be extracted trough the stent using snares and baskets. (f) When the cavity is cleared and the collection has reduced to <4 cm the stent can be extracted

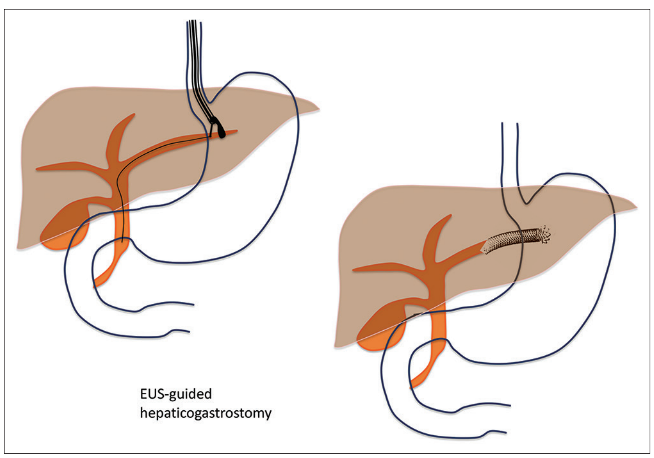

Figure 3. EUS-guided transgastric stent insertion into left hepatic bile ducts (hepaticogastostomy)

external drainages that impair daily activities, and the hospital stay is shorter.[56,59-62] The procedure can be performed during the same session of the failed ERCP. In centers with excellent expertise in EUS-BD, PTCD is not the treatment of choice after failed ERCP anymore.

Recent studies even point toward EUS BD as first-line therapy in patients with distal malignant bile duct obstruction.[63,64]

In a multi-center randomized clinical trial [Table 2], technical success was achieved in 93.8% (60/64) for EUS-BD and 90.2% (55/61) for ERCP (P = 0.003). Clinical success rates were 90.0% (54/60) in EUS-BD and 94.5% (52/55) in ERCP (P = 0.49). Complications rates were lower (6.3% *vs*. 19.7%, P = 0.03) including pancreatitis (0 *vs*. 14.8%), re-intervention (15.6% *vs*. 42.6%), and higher stent patency (85.1% *vs*. 48.9%) were observed with EUS-BD. EUS-BD also had a better quality of life than ERCP after 3 months of the procedure.[65] In two other randomized controlled studies including 30 patients and 67 patients with malignant biliary tract obstruction, respectively, EUS-BD was noninferior to transpapillary stenting using ERCP in clinical success rate.[66,67]

The expertise of EUS-BD is limited to a few expert centers. Knowledge and expertise of the entire range of PTCD[68,69] and EUS-BD techniques are required including (i) rendezvous techniques via the common bile duct or via the left liver lobe, (ii) antegrade transpapillary stent placement, or (iii) transmural stent application creating a choledochoduodenostomy or hepaticogastrostomy. The choice of techniques depends on the individual situation, proximal or distal malignant biliary obstruction, and various anatomic variations.

In future, EUS-guided BD might likely replace PTCD after failed ERCP access, but EUS-guided BD might

Table 2. Effectiveness of EUS guided biliary drainage as compared to conventional transpapillary ERCP in randomised controlled trials

Study	*n* EUS-BD *versus* ERCP	Technical success (%)	Clinical success (%)	Re-intervention (%)	Stent patency (%)	Adverse events (%)	Postprocedure pancreatitis	Median hospital stay (days)
Paik *et al.*[65]	64 *versus* 61	93.8 *versus* 90.2	90 *versus* 94.59 (*P*=0.49)	15.6 *versus* 42.6	85.1 *versus* 48.9	6.3 *versus* 19.7 (*P*=0.03)	0 *versus* 14.8	4 *versus* 5 (*P*=0.03)
Park *et al.*[66]	15 *versus* 15	93 *versus* 100 (*P*=1.00)	100 *versus* 93 (*P*=1.00)	-	69.2 *versus* 84.6 (*P*=0.65)	0 *versus* 0	0 *versus* 0	-
Bang *et al.*[67]	33 *versus* 34	90.9 *versus* 94.1 (*P*=0.67)	97 *versus* 91.2 (*P*=0.61)	3 *versus* 2.9	-	21.2 *versus* 14.7 (*P*=0.49)	-	-

Data is in frequency and percentages. EUS-BD: EUS-guided transmural biliary drainage

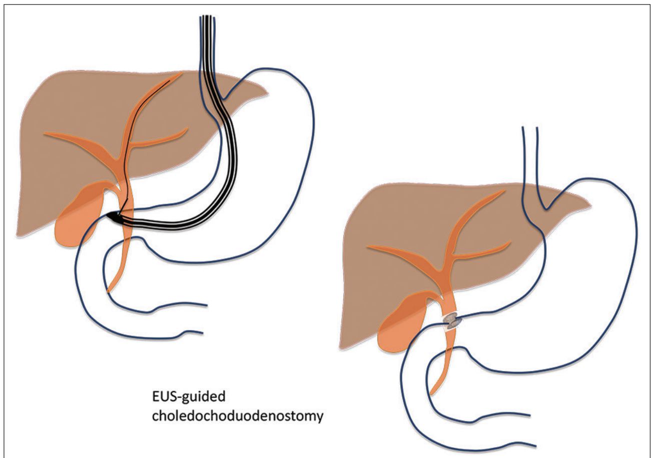

Figure 4. EUS-guided transduodenal stent insertion into common bile duct (choledochoduodenostomy)

even become the first-line approach for BD instead of ERCP in malignant distal bile duct obstruction.

Cholecystitis

High-risk patients with acute cholecystitis who are unfit for cholecystectomy due to severe comorbidities usually undergo percutaneous drainage of the gallbladder or transpapillary cystic duct stenting through ERCP. In recent years, a EUS-guided approach has become an alternative treatment option creating a fistula tract between the gallbladder and the stomach or duodenum. EUS-guided drainage of the gallbladder has been attempted using plastic stents, nasobiliary drainage tubes, or self-expandable metal stents. The development of lumen-apposing fully covered metal stents (LAMS) has minimized the risk of bile leakage due to stent migration and nonadherence. These stents fix the gallbladder to the gastrointestinal wall.

Two meta-analysis including 226 patients[70] and 189 patients[71] concluded that EUS-guided LAMS placement for acute cholecystitis is highly successful (>90%) and acceptably safe in experts hands. Compared to percutaneous gallbladder drainage, the postoperative pain, length of hospital stay, and need for antibiotics are less. The technique is also helpful in patients with coagulopathy or ascites.

Patients who underwent percutaneous transhepatic gallbladder drainage but are unfit for surgical cholecystectomy can have conversion to a transgastric EUS-stent as long-term solution.[72] Patients who underwent EUS-guided gallbladder drainage in the acute setting, can still have laparoscopic cholecystectomy later, should their clinical condition improve.[73]

Compared to transpapillary stenting of the cystic duct, the EUS-guided drainage of the gallbladder appears safer, with higher technical and clinical success.[74]

EUS-GUIDED PANCREATIC DUCT DRAINAGE

Indications for the technically extremely challenging EUS-guided pancreatic duct drainage [Figure 5] might include pancreatic duct obstruction due to stones or strictures in chronic pancreatitis when ERCP has failed, a disconnected pancreatic duct, an inaccessible papilla due to surgically altered anatomy, or a postsurgical stricture at the pancreaticoenterostomy. In the hand of expert endoscopists, EUS-guided pancreatic drainage can be achieved through rendezvous through the papilla or by transmural stent insertion into the pancreatic duct, but the adverse event rate remains high (20%–55%).[30,75-77] Even pancreatoscopy including electrohydraulic lithotripsy for pancreatic duct stones has become possible through EUS-guided transgastric access to the dilated pancreatic duct.[78]

A new ultra-tapered mechanical dilatator[79] has been introduced to avoid bleeding complications that are often seen after electrocautery dilatation following the successful needle puncture of the pancreatic duct.

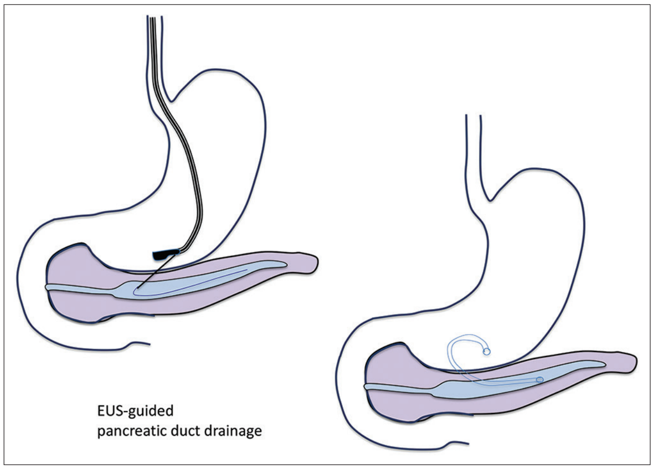

Figure 5. EUS-guided transgastric pancreatic duct drainage

Usually, transgastric or transduodenal plastic stents[80] are inserted, but recently, Oh *et al.* reported the successful long-term insertion of fully covered specially designed metal stents with antimigration features. The technical and clinical success rate was excellent (100%) in 25 patients with only mild adverse events in this single-center study.[81]

An international multicenter study compared EUS-guided pancreatic duct drainage with enteroscopy-assisted endoscopic retrograde pancreaticography after the Whipple surgical procedure.[82] Technical (92.5%) and clinical success (87.5%) was higher in the EUS group compared to 20% and 23.1% in the ERCP group, respectively. Adverse events occurred more often (35%) in the EUS group but were mild.

EUS-GUIDED CREATION OF NEW GASTRO-INTESTINAL ANASTOMOSIS

Gastroenterostomy for gastric outlet syndrome

In recent years, novel methods for EUS-guided gastroenterostomy using the lumen-apposing metal stents [Figure 1] have been introduced to treat gastric outlet obstruction in benign and malignant diseases.[83-88]

From the EUS position in the stomach, the distal part of the duodenum or a jejunal loop usually are adjacent to the gastric wall and can be reached with a needle to create a new gastroduodenotomy or gastrojejunostomy, respectively. However, the air content in the enteral loops impairs ultrasound imaging and the often collapsed status of the bowels render this puncture difficult and risky. To facilitate the enteral access and improve the ultrasound imaging, water-filling techniques with or without a balloon have been proposed.

If the obstruction can be passed by an endoscope or ultraslim endoscope, saline flushing through the scope can distend the small bowel. If a retrieval balloon can be placed across the stricture, the fluid-filled balloon can be targeted by EUS from the stomach to guide and ensure the intraluminal position before a wire is placed and coiled in the small bowel.

For the double-balloon technique, a special double-balloon enteric tube is used which allows fluid filling of the bowel segment between both inflated balloons. Over a previously placed wire into the jejunum, the balloons are positioned into the jejunum and distal duodenum, inflated and the interlaying bowel segment is filled with fluid or contrast to facilitate the EUS-guided puncture and stent deployment.

The lumen-apposing stents allow the fixation of the enteric wall to the gastric wall. The electrocautery system of the "hot-axios" (Axios-EC™) enables direct puncture of the duodenum or jejunum followed by direct stent deployment; this avoids the multiple steps of needle access, wire placement and changes of tools through the instrument channel for the enlargement of the tract which entails the risk of losing the position and access with subsequent risk of peritoneal leakage.

Compared to enteral stenting for malignant gastric outlet obstruction, EUS-guided gastroenterostomy seems to have similar clinical success and safety rate.[85,89]

Biliary drainage in altered anatomy

Lumen-apposing stents placed under EUS and fluoroscopy guidance have also been used for the reversal of Roux-en-Y bariatric surgery.[90,91] From the gastric pouch or the Roux-limb, the adjacent gastric remnant can be accessed and rejoined by placing a lumen-apposing stent. This reestablishes the continuity of the digestive tract [Figure 6].

In some patients with previous gastric bypass surgery who developed an indication for ERCP, the reconnection of the gastric pouch to the excluded gastric remnant by LAMS placement enabled the successful ERCP intervention allowing access to the duodenum through the newly placed gastrogastric stent.[91,92]

A multi-center trial compared EUS-guided gastrogastrostomy-assisted ERCP (EUS-GG-ERCP) with double-balloon or single-balloon enteroscopy-assisted ERCP in patients with the Roux-en-Y gastric bypass anatomy. Thirty patients underwent EUS-GG-ERCP and 30 (50%) underwent enteroscopy-assisted ERCP. The technical success rate was significantly higher in the EUS-GG-ERCP *versus* the enteroscopy-ERCP group (100% *vs.* 60.0%, $P < 0.001$). Procedure time was significantly less in patients who underwent EUS-GG-ERCP (49.8 min *vs.* 90.7 min, $P < 0.001$). Following procedure, the median length of hospitalization was shorter in the EUS-GG-group (1 *vs.* 10.5 days, $P = 0.02$). Both the groups had similar adverse events (10% *vs.* 6.7%, $P = 1.0$).[93]

A similar technique placing a LAMS transmurally from the Roux-limb across to an adjacent jejunal loop as jejuno-jejunostomy has been successful to overcome a distal obstruction after a Roux-en-Y reconstruction.[90,94]

Randomized multi-center studies and long-term results for the use of LAMS for creation of new anastomosis in the gastrointestinal tract are still sparse, but the pilot studies from expert centers show promising results regarding clinical success and safety profile compared to the surgical alternatives.

ABLATIVE TECHNIQUES

EUS enables accurate positioning of needles or other tools in the tumor mass under real-time imaging. This allows precise delivery of energy, fiducial markers, and anti-tumor agents or radioactive seeds for tumor therapy and destruction of neoplastic tissue.[95] Fiducial placement using EUS has a high success rate and helps to plan stereotactic radiotherapy.[96,97]

Percutaneous tumor ablation using radiofrequency or ethanol injection is the standard treatment for liver tumors in patients unfit for surgery. EUS-guided ablative techniques using radiofrequency or ethanol injection have been employed in the treatment of not only cystic and solid pancreatic masses but also liver or adrenal lesions in patients who are not eligible for surgery.

For ethanol or macrogol injection in cystic pancreatic neoplasm, the complete resolution of the pancreatic cyst reported varies widely between 9% and 85%.[98-104] An additional infusion of the cyst with the chemotherapeutic agent paclitaxel seems to increase the complete resolution rate[99,105-107] and has shown long-term remission.[105]

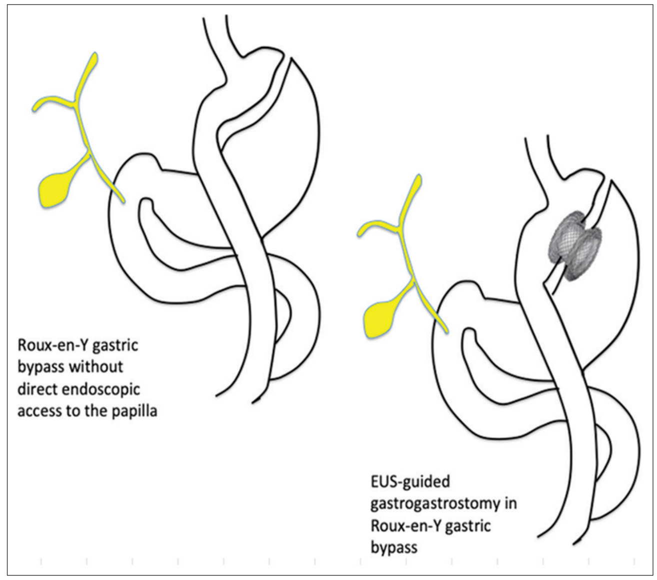

Figure 6. EUS-guided gastrogastrostomy to allow endoscopic access to the papilla for ERCP after Roux-en-Y gastric bypass surgery

A novel RFA probe has been developed for linear echoscopes which allows targeted tissue destruction by heating >45°C which induces protein degradation and irreversible cell injury. Feasibility studies in unresectable pancreatic cancer[108,109] and other solid pancreatic tumors[110,111] have been reported. Studies showing survival benefit are not yet available.

These techniques need further evaluation in prospective multicenter studies. Safety-related issues need to be carefully considered for patient selection. Adverse events of EUS-guided ablative techniques include abdominal pain, acute pancreatitis, vascular damage, and infection with abscess or fistula formation.

EUS-GUIDED ANGIOTHERAPY

The standard management of acute bleeding or selective therapy in gastric fundal varices is endoscopic cyanoacrylate injection, but this can be complicated by re-bleeding or embolic events. EUS-guided injection of coils and cyanoacrylate or thrombin allows assessment of the variceal blood flow, selective targeting of the varices and monitoring of the obliteration results,[112-117] EUS can identify gastric varix even when the endoscopic view is obscured by blood and clots in the setting of acute bleeding.[118] Direct visualization of the varix lumen with real-time imaging enables targeted injection to obliterate feeder vessels.

EUS-based hemostatic techniques combining endovascular coiling and cyanoacrylate injection seem to reduce complication rates such as re-bleeding and embolization due to improved obliteration.[119-121]

Coils are made of metal alloy containing radially extending synthetic fibers, which start clot formation and hemostasis. Coils are 2–15 mm long and loops have diameter of 2–20 mm. Coils can be deployed through 22 G needle (0.018" coil) or 19 G needle (0.035" coil). The needle stylet is used to push and deploy the coil into varix.

A retrospective trial comparing EUS-guided coil deployment to EUS-guided cyanoacrylate injection showed similar rates of varix obliteration, number of sessions and re-bleeding rate over 17-month follow-up. Cyanoacrylate group had significantly higher adverse events (58% *vs*. 9%, $P = 0.01$).[120]

The hospital stay was longer in the cyanoacrylate group and coil deployment is more expensive. Although, in practice, it is not uncommon to inject cyanoacrylate immediately after coil deployment, which offers combined hemostasis effect of both modalities and reduces glue embolization rates.

Parastomal or rectal varices have also successfully been treated using similar EUS hemostasis techniques.[122-124]

Transjugular intrahepatic portosystemic shunt plays a major role in the management of the chronic liver disease. It is used in cases of refractory ascites and refractory variceal bleed. EUS might offer an alternate approach to intrahepatic portosystemic shunt. So far, it has only been tried successfully in porcine models.[125]

COELIAC BLOCK

EUS-guided coeliac plexus/ganglia neurolysis and block is widely practiced as pain management in palliative pancreatic cancer patients and in patients with chronic pancreatitis.

The neurolytic agent can be injected centrally at the base of the coeliac axis, bilaterally or directly into the coeliac ganglia.[72,126] The coeliac ganglia can reliably be identified by EUS[127] and selectively targeted for ethanol injection. However, the injected ethanol spreads beyond the targeted ganglion and high volume ethanol injection for diffuse coeliac plexus neurolysis is more likely to also reach unidentified ganglia.[128]

Transient pain exacerbation, diarrhea, or hypotension can occur peri-procedural. Rare but serious major adverse events include retroperitoneal bleeding, ischemic complications, and abscess formation.

In a retrospective study including 123 patients with pancreatic cancer, the combination of coeliac plexus neurolysis with ethanol ablation of the tumor showed better pain relief and slightly improved survival compared to coeliac plexus neurolysis alone.[129]

CONCLUSION

Therapeutic EUS is a fascinating rapidly expanding field and new techniques, tools, and applications are introduced every year. Many reports strongly indicate the technical feasibility and efficacy of EUS interventions in the hands of highly skilled endosonographers, but there is still a relative lack of randomized controlled multicenter studies. EUS is becoming the first line treatment modality for pancreatic fluid collections and gallbladder drainage.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Morris S, Gurusamy KS, Sheringham J, *et al*. Cost-effectiveness analysis of endoscopic ultrasound versus magnetic resonance cholangiopancreatography in patients with suspected common bile duct stones. *PLoS One* 2015;10:e0121699.
2. Meeralam Y, Al-Shammari K, Yaghoobi M. Diagnostic accuracy of EUS compared with MRCP in detecting choledocholithiasis: A meta-analysis of diagnostic test accuracy in head-to-head studies. *Gastrointest Endosc* 2017;86:986-93.
3. Fusaroli P, Jenssen C, Hocke M, *et al*. EFSUMB guidelines on interventional ultrasound (INVUS), part V - EUS-guided therapeutic interventions (short version). *Ultraschall Med* 2016;37:412-20.
4. Jenssen C, Hocke M, Fusaroli P, *et al*. EFSUMB guidelines on interventional ultrasound (INVUS), part IV – EUS-guided interventions: General aspects and EUS-guided sampling (Long version). *Ultraschall Med* 2016;37:E33-76.
5. Jenssen C, Hocke M, Fusaroli P, *et al*. EFSUMB guidelines on interventional ultrasound (INVUS), part IV – EUS-guided interventions: General aspects and EUS-guided sampling (Short version). *Ultraschall Med* 2016;37:157-69.
6. Elhanafi S, Mahmud N, Vergara N, *et al*. Comparison of endoscopic ultrasound tissue acquisition methods for genomic analysis of pancreatic cancer. *J Gastroenterol Hepatol* 2019;34:907-13.
7. Bang JY, Navaneethan U, Hasan MK, *et al*. Endoscopic ultrasound-guided specimen collection and evaluation techniques affect diagnostic accuracy. *Clin Gastroenterol Hepatol* 2018;16:1820-8.e4.
8. Ramesh J, Bang JY, Hebert-Magee S, *et al*. Randomized trial comparing

the flexible 19G and 25G needles for endoscopic ultrasound-guided fine needle aspiration of solid pancreatic mass lesions. *Pancreas* 2015;44:128-33.
9. Laquière A, Lefort C, Maire F, *et al*. 19 G nitinol needle versus 22 G needle for transduodenal endoscopic ultrasound-guided sampling of pancreatic solid masses: A randomized study. *Endoscopy* 2019;51:436-43.
10. Saxena P, El Zein M, Stevens T, *et al*. Stylet slow-pull versus standard suction for endoscopic ultrasound-guided fine-needle aspiration of solid pancreatic lesions: A multicenter randomized trial. *Endoscopy* 2018;50:497-504.
11. Moura DT, de Moura EG, Matuguma SE, *et al*. EUS-FNA versus ERCP for tissue diagnosis of suspect malignant biliary strictures: A prospective comparative study. *Endosc Int Open* 2018;6:E769-77.
12. Jo JH, Cho CM, Jun JH, *et al*. Same-session endoscopic ultrasound-guided fine needle aspiration and endoscopic retrograde cholangiopancreatography-based tissue sampling in suspected malignant biliary obstruction: A multicenter experience. *J Gastroenterol Hepatol* 2019;34:799-805.
13. Khan MA, Grimm IS, Ali B, *et al*. A meta-analysis of endoscopic ultrasound-fine-needle aspiration compared to endoscopic ultrasound-fine-needle biopsy: Diagnostic yield and the value of onsite cytopathological assessment. *Endosc Int Open* 2017;5:E363-75.
14. Nagula S, Pourmand K, Aslanian H, *et al*. Comparison of endoscopic ultrasound-fine-needle aspiration and endoscopic ultrasound-fine-needle biopsy for solid lesions in a multicenter, randomized trial. *Clin Gastroenterol Hepatol* 2018;16:1307-13.e1.
15. Jovani M, Abidi WM, Lee LS. Novel fork-tip needles versus standard needles for EUS-guided tissue acquisition from solid masses of the upper GI tract: A matched cohort study. *Scand J Gastroenterol* 2017;52:784-7.
16. Naveed M, Siddiqui AA, Kowalski TE, *et al*. A multicenter comparative trial of a novel EUS-guided core biopsy needle (SharkCore™) with the 22-gauge needle in patients with solid pancreatic mass lesions. *Endosc Ultrasound* 2018;7:34-40.
17. El Chafic AH, Loren D, Siddiqui A, *et al*. Comparison of FNA and fine-needle biopsy for EUS-guided sampling of suspected GI stromal tumors. *Gastrointest Endosc* 2017;86:510-5.
18. Kandel P, Tranesh G, Nassar A, *et al*. EUS-guided fine needle biopsy sampling using a novel fork-tip needle: A case-control study. *Gastrointest Endosc* 2016;84:1034-9.
19. Nayar MK, Paranandi B, Dawwas MF, *et al*. Comparison of the diagnostic performance of 2 core biopsy needles for EUS-guided tissue acquisition from solid pancreatic lesions. *Gastrointest Endosc* 2017;85:1017-24.
20. Abdelfatah MM, Hamed A, Koutlas NJ, *et al*. The diagnostic and cellularity yield of reverse bevel versus fork-tip fine needle biopsy. *Diagn Cytopathol* 2018;46:649-55.
21. El Hajj II, Wu H, Reuss S, *et al*. Prospective assessment of the performance of a new fine needle biopsy device for EUS-guided sampling of solid lesions. *Clin Endosc* 2018;51:576-83.
22. Mukai S, Itoi T, Yamaguchi H, *et al*. A retrospective histological comparison of EUS-guided fine-needle biopsy using a novel Franseen needle and a conventional end-cut type needle. *Endosc Ultrasound* 2019;8:50-7.
23. Bang JY, Hebert-Magee S, Navaneethan U, *et al*. Randomized trial comparing the Franseen and fork-tip needles for EUS-guided fine-needle biopsy sampling of solid pancreatic mass lesions. *Gastrointest Endosc* 2018;87:1432-8.
24. Abdelfatah MM, Grimm IS, Gangarosa LM, *et al*. Cohort study comparing the diagnostic yields of 2 different EUS fine-needle biopsy needles. *Gastrointest Endosc* 2018;87:495-500.
25. Barresi L, Crinò SF, Fabbri C, *et al*. Endoscopic ultrasound-through -the-needle biopsy in pancreatic cystic lesions: A multicenter study. *Dig Endosc* 2018;30:760-70.
26. Shakhatreh MH, Naini SR, Brijbassie AA, *et al*. Use of a novel through-the-needle biopsy forceps in endoscopic ultrasound. *Endosc Int Open* 2016;4:E439-42.
27. Kovacevic B, Klausen P, Hasselby JP, *et al*. A novel endoscopic ultrasound-guided through-the-needle microbiopsy procedure improves diagnosis of pancreatic cystic lesions. *Endoscopy* 2018;50:1105-11.
28. Yang D, Samarasena JB, Jamil LH, *et al*. Endoscopic ultrasound-guided through-the-needle microforceps biopsy in the evaluation of pancreatic cystic lesions: A multicenter study. *Endosc Int Open* 2018;6:E1423-30.
29. Mittal C, Obuch JC, Hammad H, *et al*. Technical feasibility, diagnostic yield, and safety of microforceps biopsies during EUS evaluation of pancreatic cystic lesions (with video). *Gastrointest Endosc* 2018;87:1263-9.
30. Nakai Y, Isayama H, Chang KJ, *et al*. A pilot study of EUS-guided through-the-needle forceps biopsy (with video). *Gastrointest Endosc* 2016;84:158-62.
31. Banks PA, Bollen TL, Dervenis C, *et al*. Classification of acute pancreatitis--2012: Revision of the Atlanta classification and definitions by international consensus. *Gut* 2013;62:102-11.
32. Chen YI, Khashab MA, Adam V, *et al*. Plastic stents are more cost-effective than lumen-apposing metal stents in management of pancreatic pseudocysts. *Endosc Int Open* 2018;6:E780-8.
33. Shekhar C, Maher B, Forde C, *et al*. Endoscopic ultrasound-guided pancreatic fluid collections' transmural drainage outcomes in 100 consecutive cases of pseudocysts and walled off necrosis: A single-centre experience from the United Kingdom. *Scand J Gastroenterol* 2018;53:611-5.
34. Giovannini M. Endoscopic ultrasound-guided drainage of pancreatic fluid collections. *Gastrointest Endosc Clin N Am* 2018;28:157-69.
35. Siddiqui AA, Adler DG, Nieto J, *et al*. EUS-guided drainage of peripancreatic fluid collections and necrosis by using a novel lumen-apposing stent: A large retrospective, multicenter U.S. experience (with videos). *Gastrointest Endosc* 2016;83:699-707.
36. Braden B, Koutsoumpas A, Silva MA, *et al*. Endoscopic ultrasound-guided drainage of pancreatic walled-off necrosis using self-expanding metal stents without fluoroscopy. *World J Gastrointest Endosc* 2018;10:93-8.
37. Consiglieri CF, Gornals JB, Busquets J, *et al*. Fluoroscopy-assisted vs. fluoroless endoscopic ultrasound-guided transmural drainage of pancreatic fluid collections: A comparative study. *Gastroenterol Hepatol* 2018;41:12-21.
38. Chen YI, Barkun AN, Adam V, *et al*. Cost-effectiveness analysis comparing lumen-apposing metal stents with plastic stents in the management of pancreatic walled-off necrosis. *Gastrointest Endosc* 2018;88:267-76.e1.
39. Hammad T, Khan MA, Alastal Y, *et al*. Efficacy and safety of lumen-apposing metal stents in management of pancreatic fluid collections: Are they better than plastic stents? A systematic review and meta-analysis. *Dig Dis Sci* 2018;63:289-301.
40. Siddiqui AA, Kowalski TE, Loren DE, *et al*. Fully covered self-expanding metal stents versus lumen-apposing fully covered self-expanding metal stent versus plastic stents for endoscopic drainage of pancreatic walled-off necrosis: Clinical outcomes and success. *Gastrointest Endosc* 2017;85:758-65.
41. 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;68:1200-9.
42. Brimhall B, Han S, Tatman PD, *et al*. Increased incidence of pseudoaneurysm bleeding with lumen-apposing metal stents compared to double-pigtail plastic stents in patients with peripancreatic fluid collections. *Clin Gastroenterol Hepatol* 2018;16:1521-8.
43. Lang GD, Fritz C, Bhat T, *et al*. EUS-guided drainage of peripancreatic fluid collections with lumen-apposing metal stents and plastic double-pigtail stents: Comparison of efficacy and adverse event rates. *Gastrointest Endosc* 2018;87:150-7.
44. Dhir V, Adler DG, Dalal A, *et al*. Early removal of biflanged metal stents in the management of pancreatic walled-off necrosis: A prospective study. *Endoscopy* 2018;50:597-605.
45. Arvanitakis M, Dumonceau JM, Albert J, *et al*. Endoscopic management of acute necrotizing pancreatitis: European Society of Gastrointestinal Endoscopy (ESGE) evidence-based multidisciplinary guidelines. *Endoscopy* 2018;50:524-46.
46. Yan L, Dargan A, Nieto J, *et al*. Direct endoscopic necrosectomy at the time of transmural stent placement results in earlier resolution of complex walled-off pancreatic necrosis: Results from a large multicenter United States trial. *Endosc Ultrasound* 2019;8:172-9.
47. Lakhtakia S, Basha J, Talukdar R, *et al*. Endoscopic "step-up approach"

using a dedicated biflanged metal stent reduces the need for direct necrosectomy in walled-off necrosis (with videos). *Gastrointest Endosc* 2017;85:1243-52.
48. van Brunschot S, van Grinsven J, van Santvoort HC, *et al.* Endoscopic or surgical step-up approach for infected necrotising pancreatitis: A multicentre randomised trial. *Lancet* 2018;391:51-8.
49. van Brunschot S, Hollemans RA, Bakker OJ, *et al.* Minimally invasive and endoscopic versus open necrosectomy for necrotising pancreatitis: A pooled analysis of individual data for 1980 patients. *Gut* 2018;67:697-706.
50. Wundsam HV, Spaun GO, Bräuer F, *et al*. Evolution of transluminal necrosectomy for acute pancreatitis to stent in stent therapy: Step-up approach leads to low mortality and morbidity rates in 302 consecutive cases of acute pancreatitis. *J Laparoendosc Adv Surg Tech A* 2019. doi: 10.1089/lap.2018.0768.
51. Jain D, Shah M, Patel U, *et al*. Endoscopic ultrasound guided choledocho-enterostomy by using lumen apposing metal stent in patients with failed endoscopic retrograde cholangiopancreatography: A literature review. *Digestion* 2018;98:1-10.
52. Rai P, Lokesh CR, Goel A, *et al*. Endoscopic ultrasound-guided choledochoduodenostomy using partially-covered self-expandable metal stent in patients with malignant distal biliary obstruction and unsuccessful ERCP. *Endosc Int Open* 2018;6:E67-72.
53. Kahaleh M, Hernandez AJ, Tokar J, *et al.* Interventional EUS-guided cholangiography: Evaluation of a technique in evolution. *Gastrointest Endosc* 2006;64:52-9.
54. Cho DH, Lee SS, Oh D, *et al.* Long-term outcomes of a newly developed hybrid metal stent for EUS-guided biliary drainage (with videos). *Gastrointest Endosc* 2017;85:1067-75.
55. Khashab MA, Van der Merwe S, Kunda R, *et al.* Prospective international multicenter study on endoscopic ultrasound-guided biliary drainage for patients with malignant distal biliary obstruction after failed endoscopic retrograde cholangiopancreatography. *Endosc Int Open* 2016;4:E487-96.
56. Moole H, Bechtold ML, Forcione D, *et al*. A meta-analysis and systematic review: Success of endoscopic ultrasound guided biliary stenting in patients with inoperable malignant biliary strictures and a failed ERCP. *Medicine (Baltimore)* 2017;96:e5154.
57. Jacques J, Privat J, Pinard F, *et al.* Endoscopic ultrasound-guided choledochoduodenostomy with electrocautery-enhanced lumen-apposing stents: A retrospective analysis. *Endoscopy* 2019;51:540-7.
58. Ogura T, Kitano M, Takenaka M, *et al.* Multicenter prospective evaluation study of endoscopic ultrasound-guided hepaticogastrostomy combined with antegrade stenting (with video). *Dig Endosc* 2018;30:252-9.
59. Lee TH, Choi JH, Park do H, *et al*. Similar efficacies of endoscopic ultrasound-guided transmural and percutaneous drainage for malignant distal biliary obstruction. *Clin Gastroenterol Hepatol* 2016;14:1011-9.e3.
60. Giovannini M, Moutardier V, Pesenti C, *et al.* Endoscopic ultrasound-guided bilioduodenal anastomosis: A new technique for biliary drainage. *Endoscopy* 2001;33:898-900.
61. Téllez-Ávila FI, Herrera-Mora D, Duarte-Medrano G, *et al.* Biliary drainage in patients with failed ERCP: Percutaneous versus EUS-guided drainage. *Surg Laparosc Endosc Percutan Tech* 2018;28:183-7.
62. Sharaiha RZ, Kumta NA, Desai AP, *et al.* Endoscopic ultrasound-guided biliary drainage versus percutaneous transhepatic biliary drainage: Predictors of successful outcome in patients who fail endoscopic retrograde cholangiopancreatography. *Surg Endosc* 2016;30:5500-5.
63. Nakai Y, Isayama H, Kawakami H, *et al.* Prospective multicenter study of primary EUS-guided choledochoduodenostomy using a covered metal stent. *Endosc Ultrasound* 2019;8:111-7.
64. 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;89:69-76.
65. Paik WH, Lee TH, Park DH, *et al.* EUS-guided biliary drainage versus ERCP for the primary palliation of malignant biliary obstruction: A multicenter randomized clinical trial. *Am J Gastroenterol* 2018;113:987-97.
66. Park JK, Woo YS, Noh DH, *et al.* Efficacy of EUS-guided and ERCP-guided biliary drainage for malignant biliary obstruction: Prospective randomized controlled study. *Gastrointest Endosc* 2018;88:277-82.
67. 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;88:9-17.
68. Dietrich CF, Lorentzen T, Appelbaum L, *et al.* EFSUMB guidelines on interventional ultrasound (INVUS), part III – Abdominal treatment procedures (Long version). *Ultraschall Med* 2016;37:E1-32.
69. Dietrich CF, Lorentzen T, Appelbaum L, *et al.* EFSUMB guidelines on interventional ultrasound (INVUS), part III – Abdominal treatment procedures (Short version). *Ultraschall Med* 2016;37:27-45.
70. Manta R, Mutignani M, Galloro G, *et al*. Endoscopic ultrasound-guided gallbladder drainage for acute cholecystitis with a lumen-apposing metal stent: A systematic review of case series. *Eur J Gastroenterol Hepatol* 2018;30:695-8.
71. Jain D, Bhandari BS, Agrawal N, *et al*. Endoscopic ultrasound-guided gallbladder drainage using a lumen-apposing metal stent for acute cholecystitis: A systematic review. *Clin Endosc* 2018;51:450-62.
72. Minaga K, Yamashita Y, Ogura T, *et al.* Clinical efficacy and safety of endoscopic ultrasound-guided gallbladder drainage replacement of percutaneous drainage: A multicenter retrospective study. *Dig Endosc* 2019;31:180-7.
73. Saumoy M, Tyberg A, Brown E, *et al.* Successful cholecystectomy after endoscopic ultrasound gallbladder drainage compared with percutaneous cholecystostomy, can it be done? *J Clin Gastroenterol* 2019;53:231-5.
74. Oh D, Song TJ, Cho DH, *et al.* EUS-guided cholecystostomy versus endoscopic transpapillary cholecystostomy for acute cholecystitis in high-risk surgical patients. *Gastrointest Endosc* 2019;89:289-98.
75. Chapman CG, Waxman I, Siddiqui UD. Endoscopic ultrasound (EUS)-guided pancreatic duct drainage: The basics of when and how to perform EUS-guided pancreatic duct interventions. *Clin Endosc* 2016;49:161-7.
76. Baars JE, Chen F, Sandroussi C, *et al.* EUS-guided pancreatic duct drainage: Approach to a challenging procedure. *Endosc Ultrasound* 2018;7:284-5.
77. Matsunami Y, Itoi T, Sofuni A, *et al.* Evaluation of a new stent for EUS-guided pancreatic duct drainage: Long-term follow-up outcome. *Endosc Int Open* 2018;6:E505-12.
78. James TW, Baron TH. Antegrade pancreatoscopy via EUS-guided pancreaticogastrostomy allows removal of obstructive pancreatic duct stones. *Endosc Int Open* 2018;6:E735-8.
79. Honjo M, Itoi T, Tsuchiya T, *et al.* Safety and efficacy of ultra-tapered mechanical dilator for EUS-guided hepaticogastrostomy and pancreatic duct drainage compared with electrocautery dilator (with video). *Endosc Ultrasound* 2018;7:376-82.
80. Kurihara T, Itoi T, Sofuni A, *et al*. Endoscopic ultrasonography-guided pancreatic duct drainage after failed endoscopic retrograde cholangiopancreatography in patients with malignant and benign pancreatic duct obstructions. *Dig Endosc* 2013;25 Suppl 2:109-16.
81. Oh D, Park DH, Cho MK, *et al.* Feasibility and safety of a fully covered self-expandable metal stent with antimigration properties for EUS-guided pancreatic duct drainage: Early and midterm outcomes (with video). *Gastrointest Endosc* 2016;83:366-73.e2.
82. Chen YI, 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;85:170-7.
83. Itoi T, Baron TH, Khashab MA, *et al.* Technical review of endoscopic ultrasonography-guided gastroenterostomy in 2017. *Dig Endosc* 2017;29:495-502.
84. Chen YI, James TW, Agarwal A, *et al.* EUS-guided gastroenterostomy in management of benign gastric outlet obstruction. *Endosc Int Open* 2018;6:E363-8.
85. Chen YI, Kunda R, Storm AC, *et al.* EUS-guided gastroenterostomy: A multicenter study comparing the direct and balloon-assisted techniques. *Gastrointest Endosc* 2018;87:1215-21.
86. Ge PS, Young JY, Dong W, *et al.* EUS-guided gastroenterostomy versus enteral stent placement for palliation of malignant gastric outlet obstruction. *Surg Endosc* 2019. https://doi.org/10.1007/s00464-018-06636-3.
87. Kerdsirichairat T, Irani S, Yang J, *et al.* Durability and long-term outcomes

of direct EUS-guided gastroenterostomy using lumen-apposing metal stents for gastric outlet obstruction. *Endosc Int Open* 2019;7:E144-50.
88. Perez-Miranda M, Tyberg A, Poletto D, *et al*. EUS-guided gastrojejunostomy versus laparoscopic gastrojejunostomy: An international collaborative study. *J Clin Gastroenterol* 2017;51:896-9.
89. Khashab MA, Bukhari M, Baron TH, *et al.* International multicenter comparative trial of endoscopic ultrasonography-guided gastroenterostomy versus surgical gastrojejunostomy for the treatment of malignant gastric outlet obstruction. *Endosc Int Open* 2017;5:E275-81.
90. Amateau SK, Lim CH, McDonald NM, *et al.* EUS-guided endoscopic gastrointestinal anastomosis with lumen-apposing metal stent: Feasibility, safety, and efficacy. *Obes Surg* 2018;28:1445-51.
91. Ngamruengphong S, Nieto J, Kunda R, *et al.* Endoscopic ultrasound-guided creation of a transgastric fistula for the management of hepatobiliary disease in patients with roux-en-Y gastric bypass. *Endoscopy* 2017;49:549-52.
92. James TW, Baron TH. Endoscopic ultrasound-directed transgastric ERCP (EDGE): A single-center US experience with follow-up data on fistula closure. *Obes Surg* 2019;29:451-6.
93. Bukhari M, Kowalski T, Nieto J, *et al*. An international, multicenter, comparative trial of EUS-guided gastrogastrostomy-assisted ERCP versus enteroscopy-assisted ERCP in patients with roux-en-Y gastric bypass anatomy. *Gastrointest Endosc* 2018;88:486-94.
94. Lim CH, Ikramuddin S, Leslie DB, *et al*. Novel endoscopic management of a pancreatico-biliary limb obstruction by the creation of an entero-enterostomy following roux-en-Y gastric bypass. *Endoscopy* 2016;48 Suppl 1:E99-100.
95. Di Matteo FM, Saccomandi P, Martino M, *et al.* Feasibility of EUS-guided nd:YAG laser ablation of unresectable pancreatic adenocarcinoma. *Gastrointest Endosc* 2018;88:168-74.e1.
96. Phan VA, Dalfsen R, Le H, *et al*. Performance of a new preloaded fiducial needle to guide radiation therapy of upper gastrointestinal cancers. *Endoscopy* 2019;51:463-7.
97. Coronel E, Cazacu IM, Sakuraba A, *et al.* EUS-guided fiducial placement for GI malignancies: A systematic review and meta-analysis. *Gastrointest Endosc* 2019;89:659-70.e18.
98. Choi JH, Lee SH, Choi YH, *et al.* Clinical outcomes of endoscopic ultrasound-guided ethanol ablation for pancreatic cystic lesions compared with the natural course: A propensity score matching analysis. *Therap Adv Gastroenterol* 2018;11:1756284818759929.
99. Moyer MT, Dye CE, Sharzehi S, *et al.* Is alcohol required for effective pancreatic cyst ablation? The prospective randomized CHARM trial pilot study. *Endosc Int Open* 2016;4:E603-7.
100. Gómez V, Takahashi N, Levy MJ, *et al.* EUS-guided ethanol lavage does not reliably ablate pancreatic cystic neoplasms (with video). *Gastrointest Endosc* 2016;83:914-20.
101. Caillol F, Poincloux L, Bories E, *et al.* Ethanol lavage of 14 mucinous cysts of the pancreas: A retrospective study in two tertiary centers. *Endosc Ultrasound* 2012;1:48-52.
102. DiMaio CJ, DeWitt JM, Brugge WR. Ablation of pancreatic cystic lesions: The use of multiple endoscopic ultrasound-guided ethanol lavage sessions. *Pancreas* 2011;40:664-8.
103. DeWitt J, DiMaio CJ, Brugge WR. Long-term follow-up of pancreatic cysts that resolve radiologically after EUS-guided ethanol ablation. *Gastrointest Endosc* 2010;72:862-6.
104. Linghu E, Du C, Chai N, *et al.* A prospective study on the safety and effectiveness of using lauromacrogol for ablation of pancreatic cystic neoplasms with the aid of EUS. *Gastrointest Endosc* 2017;86:872-80.
105. Choi JH, Seo DW, Song TJ, *et al.* Long-term outcomes after endoscopic ultrasound-guided ablation of pancreatic cysts. *Endoscopy* 2017;49:866-73.
106. Oh HC, Seo DW, Song TJ, *et al.* Endoscopic ultrasonography-guided ethanol lavage with paclitaxel injection treats patients with pancreatic cysts. *Gastroenterology* 2011;140:172-9.
107. Attila T, Adsay V, Faigel DO. The efficacy and safety of endoscopic ultrasound-guided ablation of pancreatic cysts with alcohol and paclitaxel: A systematic review. *Eur J Gastroenterol Hepatol* 2019;31:1-9.
108. Scopelliti F, Pea A, Conigliaro R, *et al.* Technique, safety, and feasibility of EUS-guided radiofrequency ablation in unresectable pancreatic cancer. *Surg Endosc* 2018;32:4022-8.
109. Crinò SF, D'Onofrio M, Bernardoni L, *et al.* EUS-guided radiofrequency ablation (EUS-RFA) of solid pancreatic neoplasm using an 18-gauge needle electrode: Feasibility, safety, and technical success. *J Gastrointestin Liver Dis* 2018;27:67-72.
110. Choi JH, Seo DW, Song TJ, *et al.* Endoscopic ultrasound-guided radiofrequency ablation for management of benign solid pancreatic tumors. *Endoscopy* 2018;50:1099-104.
111. Barthet M, Giovannini M, Lesavre N, *et al.* Endoscopic ultrasound-guided radiofrequency ablation for pancreatic neuroendocrine tumors and pancreatic cystic neoplasms: A prospective multicenter study. *Endoscopy* 2019. doi: 10.1055/a-0824-7067. [Epub ahead of print].
112. Frost JW, Hebbar S. EUS-guided thrombin injection for management of gastric fundal varices. *Endosc Int Open* 2018;6:E664-8.
113. Bhat YM, Weilert F, Fredrick RT, *et al.* EUS-guided treatment of gastric fundal varices with combined injection of coils and cyanoacrylate glue: A large U.S. experience over 6 years (with video). *Gastrointest Endosc* 2016;83:1164-72.
114. Bick BL, Al-Haddad M, Liangpunsakul S, *et al*. EUS-guided fine needle injection is superior to direct endoscopic injection of 2-octyl cyanoacrylate for the treatment of gastric variceal bleeding. *Surg Endosc* 2018;225:1524.
115. Fujii-Lau LL, Law R, Wong Kee Song LM, *et al.* Endoscopic ultrasound (EUS)-guided coil injection therapy of esophagogastric and ectopic varices. *Surg Endosc* 2016;30:1396-404.
116. Khoury T, Massarwa M, Daher S, *et al.* Endoscopic ultrasound-guided angiotherapy for gastric varices: A single center experience. *Hepatol Commun* 2019;3:207-12.
117. Mukkada RJ, Antony R, Chooracken MJ, *et al.* Endoscopic ultrasound-guided coil or glue injection in post-cyanoacrylate gastric variceal re-bleed. *Indian J Gastroenterol* 2018;37:153-9.
118. Tang RS, Teoh AY, Lau JY. EUS-guided cyanoacrylate injection for treatment of endoscopically obscured bleeding gastric varices. *Gastrointest Endosc* 2016;83:1032-3.
119. Weilert F, Binmoeller KF. Endoscopic management of gastric variceal bleeding. *Gastroenterol Clin North Am* 2014;43:807-18.
120. Romero-Castro R, Ellrichmann M, Ortiz-Moyano C, *et al.* EUS-guided coil versus cyanoacrylate therapy for the treatment of gastric varices: A multicenter study (with videos). *Gastrointest Endosc* 2013;78:711-21.
121. Binmoeller KF, Weilert F, Shah JN, *et al*. EUS-guided transesophageal treatment of gastric fundal varices with combined coiling and cyanoacrylate glue injection (with videos). *Gastrointest Endosc* 2011;74:1019-25.
122. Tsynman DN, DeCross AJ, Maliakkal B, *et al.* Novel use of EUS to successfully treat bleeding parastomal varices with N-butyl-2-cyanoacrylate. *Gastrointest Endosc* 2014;79:1007-8.
123. Mukkada RJ, Mathew PG, Francis Jose V, *et al.* EUS-guided coiling of rectal varices. *VideoGIE* 2017;2:208-10.
124. Connor EK, Duran-Castro OL, Attam R. Therapy for recurrent bleeding from rectal varices by EUS-guided sclerosis. *Gastrointest Endosc* 2015;81:1280-1.
125. Schulman AR, Ryou M, Aihara H, *et al*. EUS-guided intrahepatic portosystemic shunt with direct portal pressure measurements: A novel alternative to transjugular intrahepatic portosystemic shunting. *Gastrointest Endosc* 2017;85:243-7.
126. Yasuda I, Wang HP. Endoscopic ultrasound-guided celiac plexus block and neurolysis. *Dig Endosc* 2017;29:455-62.
127. Malikowski T, Lehrke HD, Henry MR, *et al.* Accuracy of endoscopic ultrasound imaging in distinguishing celiac ganglia from celiac lymph nodes. *Clin Gastroenterol Hepatol* 2019;17:148-55.
128. Kappelle WF, Bleys RL, van Wijck AJ, *et al*. EUS-guided celiac ganglia neurolysis: A clinical and human cadaver study (with video). *Gastrointest Endosc* 2017;86:655-63.
129. Facciorusso A, Di Maso M, Serviddio G, *et al.* Echoendoscopic ethanol ablation of tumor combined with celiac plexus neurolysis in patients with pancreatic adenocarcinoma. *J Gastroenterol Hepatol* 2017;32:439-45.