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# A review of endoscopic ultrasound-guided gallbladder drainage and gastroenterostomy: assisted approaches and comparison with alternative techniques

**Rongmin Xu*, Kai Zhang*, Jintao Guo* and Siyu Sun**

***Abstract*:** Over the last 40 years, the role of endoscopic ultrasound (EUS) has evolved from being diagnostic to therapeutic. EUS-guided gallbladder drainage (EUS-GBD) and EUS-guided gastroenterostomy (EUS-GE) are emerging techniques in recent years; however, there are limited studies and inconsistent results regarding these techniques. In addition, EUS has become a more common alternative to traditional interventions due to its super minimally invasive nature, but the mobility of both the gallbladder and intestine makes it challenging to introduce stents. An increasing number of researchers are dedicating themselves to solving this problem, leading to the development of various assisted technologies. Consequently, this review focused on the comparison of EUS-GBD and EUS-GE with other alternative approaches and explored the various assisted techniques employed for EUS-GBD and EUS-GE.

## Plain language summary

Endoscopic ultrasound-guided gallbladder drainage (EUS-GBD) and endoscopic ultrasound-guided gastroenterostomy (EUS-GE) have emerged as novel, minimally invasive endoscopic interventional techniques in recent years, have become the increasingly popular alternative to conventional surgical and percutaneous interventions. However, the superiority of endoscopic ultrasound-guided interventional therapy remains controversial topics in the medical literature. Additionally, the mobility of gallbladder and intestine reduces technical success rate. Therefore, this article comprehensively compares EUS-GBD, EUS-GE and other alternative methods, as well as the assisted methods of them.

***Keywords:*** endoscopic enteral stenting, EUS-GBD, EUS-GE, laparoscopic cholecystectomy, peroral cholecystoscopy, PT-GBD

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## Introduction

Endoscopic ultrasound (EUS)[1] has distinctive advantages, such as reduced interference from subcutaneous tissue, bones, and gas, because it is performed close to the targeted tissue. High-resolution real-time imaging facilitates the identification of minute lesions; therefore, EUS has emerged as a primary diagnostic approach for gastrointestinal lesions. With advancements in EUS, it is now possible to diagnose and provide therapy.[2–4] In patients with upper digestive system diseases, such as obstruction and inflammation, metal or plastic stents can be employed to achieve anastomosis of the two luminal walls, thereby alleviating symptoms.[5–8] EUS-guided gallbladder drainage (EUS-GBD) and

EUS-guided gastroenterostomy (EUS-GE) are emerging and super minimally invasive techniques in recent years. EUS-GBD involves positioning a stent such as a lumen-apposing metal stent (LAMS) to an anastomose gallbladder with gastric or duodenal wall under the guidance of EUS with or without a guidewire, to treat acute cholecystitis (AC) and noninflammatory diseases.[9] Similarly, EUS-GE is anastomosis of the stomach and duodenum or jejunum to relieve gastric outlet obstruction (GOO) and afferent loop syndrome.[10] Due to the minimally invasive characteristics of EUS-guided interventions, both EUS-GBD and EUS-GE are suitable for patients with poor baseline conditions who are not suitable for surgery. However, there is limited research on them and low-quality evidence in the guidelines.[10,11] Moreover, the gallbladder and intestine are easily mobile, which makes endoscopic therapy difficult, and researchers are committed to solving the aforementioned problems. In addition, EUS has become an increasingly popular alternative to conventional surgical and percutaneous interventions. However, the current research results are controversial. Therefore, this review aims to compare EUS-GBD and EUS-GE with other alternative approaches and explore the various assisted techniques employed for EUS-GBD and EUS-GE.

## EUS-guided gallbladder drainage

Indications for EUS-GBD include AC and noninflammatory diseases. Noninflammatory diseases represent a distinct classification when compared to AC. Most cases of AC result from gallstone formation.[9] Open or laparoscopic cholecystectomy (LC) was commonly used in the past to treat AC. According to the Tokyo Guidelines 2018,[12] LC is widely regarded as the gold standard of treatment for AC. Nevertheless, many elderly patients are unsuitable for LC owing to poor conditions or comorbidities, such as liver cirrhosis, ascites, coagulation disorders, tumors, and cardiopulmonary disorders. In addition, a growing body of research on postcholecystectomy complications has indicated the intricate and crucial role of the gallbladder as an essential immune and digestive organ. Surgical resection of the gallbladder can lead to disturbances in the intestinal flora and is associated with an increased risk of developing gastrointestinal tumors.[13–15] Hence, percutaneous gallbladder drainage (PT-GBD) has emerged as a substitute for surgery since 1970; however, it is used only as a bridge to surgery, and removal of the drainage catheter may lead to cholecystitis recurrence.[16] EUS-GBD can be used as a substitute for PT-GBD. The technical success rates of LAMS for EUS-GBD vary between 88.5% and 98%, clinical success rates range from 88.9% to 95.4%, and the overall adverse events (AEs) rates are between 11.5% and 18.3%.[17–19] The AEs are consistent with other endoscopic surgeries involving stents, including stent dislodgement or occlusion, bleeding, perforation, and recurrent cholecystitis or cholangitis. Notably, stent-related complications occur most frequently, approximating 8.1%.[17] A recent meta-analysis revealed an overall AE rate of 14.6% in patients with long-term LAMS placement, with recurrent biliary events constituting 6.1%.[20] Furthermore, indications for noninflammatory diseases include malignant biliary obstruction (MBO), symptomatic cholelithiasis, choledocholithiasis, Mirizzi syndrome (gallstones can obstruct the cystic duct or the fundus of the gallbladder, exerting external pressure on the common hepatic duct, which results in its obstruction), and secondary prevention of choledocholithiasis.[21,22]

### *EUS-GBD versus PT-GBD*

Previous research comparing EUS-GBD with PT-GBD has shown that both techniques were comparable in terms of technical and clinical success rates for AC; however, EUS-GBD was associated with similar or fewer AEs, shorter hospitalizations, lower pain scores, and fewer reinterventions than PT-GBD.[5,23–30] The classification and severity of AEs were evaluated based on the lexicon of endoscopic AEs[31] or the Clavien Dindo scale.[32] Therein, a study indicated that the AE rates of EUS-GBD significantly decreased at both 1 year (25.6% vs 77.5%, $p < 0.001$) and 30 days (12.8% vs 47.5%, $p = 0.001$).[5] In addition, some studies revealed the overall or early AE rates reduced compared to PT-GBD.[24,25,27–30] Two studies showed no statistically significant differences in AEs.[23,26] The primary AEs of PT-GBD were stent dislodgement and occlusion, which led to an increased reintervention rate.[5,27] A trial sequential analysis demonstrated that EUS-GBD reduces AEs and unplanned readmissions, but when the sample size is large enough, the technical success rate of EUS-GBD may be lower than that of PT-GBD.[33] Recently, a meta-analysis reported that only the use of an electrocautery-enhanced LAMS in EUS-GBD results in fewer AEs, cholecystitis recurrence, and readmissions than in PT-GBD; otherwise, the techniques had similar clinical outcomes in the treatment of patients with AC.[34] Interestingly, a different meta-analysis that adopted the latest GRADE criteria for AEs demonstrated that overall AEs (odds ratio (OR) = 0.43; 95% confidence interval (CI): 0.30–0.61; $p < 0.01$) and delayed AEs (OR = 0.21; 95% CI: 0.07–0.61; $p < 0.01$) for EUS-GBD with LAMS are lower.[35] The aforementioned studies suggested that EUS-GBD with LAMS leads to a reduction in AEs and readmissions. Further randomized controlled trials (RCTs) are required to validate these findings, particularly regarding the technical success rates.

Concerning noninflammatory diseases like MBO, EUS-GBD is considered a salvage strategy when other approaches fail or are unsuitable. The technical success and AE rates of EUS-GBD for MBO-failing EUS-guided biliary drainage and endoscopic retrograde cholangiopancreatography were 85% and 13%, respectively.[36] There is limited research on other noninflammatory indications; however, the clinical success, technical success, and AE rates are reportedly 92%, 100%, and 25%, respectively.[21] EUS-GBD can serve as both a salvage strategy and a first-time intervention for MBO. A case series involving nine patients has demonstrated that the initial intervention of EUS-GBD with LAMS for MBO showed rates of 87% for technical success, 100% for clinical success, and 0% for AEs rate.[37] Recently, a prospective study involving 37 patients indicated that EUS-GBD achieved 100% technical and clinical success rates for primary intervention in MBO, with AE rates of 14.8%.[38] AC following self-expandable metallic stent (SEMS) placement is sometimes a potentially deadly AE. The incidence of AC ranges from 7.4% to 15.3% in patients undergoing SEMS placement for distal MBO.[38–40] Regarding the treatment of AC after SEMS placement, EUS-GBD has comparable technical and clinical success rates of 97% and 100%, respectively.[40] Moreover, a recent study revealed that after the introduction of SEMS for distal MBO and tumors at the opening of the cystic duct, prophylactic EUS-GBD can reduce the incidence of AC and may subsequently decrease the rate of pancreatitis.[41] Nonetheless, this study has limitations such as different definitions of definite cholecystitis and lack of close follow-up, further RCTs are needed to validate the above results and fully consider the risks and benefits of the intervention.[42,43] Overall, EUS-GBD is safe in patients with AC and MBO, with low AEs and high success rates; nevertheless, large-scale studies are needed to confirm this.

### *EUS-GBD versus LC*

Previously, PT-GBD was regarded as an alternative to LC, and most studies have compared EUS-GBD with PT-GBD. Few studies have directly compared EUS-GBD with LC. In a propensity score matching (PSM) study, the prevailing dogma was challenged; the EUS-GBD group ($n = 30$) included high-risk surgical patients, and the other group ($n = 30$) underwent LC. The clinical and technical success rates, 30-day AEs, time to hospitalization, readmissions, rates of recurrent biliary diseases, and mortality were similar between the two groups.[44] Despite these similarities, the reintervention rates were different. In the LC group, the need for reintervention arose owing to undetected bile duct stones. Nevertheless, the study had limitations; for example, it was not randomized, the follow-up duration was short, and the number of patients was relatively small. A retrospective study comparing open surgery, LC, EUS-GBD, and PT-GBD demonstrated that EUS-GBD and LC exhibited comparable AEs, technical success, clinical success, and recurrence rates. No AEs related to the procedure. Unfortunately, this study did not analyze the groups individually.[45] Given existing evidence demonstrating that EUS-GBD and LC are comparable in high-risk surgical patients, further RCTs are required to compare EUS-GBD and LC in homogeneous cohorts and in low- or middle-risk surgical patients to determine their comparative efficacy.

### *Puncture sites, different techniques, and assisted approaches for EUS-GBD*

Currently, EUS-GBD can be performed via transgastric and transduodenal drainage. The choice of puncture site requires that the gallbladder be close to the gastrointestinal tract walls and that major blood vessels be avoided. The transgastric method involves anastomosis of the gastric antrum to the body of the gallbladder, which makes placing stents easy because of the large puncture point. Transgastric drainage is more suitable for patients with duodenal obstruction caused by pancreaticobiliary malignancy or those

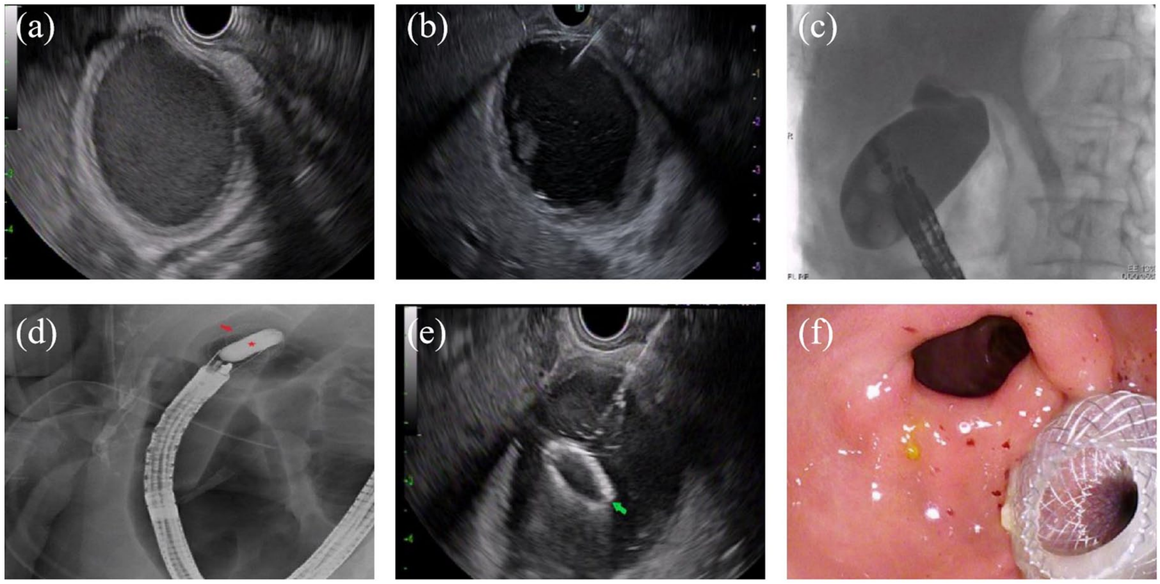


**Figure 1.** Steps of EUS-GBD. (a) EUS imaging reveals a dilated gallbladder filled with sludge and exhibiting thickened walls, indicative of acute cholecystitis. (b) EUS-guided fine-needle aspiration of the gallbladder is shown. (c) A fluoroscopic image illustrates the contrast filling the gallbladder. (d) Balloon dilation (red star) of the LAMS (red arrow). (e) The distal flange (green arrow) is deployed under EUS guidance. (f) Endoscopic imaging follows the successful transgastric placement of the LAMS into the gallbladder.
Source: Reproduced with permission from Luk et al.[21] CC BY Copyright 2023 Nicholas J Koutlas.
EUS, endoscopic ultrasound; EUS-GBD, EUS-guided gallbladder drainage; LAMS, lumen-apposing metal stent.

who may undergo cholecystectomy.[46,47] The transduodenal method involves anastomosis of the duodenal bulb to the neck of the gallbladder; since the duodenum is less mobile than the stomach, there is a lower risk of stent dislocation and less food gavage.[48,49] However, so far, there is no obvious difference in technical success, clinical success, and AEs between the two approaches. The European Society of Gastrointestinal Endoscopy demonstrated that puncture sites should be determined on a patient-by-patient basis.[11]

Once the puncture sites are determined, the gallbladder undergoes anastomosis to the stomach or duodenum under EUS guidance. A fine-needle aspiration needle (either 22 or 19 gauge) can then aspirate the contents of the gallbladder, inject contrast for fluoroscopic anatomical delineation, and a 0.025- or 0.035-inch guidewire is introduced through the needle, then the fistula can be dilated by a tapered tip balloon dilator (4 mm), bougie (6 or 7 F), needle-knife, or a cystostomy. Finally, the distal flange of LAMS is deployed first and then the proximal flange is deployed[11,50] (Figure 1). Subsequently, with the advancement of devices, an electrocautery-enhanced LAMS can be inserted in a single step, eliminating the need for fistula dilation, which has been shown to decrease procedural duration.[44,51]

EUS-GBD is distressing because of the easy mobility and collapse of the gallbladder. Zhang et al.[52] used retrievable puncture anchor traction (RPAT) for EUS-GBD in a porcine model and achieved technical success of 100%, which was remarkably higher than that of the control group (50%), which had cases of failure due to gallbladder collapse. All pigs in the experimental group with the application of the anchor survived, whereas all pigs in the control group died. This study has suggested that RPAT potentially enhances the efficacy and safety of EUS-GBD and reduces gallbladder collapse. Consequently, we anticipate the potential application of this approach to EUS-GBD in the imminent future. However, this research is an animal study, and relevant studies remain limited. Further clinical data are necessary to substantiate this result.

### *Interventions followed by EUS-GBD*

EUS-GBD can be performed not only for drainage but also for subsequent interventions through the fistula created between the gastrointestinal tract wall and the gallbladder. The fistula enables peroral exploration inside the gallbladder using an endoscope, that is, peroral cholecystoscopy.[53,54] The applications encompass gallbladder mucosa detection (e.g., confocal endomicroscopy, magnifying endoscopy observation, and electronic staining),[51] gallstone removal,[55,56] gallstone lithotripsy,[57] and gallbladder polypectomy.[58] As we mentioned earlier, the gallbladder mucosal detection method is widely used in the digestive system such as the gastrointestinal tract, but there is limited research on its application in the gallbladder. Confocal endomicroscopy can perform real-time cellular-level histological examination on the mucosa in vivo, known as "optical biopsy." Probe-based confocal laser endomicroscopy (pCLE) can enter the gallbladder through the LAMS during the EUS-GBD to detect gallbladder mucosa. Similarly, magnifying endoscopy and electronic staining can enhance the visualization of mucosal micro-vascularity and micro-villus structures, identifying subtle mucosal morphological changes and further improving the accuracy of biopsy. Teoh et al.[59] reported for the first time that a senior male patient underwent EUS-GBD for AC, with a subsequent discovery of a 2 cm polypoid lesion on gallbladder mucosa during endoscopic follow-up at 3 months postoperatively. Suspicion of malignancy arose through pCLE and narrow-band imaging (NBI) magnifying endoscopy, ultimately confirmed as gallbladder adenocarcinoma by pathologic diagnosis. Analogously, a recent case report showed an elderly female patient undergoing EUS-GBD for AC, finding a lobulated lesion on gallbladder mucosa intraoperatively. Utilizing texture and color enhancement imaging (TXI) and red dichromatic imaging (RDI), the final pathology confirmed gallbladder adenocarcinoma. TXI differs from NBI in maintaining the normal appearance of the image while enhancing lesion characterization and detection, whereas RDI aids in identifying bleeding points during surgery.[60] Tang et al.[61] retrospectively included 28 patients undergoing EUS-GBD, subsequent gallstone removal, and gallbladder polypectomy, with postoperative pathology as the gold standard, achieving 100% accuracy in pCLE diagnosis during surgery. Current research remains limited, yet the case reports and retrospective studies highlighted above indicate that EUS-guided gallbladder mucosal detection is indeed feasible. Despite the lack of widespread adoption, likely due to technical challenges and other factors. However, advancements in technology are expected to increase the application in clinical practice. Endoscopic cholecystolithotomy is the most commonly performed surgical procedure.[62] Ge et al.[63] performed gallstone removal after EUS-GBD in four pigs through the fistula 4 weeks later, and it was found to be completely healed at subsequent necropsy. This finding indicated that endoscopic cholecystolithotomy is safe. Subsequently, they performed endoscopic cholecystolithotomy with a clinical success rate of 100%.[64] Further clinical studies on cholecystolithotomy based on EUS-GBD are presented in Table 1.

Recently, a case of a giant gallstone that caused a shadow covering almost the entire gallbladder field was reported.[57] This case indicates that lithotripsy and lithotomy followed by EUS-GBD are

**Table 1.** Clinical studies of endoscopic cholecystolithotomy.

| Author, year (reference) | No. patients | Puncture sites | | Stent type | Stent diameter | Indwelling time | Stone clearance |
|---|---|---|---|---|---|---|---|
| | | Stomach | Duodenum | | | | |
| Ge et al. (2016)[64] | 7 | 4 | 3 | Microtech stent | 10/35 mm | 9 days | 7/7 |
| Chan et al. (2017)[51] | 25 | 6 | 19 | Cold/Hot AXIOS | 15/10 mm | 1–3 months | 22/25 |
| Shen et al. (2020)[62] | 3 | 1 | 2 | Microtech stent | 10 mm | 5 days | 3/3 |
| Vanella et al. (2022)[55] | 3 | 2 | 1 | Hot AXIOS ± DPPS | 10 mm ± 10 F | 4 weeks | 3/3 |

No., number; F, French.

not limited to the size of the gallstone, which promotes the clinical application of this technique. A prospective study demonstrated a technical success rate of 100% for gallbladder polypectomy based on EUS-GBD, with no polyp recurrence after 3–15 months of follow-up,[65] demonstrating a new option for patients with gallbladder polyps who have good gallbladder function or who do not wish to undergo surgery.

## EUS-guided gastroenterostomy

The indications for EUS-GE are GOO and afferent loop syndrome.[10,66] In the last decade, most studies on GOO have focused on malignancy. Malignant obstruction can be relieved by surgical gastroenterostomy (SGE); however, many patients with malignancy experience fatigue and other concomitant diseases that make it difficult for them to tolerate surgery. Endoscopic enteral stenting (ES) is an alternative therapy. Although ES has been shown to have a low risk of AEs, stent dysfunction remains problematic in up to one-third of the patients.[67] Conversely, EUS-GE is a minimally invasive technique; it has comparable success rates but fewer AEs compared to SGE[6] and ES.[68] The rates of EUS-GE for technical success, clinical success, and AEs ranged from 90% to 92%, 85% to 92%, and 7% to 12%, respectively.[69–73] The most frequently observed AEs were abdominal pain and erosion or ulceration of the contralateral wall attributed to the stent mesh among post-procedural patients.[74] Long-term AEs primarily related to stent migration or blockage.[75] Surgery can also be avoided for benign GOO caused by peptic ulcer disease, pancreatitis, caustic ingestion, and extraluminal fluid collections.[75] However, these findings remain controversial. Afferent loop syndrome after Roux-en-Y hepaticojejunostomy, pancreaticoduodenectomy, or Billroth II gastrectomy can also be alleviated by EUS-GE,[76] as the technical and clinical success rates are 100%, with an AE rate of 8%.[77]

### *EUS-GE versus SGE*

Clinical trials have demonstrated that EUS-GE has comparable success rates but fewer AEs[6,78–80] or similar success rates and AEs[74,81,82] compared to SGE. Common AEs associated with SGE encompass infections, gastroparesis, hemorrhage, and anastomotic leaks. Unfortunately, these studies have limitations owing to their retrospective design, small sample sizes, and various EUS-guided and operative methods. In particular, two preliminary trials might have encountered challenges because of limited experience with the novel technique, leading to a substantial occurrence of LAMS misdeployment observed in 10% (3/30)[74] and 36% (9/25) of patients.[79] Two meta-analyses reached similar conclusions and stated that EUS-GE has a lower technical success rate and overall AE rates compared to SGE, and common AEs associated with SGE encompassed gastroparesis, infections, hemorrhage, and anastomotic leaks.[83,84] We think that the reduced technical success rate of EUS-GE may also relate to the lack of experience. There is a growing body of experience in EUS-GE. A recent study reported a stent migration rate of 1.7% (4/232),[72] with technical and clinical success rates of 92% each (22/25).[73] More RCTs are needed to compare the clinical outcomes of the two approaches, particularly regarding AEs, given the aforementioned constraints and divergent findings in the current research on reintervention rates. The ENDURO study is currently recruiting patients.[85]

### *EUS-GE versus ES*

EUS-GE has similar or higher success rates and lower reintervention rates and AEs than ES, especially in stent dysfunction.[68,72,86–94] However, a meta-analysis and a PSM study reported that the difference in AEs between them is not statistically significant.[95,96] Teoh et al.[97] conducted an RCT on EUS-GE and uncovered ES; EUS-GE had a lower reintervention rate within 6 months (4% vs 29%) and a better GOO score than ES, with comparable AEs. EUS-GE can also be used as a salvage method for reobstruction after ES for GOO, with clinical and technical success rates of 88% and 89.3%, respectively, and an AE rate of 7.1%.[98] EUS-GE can be used to avoid surgery and reduce the recurrence rate in patients with benign GOO,[75,99] and EUS-GE for benign GOO has similar success rates, hospital length of stay, and average procedure time as that for malignant GOO.[100–102] EUS-GE seems to be an essential replacement for surgery and ES in the management of GOO. Future studies should provide high-quality evidence to support the aforementioned results.

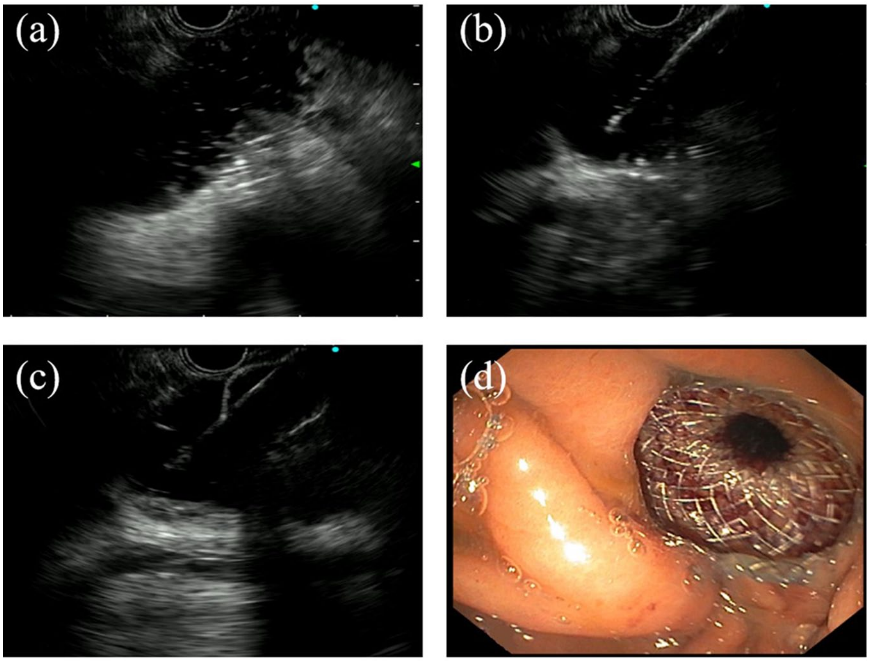


**Figure 2.** WEST of EUS-GE. (a) The proximal jejunal limb is dilated by the oroenteric catheter. The hyperechogenic spots are the contrast. (b) A free-hand gastrojejunal perforation is made using the catheter of the LAMS. (c) Deployment of the distal flange of the LAMS under EUS control. (d) Endoscopic view of the proximal flange of the LAMS completely deployed.
Source: Reproduced with permission from Perez-Cuadrado-Robles et al.[98] CC BY Copyright 2022 Enrique Perez-Cuadrado-Robles.
EUS, endoscopic ultrasound; EUS-GE, EUS-guided gastroenterostomy; LAMS, lumen-apposing metal stent; WEST, wireless endoscopic simplified technique.

### *Different approaches and assisted techniques of EUS-GE*

Various techniques are used in EUS-GE, where a stent is introduced between the stomach and duodenum or jejunum to palliate GOO.[103] Generally, once the proximal jejunum or distal duodenum is filled with saline or a contrast agent, the stomach and intestine are anastomosed using a metal stent. The following two approaches are used in EUS-GE: direct technique over a guidewire (DTOG) and wireless endoscopic simplified technique (WEST). The difference between them is that the former uses a guidewire to assist in stent placement, whereas the latter uses an electrocautery-enhanced stent that does not require a guidewire (Figure 2). However, there is a lack of knowledge regarding the optimal approach for conducting EUS-guided anastomosis, owing to the absence of standardization. A retrospective study of 45 patients reported the technical success rate of WEST as 95%.[104] Monino et al.[105] compared WEST and DTOG and reported that WEST exhibited a superior technical success rate and lower AEs than DTOG while maintaining a comparable clinical success rate. Nonetheless, it is vital to note that the present study was retrospective and limited to related trials. Hence, additional research is necessary for a more comprehensive comparison of these two approaches.

Owing to the flexibility and mobility of the intestines, performing EUS-GE procedures can be challenging. To address this issue, assisted EUS-GE techniques have been employed, which involve the use of stone extraction balloons, dilation balloons, or double balloons for subsequent puncture and stent placement[67,106–108] (Figure 3). In a recent pilot study, the modified EUS-guided double-balloon-occluded gastroenterostomy bypass (EPASS) technique was employed for EUS-GE in 11 patients, achieving a technical success rate of 91%. The clinical success and AE rates were 80% and 9%, respectively.[109] Chan et al.[110] conducted a study including 114 patients (30 EPASS, 35 SGE, 49 ES). The technical (93.3% vs 100% vs 100%, $p = 0.058$) and clinical success rates (93.3% vs 80% vs 87.8%, $p = 0.276$)

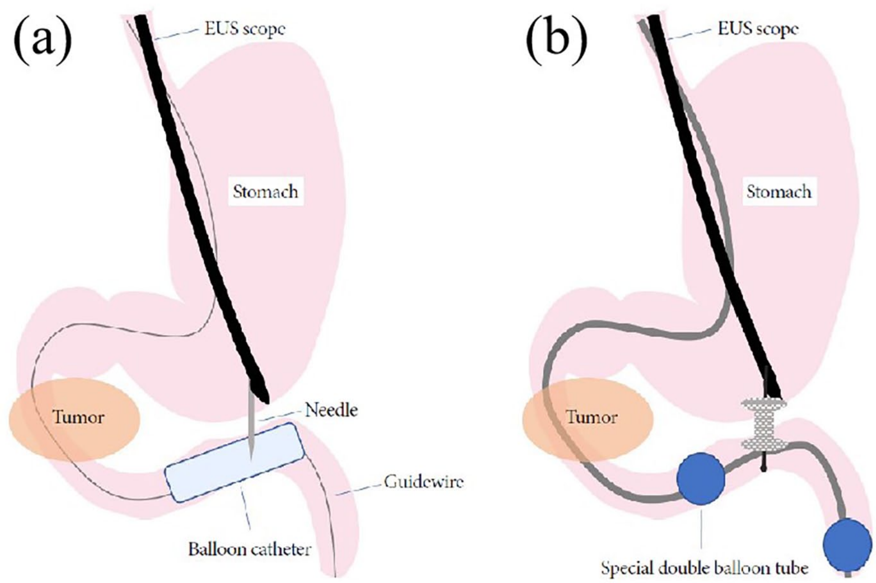


**Figure 3.** Part of assisted EUS-GE techniques. (a) Balloon-assisted dilation. (b) EPASS.
Source: Reproduced with permission from Tonozuka et al.[107] CC BY 3.0. Copyright 2020 Ryosuke Tonozuka.
EPASS, EUS-guided double-balloon-occluded gastroenterostomy bypass; EUS, endoscopic ultrasound; EUS-GE, EUS-guided gastroenterostomy.

were comparable. In addition, the EPASS group demonstrated the shortest hospital stay (1.5 (1–17) days, $p < 0.001$), the lowest rates of recurrent obstruction (3.3%, $p = 0.002$), and re-intervention (3.3%, $p = 0.031$). The 1-month GOO score was highest in the EPASS group (3 (1–3), $p = 0.028$). The modification potentially enhanced the safety and clinical application of EUS-GE. Hu et al.[111] presented a case wherein the application of RPAT for EUS-GE alleviated obstruction in a patient with postpancreatitis GOO. This case demonstrated the feasibility and effectiveness of RPAT in treating benign GOO while avoiding surgery and minimizing patient trauma. Wang et al.[112] further validated the efficacy of RPAT by performing EUS-GE in six pigs with malignant GOO, with no AEs or technical failures. RPAT may be both safe and effective; however, further RCTs remain essential to validate these findings.

## Discussion

With the advent of technology and a better understanding of the disease, patients tend to undergo surgeries using minimally invasive methods and have faster recovery times. Consequently, EUS-guided interventions are gaining increasing popularity.[113–116] As previously mentioned, symptoms can be alleviated using a stent to achieve anastomosis of the two luminal walls. The methods of EUS-guided upper gastrointestinal anastomosis encompass EUS-guided biliary drainage, EUS-guided peripancreatic fluid collection drainage, EUS-GBD, and EUS-GE.[6,18,117–119] The first two drainage techniques have seen more frequent application and are backed by a significant amount of literature. Notably, the use of EUS-GBD and EUS-GE has experienced considerable growth in recent years. Although the existing research findings are not entirely consistent, EUS-GBD and EUS-GE have demonstrated similar success and AE rates, and even higher success rates with lower AE rates than alternative approaches. In addition, EUS-guided methods have extended indications and can serve as salvage methods for other approaches. One issue with EUS-GBD is the possibility of increased complexity in the subsequent cholecystectomy.[120] Tyberg et al.[121] conducted a multicenter international cohort study and reported that the technical success rate of cholecystectomy after EUS-GBD was 95.7%. Nonetheless, the technical success rates for PT-GBD and EUS-GBD are comparable. In addition, EUS-GBD reduced the operative time, time to symptomatic relief, and duration of hospitalization. This suggests that

EUS-GBD does not increase the complexity of cholecystectomies. EUS-GE not only offers immediate improvement in patients' GOO but also demonstrates positive outcomes in terms of quality of life. A prospective study assessing such improvements reported a 30-day clinical success rate of 83.3% and a notable improvement of 21.6 points on the Global Health Status scale.[122] When some situations preclude EUS-GE (e.g., colon intervention, distance of anastomosis >1 cm, the small bowel is trapped by adhesions on the right side of the abdominal cavity, or the stricture is either extensive or sharply angled), EUS-guided duodenojejunostomy or jejunojejunostomy can be employed. A case series involving five patients reported a technical success rate of 100% but a clinical success rate of only 60%, with one instance of bleeding and no reinterventions.[123] Although the clinical success rate was low, only a small number of patients were included in this study. EUS-guided duodenojejunostomy and jejunojejunostomy could serve as alternatives to EUS-GE under certain circumstances.

## Conclusion

This review comprehensively compares EUS-GBD and EUS-GE with other alternative approaches and explores the various assisted techniques employed for EUS-GBD and EUS-GE. The advantages and disadvantages of EUS-GBD and EUS-GE were clearly shown, and the summary of assisted techniques also provided a reference for choosing a more suitable method in clinical practice. Most previous studies primarily assessed the technical success, clinical success, and AE rates, with minimal emphasis on the success rate of the initial puncture or remedial measures following puncture failure. In studies on EUS-GBD, the focus was on the drainage of AC, with limited attention given to the drainage of patients with noninflammatory diseases. Similarly, for EUS-GE, most studies focused on malignant GOO, with few investigations on the drainage of benign obstructions or the differentiation between benign and malignant obstructions. Thus, further studies are required to validate these findings. A growing body of literature is focusing on assisted technologies to improve the mobility of the gallbladder and small bowel, improve success rates, and minimize AEs. Even RCTs are currently recruiting patients because of inconsistent research findings. Despite certain limitations, EUS-GBD and EUS-GE are safe, efficient, and minimally invasive.

## Declarations

### *Ethics approval and consent to participate*

Not applicable.

### *Consent for publication*

Not applicable.

### *Author contributions*

**Rongmin Xu:** Formal analysis; Writing – original draft.

**Kai Zhang:** Methodology; Writing – review & editing.

**Jintao Guo:** Investigation; Writing – review & editing.

**Siyu Sun:** Conceptualization; Writing – review & editing.

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### *Competing interests*

The authors declare that there is no conflict of interest.

### *Availability of data and materials*

The information can be obtained from PubMed and Web of Science.

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