Training Course

Endoscopic Ultrasound

OPEN

Mishaps with EUS–guided lumen-apposing metal stents in therapeutic pancreatic EUS: Management and prevention

Barbara Braden[1,*], Michael Hocke[2], Emmanuel Selvaraj[1], Kanav Kaushal[1], Kathleen Möller[3], Andrè Ignee[4], Giuseppe Vanella[5], Paolo Giorgio Arcidiacono[5], Anthony Teoh[6], Alberto Larghi[7], Mihai Rimbas[8], Stefan Hollerbach[9], Bertrand Napoleon[10], Yi Dong[11], Christoph F. Dietrich[12]

ABSTRACT

EUS–guided interventions have become widely accepted therapeutic management options for drainage of peripancreatic fluid collections. Apart from endosonographic skills, EUS interventions require knowledge of the endoscopic stenting techniques and familiarity with the available stents and deployment systems. Although generally safe and effective, technical failure of correct stent positioning or serious adverse events can occur, even in experts' hands.

In this article, we address common and rare adverse events in transmural EUS-guided stenting, ways to prevent them, and management options when they occur. Knowing the risks of what can go wrong combined with clinical expertise, high levels of technical skills, and adequate training allows for the safe performance of EUS-guided drainage procedures. Discussing the procedural risks and their likelihood with the patient is a fundamental part of the consenting process.

Key words: Walled-off pancreatic necrosis; Peripancreatic fluid collection; Stent migration; Bleeding; Pancreatitis

INTRODUCTION

EUS–guided transmural drainage of peripancreatic fluid collections is considered the first-choice treatment for patients with pancreatic pseudocysts or walled-off necrosis (WON).[1–4] The development of lumen-apposing metal stents (LAMS) has made interventional procedures simpler and quicker, with facilitation of further maneuvers such as direct endoscopic necrosectomy.[5] In 2012, the first report of EUS-guided drainage of peripancreatic fluid collections using LAMS was published by Itoi et al.[6]

Since then, the use of LAMS in the management of peripancreatic fluid collections has gained widespread popularity. Although generally safe, the EUS-guided insertion of LAMS can cause immediate or delayed adverse events including serious bleeding, stent maldeployment, infection, and perforation, to name the most common.

The specific LAMS design, with a dumbbell shape and a high radial force, significantly reduces the risk of late migration, perforation, and leakage of intestinal or necrotic material, when the stent has been appropriately placed. Hence, the most dramatic part of the procedure is the release of the LAMS itself, for which specific competences need to be gained through appropriate ex vivo and in vivo training. Finally, whereas LAMS deployment, especially with the built-in electrocautery-enhanced delivery system, can appear intuitive and easy, endoscopists facing therapeutic EUS should have proficiency in handling complications such as bleeding, perforation, and maldeployment.

STENT MALDEPLOYMENT/STENT MIGRATION

Stent misplaced into the collection (internal misplacement)

One of the most dreaded stent misplacements is inadvertent deployments of the stent into the peripancreatic fluid collection [Figure 1]. Retrieving the stent endoscopically can be very challenging, and heroic attempts may cause more problems. It might be prudent to first secure adequate drainage of the collection by placing a second stent, whereas attempts to retrieve the misplaced stent can also be deferred according to the patient's clinical situation. When the maldeployment has been noticed, the stent catheter might still be inside the collection and therefore used to secure a guidewire inside the collection. In this way, a new LAMS can be placed over the wire through the same tract. The misplaced stent can be extracted after entering the peripancreatic collection through the correctly placed

[1] Translational Gastroenterology Unit, Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom; [2] Medical Department II, Helios Klinikum Meiningen, Meiningen, Germany; [3] Medical Department I/Gastroenterology, Sana Hospital Lichtenberg, Berlin, Germany; [4] Medical Department Gastroenterology, Julius-Spital Würzburg, Germany; [5] Pancreatobiliary Endoscopy and Endosonography Division, Pancreas Translational & Clinical Research Center, IRCCS San Raffaele Scientific Institute, Vita-Salute San Raffaele University, Milan, Italy; [6] Division of Upper Gastrointestinal and Metabolic Surgery, The Prince of Wales Hospital, The Chinese University of Hong Kong, China; [7] Digestive Endoscopy Unit, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy; [8] Gastroenterology Department, Colentina Clinical Hospital, Carol Davila University of Medicine, Bucharest, Romania; [9] Department of Gastroenterology/GI Endoscopy, AKH Celle, Academic Teaching Hospital of Medizinische Hochschule, Hannover, Germany; [10] Digestive Endoscopy Unit, Hopital Privé J Mermoz Ramsay Générale de Santé, Lyon, France; [11] Department of Ultrasound, Zhongshan Hospital, Fudan University, 200032 Shanghai, China; [12] Department Allgemeine Innere Medizin, Kliniken Hirslanden, Beau Site, Salem und Permanence, Bern, Switzerland

* **Address for correspondence:** Translational Gastroenterology Unit, Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom. E-mail: braden@em.uni-frankfurt.de (B. Braden).

Endoscopic Ultrasound (2023) 12:5

Received: 04 October 2022; **Accepted:** 12 April 2023

Published online: 28 September 2023

http://dx.doi.org/10.1097/eus.0000000000000018

and fully opened transgastric stent. Perhaps a larger lumen diameter can be chosen for the second stent to facilitate later retrieval.[7]

When the necrotic cavity is entered endoscopically at a later date, one of flange ends of the intracavitary stent needs to be grasped with an extraction forceps. Pulling the flange end lengthens the soft metal stent, therefore enabling safe extraction through the correctly placed stent without dislodging it.

Inadvertent deployment into the collection should be avoided by ensuring that the delivery system is pulled back to the gastric wall after opening of the first flange. The distance between the peripancreatic fluid collection and transducer should not be more than the length of the stent, typically 10 mm, but more novel stents allow for longer distances.[8] The inner axis of the delivery system should touch the edge of the opened distal flange (rugby ball sign) to ensure close contact to the wall. Before the second flange is deployed in the instrument channel, the system must be securely locked again. After intrachannel deployment of the second flange, the stent end should be released from the operative channel by a gentle endoscope torquing and/or tip deflection or left/right rotation to change the axis with respect to the fistula while providing sufficient space for the flange to open without advancing toward the fistula.

Correct handling of the stent delivery system is crucial to avoid unintentional stent release. The LAMS delivery system is designed with a stent deployment hub that is stopped by the locking system on the stent deployment hub after the deployment of the first flange. This allows for correct positioning of the half-opened stent. Inadvertent touching of the locking system during stent deployment might open this lock and result in uncontrolled deployment of both flanges.[9]

During endoscopic necrosectomy when the fistula has already matured, the movement of the endoscope and tools through the LAMS can result in its dislodgement into the cavity or the gastric lumen. Often the stent can then be repositioned endoscopically with the help of forceps or snares.[10–12] If the tract is fully matured, the necrosectomy can be pursued without the need of reinserting a

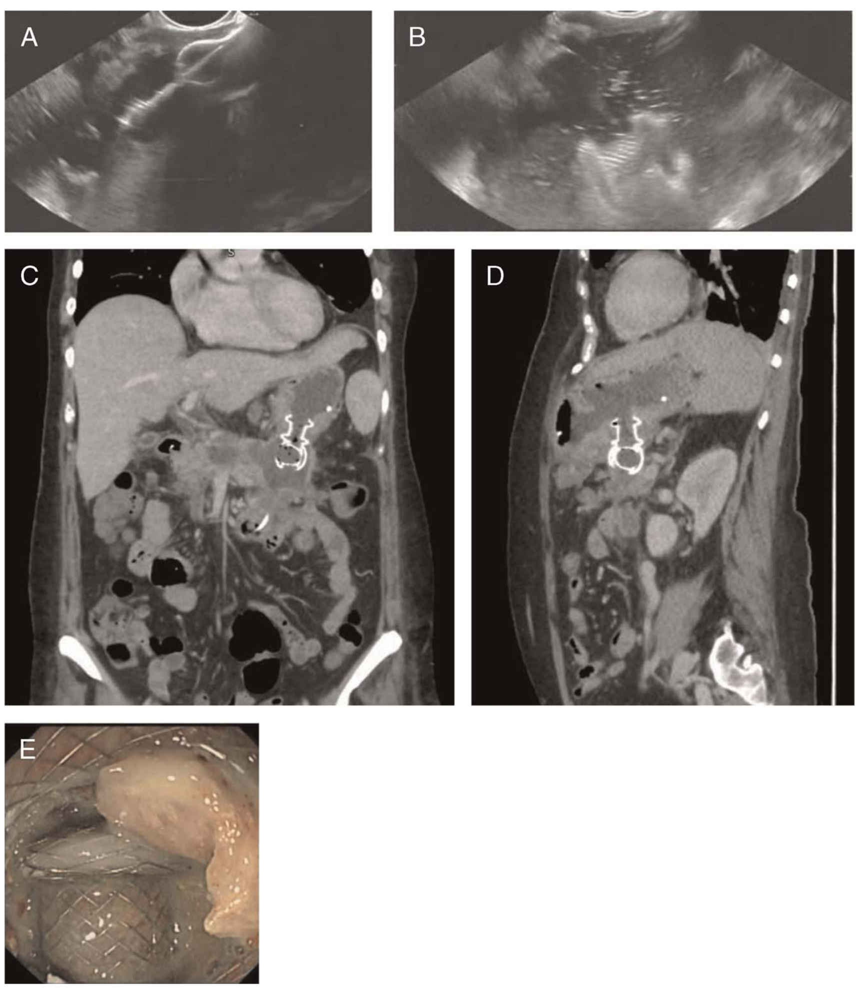

Figure 1. A, EUS-guided deployment of a 15-mm-diameter LAMS. B, EUS views of the stent misplaced in the peripancreatic fluid collection. C and D, Coronal and axial CT scans showing the stent misplaced within the pancreatic walled-off necrosis and the second correctly placed transgastric Hot AXIOS stent. E, After 3 weeks and improvement in clinical situation, the misplaced stent could be retrieved endoscopically using a biopsy forceps through the correctly placed also 15-mm-diameter stent, leaving the correctly placed stent for 4 more weeks until near-complete resolution of the collection. CT: computed tomography; LAMS: lumen-apposing metal stents.

LAMS. It might also be helpful to complete the necrosectomy, as sometimes LAMS might hamper the access to some areas requiring necrosectomy. In cases of WON with a large amount of debris when the need for later endoscopic necrosectomy seems likely, large-caliber LAMS with 15- or 20-mm diameter should be placed initially to facilitate the endoscopic access to the cavity.

Stent dislodged into the gastrointestinal lumen (external dislocation)

If the stent is dislodged into the gastrointestinal lumen during the procedure, the main intention should be to secure the orifice to place another stent. Ideally, the second stent should be placed via the same tract to avoid leakage, but if the misplaced stent has inadvertently been extracted with the scope, the access usually has been lost. In this scenario, the placement of a second stent should reduce retroperitoneal leakage from the first tract by decompression of the collection.

Ideally, the fistula tract from the unsuccessful stenting attempt should be closed with clips; however, defects generated by a 10F electrocautery-enhanced delivery system might be functionally silent, and contrast injection might suffice to exclude the need for active closure. Usually, there is no (retro-)peritoneal leakage due to inflammatory adherence of the pancreatic cavity to the gastric wall.

An intragastrically dislodged stent can generally easily be extracted with a stent grabber or a polypectomy snare. If the intraluminally lost stent cannot be retrieved, its spontaneous passage through the gastrointestinal tract in the absence of any gastrointestinal strictures is unlikely to cause any harm.

The design of the commercially available stents for EUS-guided drainage of peripancreatic fluid collections has wide internal and external flanges to prevent stent migration. However, the short length of the saddle, the effective length of usually 10 mm for lumen-apposing stents, requires precision positioning.

After opening of the first flange and pulling it back to the wall of the peripancreatic fluid collection, the second flange can be opened while still in the instrument channel. A gentle move away from the gastrointestinal wall paired with gentle advancing of the catheter then sets the second flange free from the instrument channel and enables the endoscopic view.

The correct stent positioning can be usually confirmed endoscopically by fluid pouring through the stent into the gastric lumen and endosonographic imaging.

If the LAMS extends too far into the lumen of the stomach but the ostium to the cavity is visible, an attempt can be made to correct the position by inserting a 10- to 12-mm balloon into the stent. If the balloon is then filled and fills the stent lumen, dilating the access path across the gastric wall somewhat, the stent can be slightly pushed forward and more centrally positioned. This procedure is very demanding and must be performed extremely carefully so as not to have the opposite effect and dislocate the stent into the necrotic cavity or perhaps injure the gastric wall in the process.

It has been postulated that coaxial placement of double-pigtail plastic stents (DPPS) or a nasocystic tube through the correctly positioned transmural LAMS would prevent stent clogging and migration and reduce bleeding complications resulting from mechanical irritation of the flange on the contralateral wall.[13,14] This has not been confirmed in a recent retrospective multicenter study,[15] and a large randomized controlled trial is planned.[16] A most recent randomized controlled study showed less stent obstruction when double-pigtail plastic stents were additionally inserted.[17]

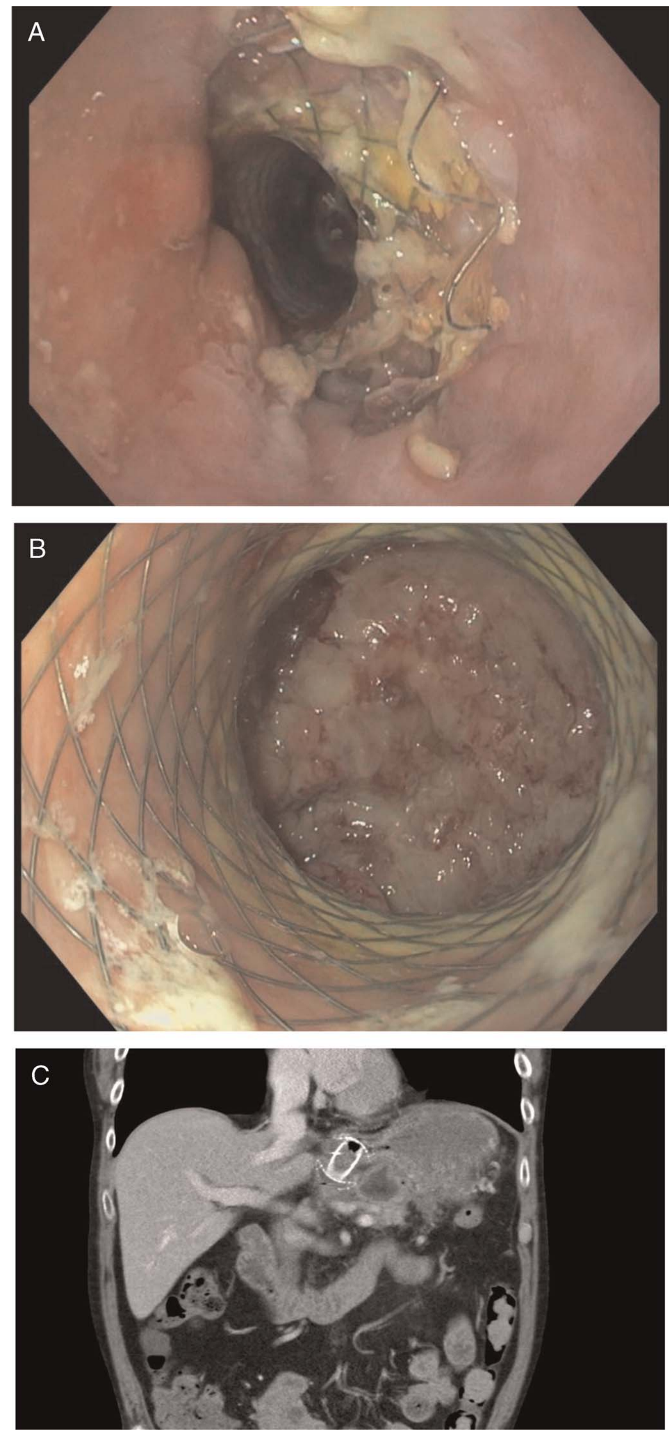

Figure 2. A LAMS placed close to the esophagogastric junction causes obstruction of the food passage. A, Endoscopic view from the esophagus. B. Endoscopic view through the stent into the pancreatic cavity. C, The CT scan visualizes the position of the stent close to the cardia. CT: computed tomography; LAMS: lumen-apposing metal stents.

Pitfalls of a target mistake (stent into ascites/peritoneum/gallbladder/liver or kidney cyst or into other echo-free structures)

Not everything that appears echo-free is a peripancreatic fluid collection resulting from prior pancreatitis. Inexperienced EUS endoscopists might mistake ascites, the gallbladder, or liver and kidney cysts for a peripancreatic fluid collection and are at risk to attempt stent insertion with potentially deleterious consequences. Another serious mistake is to mix up a pseudocyst and a pseudoaneurysm.

These are avoidable serious adverse events that could be prevented by reviewing of the preprocedural imaging and a careful orientating EUS assessment with identification of the anatomic landmarks, definition of the walls of the collection and the retroperitoneal location, and Doppler analysis before commencing the stent insertion.

If infected WON with heterogenous echogenicity B-mode visualization can be poor, then contrast-enhanced EUS can help to define the margins of the necrosis to the surrounding tissue for targeted stenting.[18] In WON with large amounts of debris and only small pockets of liquid content, the injection of saline will enlarge the echo-free space and improve the visibility for stent deployment.[19]

Stent obstruction of the gastrointestinal tract

Lumen-apposing metal stents can be applied in all positions that can be reached by an echoendoscope in the upper and lower gastrointestinal tract. Important criteria for correct positioning of the stent are to find the closest position of the cavity to the gastrointestinal wall and to avoid intercepting large vessels. Occasionally, the chosen position may cause problems with transit of food through the gastrointestinal tract. Although stent position in the lower esophagus or cardia region [Figure 2] rarely tends to cause mechanical problems due to the angle of the deployed stent, positioning in the antrum region can be tricky. If the stent is deployed close to the pylorus, the stent lumen opens into the direction of food passage and the inner stent flange can obliterate the pylorus.[20] Several solutions can be used if this situation arises. One solution would be to apply a feeding tube to bypass the flange and avoid solid food intake as long as the clearance of the cavity is ongoing. Another solution is to exchange the LAMS with plastic double-pigtail stents, which do not obstruct the pylorus anymore.

It is also possible to apply a fully covered pyloric stent next to the LAMS to keep the pylorus open and maintain the drainage of the peripancreatic fluid collection [Figure 3].[21] Because both stents are fully covered stents, extraction is still possible up to 4 weeks.

Food passage into the pancreatic cavity can be avoided by inserting one or multiple double-pigtail plastic stents. This stops solid food entering the pancreatic cavity while still allowing for a sufficient room for fluid drainage into the gastric lumen.

BLEEDING

The risk of bleeding for EUS-guided interventions has been reported as 5.4% in a meta-analysis by Mohan et al.[22] In analyzing retrospective data from 18 UK and Ireland units with a total of 1018 patients, initial bleeding was seen in 1.1% of cases and delayed bleeding in 18 of 952 (1.9%).[23]

Intraprocedural bleeding

Before accepting a patient for EUS-guided stent placement, the usual criteria for high-risk endoscopic interventions should be followed. A platelet count >50 × 10^9/L and international normalized ratio <1.5 are generally accepted as prerequisite criteria. For advice on per-procedural interruption of antiplatelet and anticoagulation

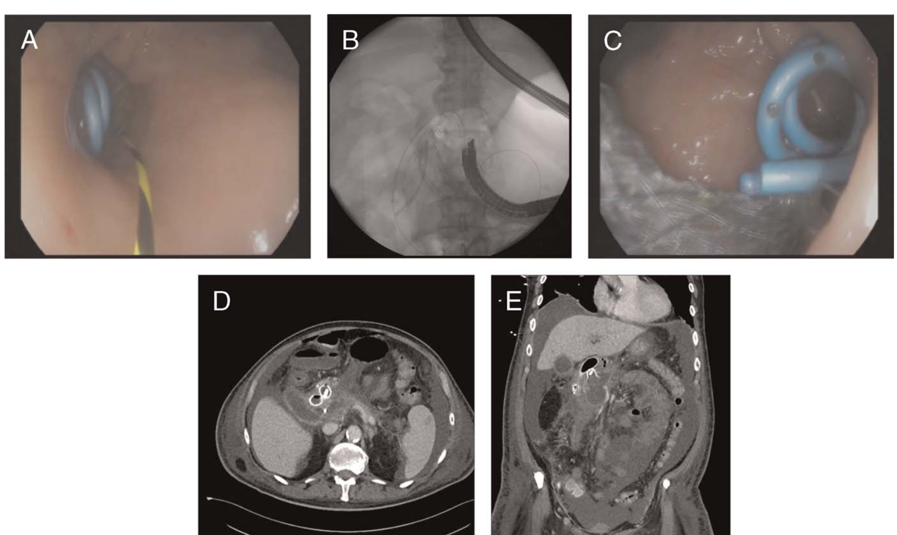

Figure 3. Obstruction of the pylorus by closely applied LAMS into a necrotic pancreatic cavity. A, The LAMS is applied and the lumen is protected by two double-pigtail drainages to avoid food passage into the cavity, and a guidewire is applied next to the LAMS through the pylorus into the duodenum. B, Radiologic view after inserting the fully covered intestinal stent next to the LAMS with two double-pigtail drainages. C, View onto the applied intestinal stent and the visible two double-pigtail drainages into the necrotic cavity. D, Axial CT scan with stents in position—the LAMS can be identified with the double-pigtail drainage in the stent lumen. E, Coronal CT scan of the same area—the intestinal stent can be seen on top of the LAMS with the distal ending in the necrotic cavity. CT: computed tomography; LAMS: lumen-apposing metal stents.

treatment in patients undergoing LAMS insertion, the updated guidelines from the British Society of Gastroenterology and the European Society of Gastroenterology and Endoscopy that categorizes EUS interventions as high-risk procedures should be followed.[24]

To reduce the risk of intraprocedural bleeding, the projected path of the diathermy access should be checked using Doppler sonography to exclude interposed vessels that might get injured. It is important not to compress the wall with the ultrasound tip because this maneuver can result in an underestimation of the interposed vessels. Although the endosonographic visualization of collaterals and blood vessels using color flow is excellent, it cannot completely exclude the risk of bleeding during the procedure. The bleeding can originate either from the site of access in the gastric wall or from vessels within the cavity.

When the best access point and projected path have been selected and the tip of the electrocautery system is visible on EUS just touching the gastrointestinal wall, it is important to activate electrocautery by pressing the foot pedal before advancing the system to avoid inadvertent tangential deviation into the gastric wall.

Hemorrhage into the necrosis cavity can be suspected if the liquid content in B-mode is suddenly whirled up. Duplex sonography may show a jet-like hemorrhage into the cavity. In this situation, it is important to remain calm and continue the stenting procedure rapidly. Usually, the bleeding into the necrosis cavity is compressed by the radial forces of the stent, and the bleeding is stopped without further intervention and only by the stent implantation.

Should intraprocedural hemorrhage occur, the management varies depending on severity and the site. Minor bleeding from the access site often stops spontaneously or because of radial forces exerted by the LAMS on surrounding tissues.[25] Conventional endoscopic hemostasis techniques such as adrenaline injection [Figure 4], endoclip placement, clipping, electrocoagulation, or hemospray[26] can be applied. Balloon occlusion might control further bleeding by tamponade effect.[27] Finally, if anything fails, an occlusion of the stent with an endoloop can be attempted.

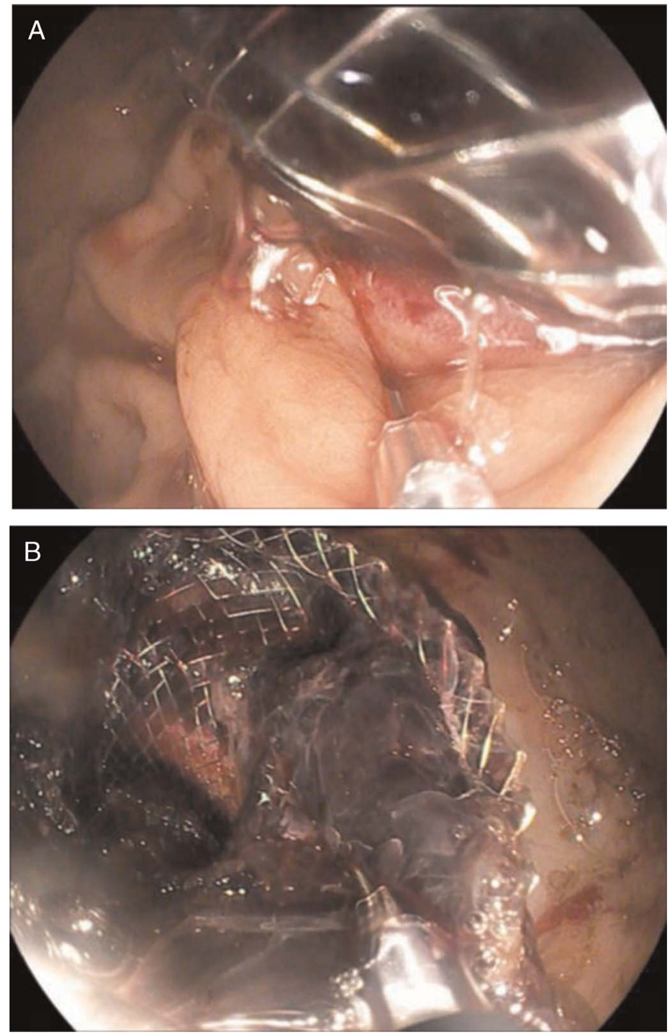

Figure 4. Hematemesis and melena 6 hours after the EUS-guided LAMS placement. A, The bleeding had already stopped at the time of endoscopy. B, However, 4-quadrant injection of small amounts of diluted adrenaline was performed both outside and inside the stent. LAMS: lumen-apposing metal stents.

Delayed bleeding

Two studies have raised concerns about high rates of delayed bleeding with LAMS insertion for peripancreatic fluid collections.[28,29] Delayed bleeding events might occur when the embedded stent erodes over time with collapsing of the cavity into adjacent vessels or induces pseudoaneurysm formation. The risk of bleeding seems higher when the LAMS is left in place for longer, given that the collapse of the cavity after drainage may cause the edge of the LAMS to erase the posterior wall of the cavity.[30–32]

In cases of severe hemorrhage, a computed tomography angiography and interventional radiology-guided coil embolization may be required to achieve hemostasis.[1] Surgical management with exploration and blood vessel ligation or packing of the pancreatic cavity should be reserved as a last resort for life-threatening situations when all other measures have failed.

To avoid these bleeding events, coaxial double pigtail plastic stent (DPPS) placement and a LAMS removal or exchange for DPPS within 3 to 4 weeks from placement have been advocated.[14,29] The European Society of Gastroenterology and Endoscopy recommends that LAMS should be removed within 4 weeks of placement to avoid this complication. However, there is mounting evidence that challenges this notion showing no different in adverse outcomes between early (<4 weeks) and late (>4 weeks) LAMS removal.[23] Therefore, an increasing number of stents are being left longer than 4 weeks with imaging monitoring if the desired clinical outcome has not yet been achieved.

Bleeding is also the most common complication during endoscopic necrosectomy, sometimes even with fatal outcome.[33] The often minor bleeding seen during and immediately after stent removal is usually self-limiting. If not, the previously discussed hemostasis techniques can be applied.

PERFORATION/INTRA-ABDOMINAL LEAKAGE

Peritonitis and/or pneumoperitoneum develops if the newly created fistula tract between the gastroduodenal opening and the peripancreatic fluid collection is not sealed completely by the stent and allows for leakage of air and fluid into the peritoneal space.

This happens with incorrect stent placement, mainly when the capsule of the collection has not yet matured and is not adherent to the gastric or duodenal wall, potentially leading to intraperitoneal deployment of the distal flange. In other cases, the stent does not completely bridge the gap.

Walled-off necrosis requires drainage treatment if it becomes symptomatic (gastric outlet syndrome, intractable pain, biliary compression) or infected. Ideally, according to guidelines, intervention for pancreatic necrosis should be delayed by at least 4 weeks since the onset of acute necrotizing pancreatitis until the necrotic tissue has liquefied and demarcated with a thick capsule wall. However, the decision for EUS-guided intervention is driven by the patient's clinical condition, and transmural endoscopic drainage of an acute necrotic collection can also be safely and successfully performed—if necessary in urgent cases—in the early phase of acute pancreatitis.[34]

The self-expanding forces and the fully covered design of LAMS should prevent leakage if the stent is correctly placed. Perforation occurred in 2.4% when LAMS were inserted to drain peripancreatic fluid collections according to the meta-analysis by Mohan et al.[22]

If the misplaced stent causing the perforation is extracted and the gastric lumen is closed endoscopically by clips, pancreatic juice from the opened collection might still leak into the peritoneum. Conservative management with intravenous antibiotics and fluids might be justified in stable patients with small perforation, but surgical consultation should be obtained.

To avoid leakage of air and fluids into the peritoneum by separation of the capsule of the collection and the stomach wall, a retroperitoneal access site with clear wall apposition and distance of less than 1 cm should be selected. Use of carbon dioxide lowers the risk of pneumomediastinum, pneumothorax, and abdominal compartment, should a perforation occur, and it should be mandatory when performing therapeutic EUS.[1]

Generally, WON is still associated with high mortality, and its management requires a multidisciplinary approach. The decision making regarding periprocedural adverse events of EUS-guided stenting such as perforation, bleeding, and infection will also benefit from the combined expertise of surgeons, interventional radiologists and endoscopists, infectiologists, and the nutritional team.

INFECTION

EUS–guided cystogastrostomy to drain peripancreatic fluid collections creates a new fistula tract, an artificial connection between internal organs and the stomach or duodenum, thereby exposing usually separated tissues to the gastric contaminated environment. Subsequently, development of infection up to sepsis (4.5%) is an adverse event observed after EUS-guided stent insertion.[22]

Although evidence is not based on randomized controlled trials, the US, Asian, and European guidelines recommend application of periprocedural antibiotics. Mainly, second- or third-generation cephalosporines or meropenem is given for 3 to 5 days.[1,35,36] However, because the more frequent indication for drainage is superinfection, most patients will already arrive in the endoscopy suite under antibiotic therapy.

Secondary infections can occur when the inserted stent becomes occluded, mainly by debris from the necrotic cavity. In this case, endoscopy with direct fluid irrigation or placement of a nasocystic tube and the option for endoscopic necrosectomy to clear debris from the stent and from the WON are indicated. Also, insertion of additional drainage by inserting a second stent (multi-gateway approach) or by the percutaneous route might be needed in complex

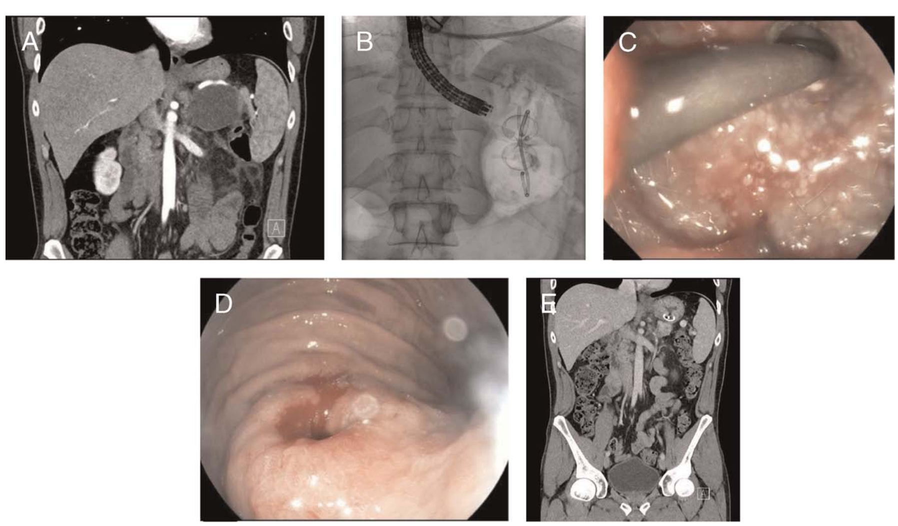

Figure 5. Buried stent syndrome 8 weeks after initial placement. A, Initial CT scan of the infected pancreatic pseudocyst—please note the intercepting vessel because of portal hypertension. B, Placement of the LAMS and an additional plastic double-pigtail stent to increase the drainage effect by avoiding stent obstruction. C, View into the lumen of the buried stent with the double-pigtail stent still in place. D, View of the buried stent after removal of the double-pigtail stent. E, CT scan before stent removal—please note the overgrown proximal stent flange. CT: computed tomography; LAMS: lumen-apposing metal stents.

large cavities.[37] The role of prophylactic coaxial DPPS placement during the first drainage deserves further exploration.[14,16]

BURIED STENT SYNDROME

Mucosal overgrowth of the gastric or duodenal flange (buried stent syndrome) renders the endoscopic removal technically challenging and might result in bleeding. If the flange is completely embedded by overgrown mucosa, the stent and the former opening of the stent lumen cannot be visualized endoscopically and only a bulge in the gastric lumen might be noted [Figure 5]. In this scenario, the stent will be visible on fluoroscopy or EUS assessment, which can facilitate the recannulation of the lumen.[38]

Buried stent syndrome was found to be one of the most common delayed adverse events with an overall rate of 4.7% in the multicenter study by Nayar et al.,[23] 2.1% in a study by Bang et al.,[39] and 1% in an Australian multicenter study.[40]

Grasping a visible flange edge of a partially embedded stent with rat-tooth forceps or biopsy forceps usually allows for the extraction. Opening the mucosal cover with a needle knife, argon plasma coagulation, and initial dilatation of the tract to facilitate removal of completely embedded stents have been reported. Partially ingrown tissue can be freed by using argon plasma coagulation, as reported in one case with damaged silicon membrane.[41] It might be easier when the proximal flange is largely covered by overgrown mucosa to insert a scope through the embedded stent and grasp the distal flange from within the cavity inverting the stent on extraction.[42,43]

After many years of stent indwelling in patients lost to follow-up, the metal mesh and membrane start disintegrating, and wires can become lose and tangled. Stent-in-stent technique has also been applied to induce mucosal necrosis by exerting pressure due to expansion of the new stent before attempting the removal of the ingrown stent.[44]

To avoid the buried stent syndrome, LAMS should be extracted as soon as the collection has resolved, ideally within 4 weeks. Units performing EUS-guided cystgastrostomy using LAMS should maintain a registry with insertion dates to call patients back for imaging and stent extraction in or to prevent loss to follow-up. An app to facilitate the timely recall of patients has been developed.[45]

STENTING A CYSTIC TUMOR AND NOT A PERIPANCREATIC FLUID COLLECTION AFTER PANCREATITIS

Sometimes cystic tumors can mimic peripancreatic fluid collections caused by pancreatitis. However, the inadvertent stenting of a cystic tumor might have grave consequences, as it has a high risk of tumor cell dissemination.

To prevent insertion of a LAMS in a cystic-appearing tumor, all preprocedure imaging should be carefully reviewed in a multidisciplinary team meeting with gastrointestinal specialized radiologists in the context of the clinical situation and laboratory parameters. Irregularities of the wall, presence of nodules, and lymph adenopathy should be carefully looked for. If the clinical history does not entail the typical event of an acute pancreatitis, the differential diagnosis of a cystic-appearing neoplasm should be considered. On the other hand, tumors can also cause acute pancreatitis.

If in doubt, a fine needle aspiration of the cystic fluid with analysis of glucose, carcinoembryonic antigen, and amylases and biopsy of the wall could be arranged first. Most importantly, operators should be aware of the differential diagnosis of cystic tumors. Neuroendocrine tumors, gastrointestinal stromal tumors, and mucinous cystadenoma can present like a peripancreatic fluid collection, but rarely also other tumors with large necrosis or hemorrhage can mimic cystic appearance, for example, sarcoma [Figure 6].

AIR EMBOLISM

Air embolism occurs when direct contact between a source of gas and the blood vasculature is given and a pressure gradient favors the flow of gas into the arterial or venous blood stream.

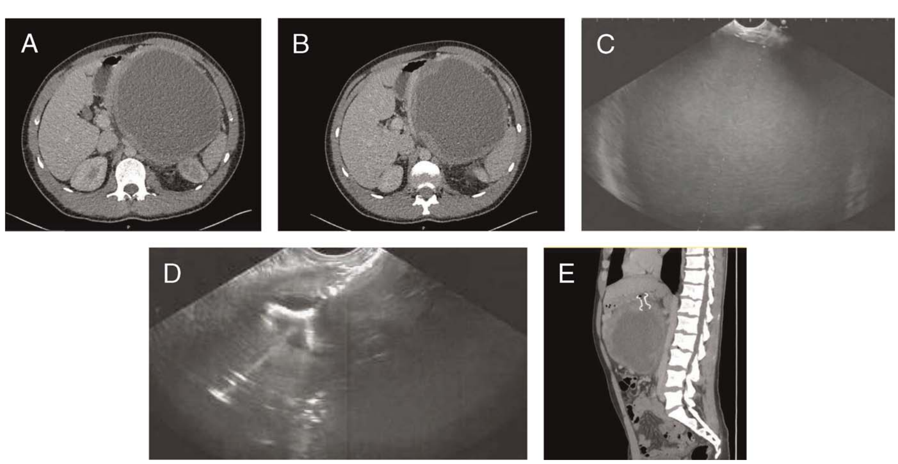

Figure 6. EUS–guided stent insertion in assumed peripancreatic fluid collection in a young man who was referred for EUS-cystgastrostomy of "walled-off necrosis after necrotizing pancreatitis" but was finally diagnosed with Ewing sarcoma after EUS-FNB of the thick wall. A and B, Huge peripancreatic fluid collection but with some wall irregularities in panel B. Corresponding EUS image of the collection (C) and stent deployment into thick-walled collection (D), which revealed old blood as content. E, After partial drainage, the irregular thickened wall becomes more apparent. The LAMS is visible in correct position but blocked by a blood clot. EUS–FNB of the wall confirmed Ewing sarcoma. FNB: fine needle biopsy; LAMS: lumen-apposing metal stents.

Table 1

Incidence of complications from LAMS insertion from recent studies

Complications	Incidence, %	Literature
Immediate		
Bleeding	0.9–6.2	22,23,30,40,47–50
Maldeployment	2.2–3.4	23,40
Perforation	0.5–3.8	22,30,48,50
Delayed		
Bleeding	1.9–3.0	23,40
Migration	0.9–7.8	22,23,30,40,47–50
Buried stent	1.0–4.7	23,40
Occlusion	0.7–12.7	23,30,48–50
Infection	1.9–9.2	22,40,47–49
Death	0.5–1.1	40,47,48

LAMS: lumen-apposing metal stents.

Air embolism during EUS-guided intervention in the retroperitoneum is rare (<1%) but can become fatal. It occurs mainly during endoscopic necrosectomy where gas might get in contact with the blood stream. The duration of the procedure and the use of air instead of carbon dioxide increase the risk of air embolism. The inflammatory process in tissues around vascular structures as commonly seen in pancreatitis enables the penetration of gas and direct contact with the blood stream.

A high suspicion and the knowledge of clinical symptoms caused by air embolism (cardiovascular, respiratory, and neurological symptoms) are paramount to directly initiate the potentially lifesaving management in the endoscopy room (stop the procedure, Trendelenburg position, high-flow 100% oxygen, high-volume saline infusion, and resuscitation).

Using carbon dioxide instead of air for insufflation reduces the risk of air embolism substantially because it is rapidly absorbed.[46]

CONCLUSIONS

Although EUS-guided deployment of LAMS might seem simple and intuitive, the knowledge of adverse events potentially occurring during this procedure (summarized in Table 1) is an integral part of the competencies of therapeutic endosonographers. EUS–endoscopists should be proficient in handling both standard endoscopic complications (such as bleedings and perforations) and specific complications coming from these peculiar procedures. Reading literature describing these events and how they might be prevented and rescued should be encouraged for those approaching this topic. The knowledge of potential adverse events and the understanding of what causes them will help to avoid and reduce their occurrence.

Conflicts of Interests

Christoph F. Dietrich is a Co-Editor-in-Chief of the journal; Paolo Giorgio Arcidiacono is an associate Editor; and Michael Hocke, Anthony Teoh, and Alberto Larghi are Editorial Board Members. This article was subject to the journal's standard procedures, with peer review handled independently of the editors and their research groups.

Funding

None.

Authorship

All authors have contributed to this review, and the final version has been read and approved by all.

References

1. van der Merwe SW, van Wanrooij RLJ, Bronswijk M, et al. Therapeutic endoscopic ultrasound: European Society of Gastrointestinal Endoscopy (ESGE) guideline. *Endoscopy* 2022;54:185–205.
2. Bang JY, Arnoletti JP, Holt BA, et al. An endoscopic transluminal approach, compared with minimally invasive surgery, reduces complications and costs for patients with necrotizing pancreatitis. *Gastroenterology* 2019;156:1027–1040 e3.
3. Bakker OJ, van Santvoort HC, van Brunschot S, et al. Endoscopic transgastric vs surgical necrosectomy for infected necrotizing pancreatitis: a randomized trial. *JAMA* 2012;307:1053–1061.
4. 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;391:51–58.
5. Ge PS, Young JY, Jirapinyo P, et al. Comparative study evaluating lumen apposing metal stents versus double pigtail plastic stents for treatment of walled-off necrosis. *Pancreas* 2020;49:236–241.
6. Itoi T, Binmoeller KF, Shah J, et al. Clinical evaluation of a novel lumen-apposing metal stent for endosonography-guided pancreatic pseudocyst and gallbladder drainage (with videos). *Gastrointest Endosc* 2012;75:870–876.
7. Fujimori N, Minoda Y, Murakami M, et al. Endoscopic removal of a lumen-apposing metal stent that migrated into the walled-off necrosis during the first drainage procedure. *Endoscopy* 2020;52:E51–E52.
8. Mukai S, Itoi T, Tsuchiya T, et al. Experimental study of a physician-controlled electrocautery-enhanced delivery system incorporating a newly developed lumen-apposing metal stent for interventional endoscopic ultrasound (with videos). *J Hepatobiliary Pancreat Sci* 2022;29:817–824.
9. Ishii T, Hayashi T, Katanuma A. Do not touch the locking system of Hot Axios during handling of the stent deployment hub. *Dig Endosc* 2020;32:e71–e72.
10. Okuno M, Mukai T, Ichikawa H, et al. Endoscopic replacement technique for migrated lumen-apposing metal stent during endoscopic pancreatic necrosectomy. *VideoGIE* 2019;4:220–222.
11. Kumta NA, Doshi R, Reinoso PJ Jr., et al. Retrieval and reuse of a dislodged lumen-apposing metal stent during endoscopic necrosectomy for pancreatic necrosis. *Gastrointest Endosc* 2016;84:364.
12. Siddiqui A, Naveed M, Basha J, et al. International, multicenter retrospective trial comparing the efficacy and safety of bi-flanged versus lumen-apposing metal stents for endoscopic drainage of walled-off pancreatic necrosis. *Ann Gastroenterol* 2021;34:273–281.
13. Aburajab M, Smith Z, Khan A, et al. Safety and efficacy of lumen-apposing metal stents with and without simultaneous double-pigtail plastic stents for draining pancreatic pseudocyst. *Gastrointest Endosc* 2018;87:1248–1255.
14. Puga M, Consiglieri CF, Busquets J, et al. Safety of lumen-apposing stent with or without coaxial plastic stent for endoscopic ultrasound-guided drainage of pancreatic fluid collections: a retrospective study. *Endoscopy* 2018;50:1022–1026.
15. Shamah SP, Sahakian AB, Chapman CG, et al. Double pigtail stent placement as an adjunct to lumen-apposing metal stentsfor drainage of pancreatic fluid collections may not affect outcomes: a multicenter experience. *Endosc Ultrasound* 2022;11:53–58.
16. Garcia-Sumalla A, Loras C, Sanchiz V, et al. Multicenter study of lumen-apposing metal stents with or without pigtail in endoscopic ultrasound-guided biliary drainage for malignant obstruction-BAMPI TRIAL: an open-label, randomized controlled trial protocol. *Trials* 2022;23:181.
17. Vanek P, Falt P, Vitek P, et al. Endoscopic ultrasound-guided transluminal drainage using lumen-apposing metal stent with or without coaxial plastic stent for treatment of walled-off necrotizing pancreatitis: a prospective bicentric randomized controlled trial. *Gastrointest Endosc* 2023;S0016–5107(23):00012–00013. doi:10.1016/j.gie.2022.12.026.
18. Minaga K, Takenaka M, Omoto S, et al. A case of successful transluminal drainage of walled-off necrosis under contrast-enhanced harmonic endoscopic ultrasonography guidance. *J Med Ultrason (2001)* 2018;45:161–165.
19. Mukai S, Itoi T, Tsuchiya T, et al. New deployment techniques of the lumen-apposing metal stent in walled-off necrosis filled with necrotic tissue: chick opening its mouth (with video). *Dig Endosc* 2021;33:985–989.
20. Bazaga Pérez de Rozas S, Carbajo AY, Garcia-Alonso FJ, et al. A retrospective, multicenter analysis of incidents associated with Axios™ lumen-apposing stents. *Rev Esp Enferm Dig* 2019;111:419–424.

21. Seo SY, Lee CH, Kim IH, et al. An unusual complication of pyloric ring obstruction caused by flange of lumen apposing metal stent in endoscopic ultrasound-guided gallbladder drainage: a case report. *Medicine (Baltimore)* 2020;99:e21017.
22. Mohan BP, Jayaraj M, Asokkumar R, et al. Lumen apposing metal stents in drainage of pancreatic walled-off necrosis, are they any better than plastic stents? A systematic review and meta-analysis of studies published since the revised Atlanta classification of pancreatic fluid collections. *Endosc Ultrasound* 2019;8:82–90.
23. Nayar M, Leeds JS, UK & Ireland LAMS Colloborative et al. Lumen-apposing metal stents for drainage of pancreatic fluid collections: does timing of removal matter? Gut 2022; 71: 850–853.
24. Veitch AM, Radaelli F, Alikhan R, et al. Endoscopy in patients on antiplatelet or anticoagulant therapy: British Society of Gastroenterology (BSG) and European Society of Gastrointestinal Endoscopy (ESGE) guideline update. *Gut* 2021;70:1611–1628.
25. Saftoiu A, Ciobanu L, Seicean A, et al. Arterial bleeding during EUS-guided pseudocyst drainage stopped by placement of a covered self-expandable metal stent. *BMC Gastroenterol* 2013;13:93.
26. Tarantino I, Barresi L, Granata A, et al. Hemospray for arterial hemorrhage following endoscopic ultrasound-guided pseudocyst drainage. *Endoscopy* 2014;46(Suppl 1 UCTN):E71.
27. Wang BH, Xie LT, Zhao QY, et al. Balloon dilator controls massive bleeding during endoscopic ultrasound-guided drainage for pancreatic pseudocyst: a case report and review of literature. *World J Clin Cases* 2018;6:459–465.
28. 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;87:150–157.
29. 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;68:1200–1209.
30. Bazerbachi F, Sawas T, Vargas EJ, et al. Metal stents versus plastic stents for the management of pancreatic walled-off necrosis: a systematic review and meta-analysis. *Gastrointest Endosc* 2018;87:30–42.e15.
31. Bang JY, Hasan MK, Navaneethan U, et al. Lumen-apposing metal stents for drainage of pancreatic fluid collections: when and for whom? *Dig Endosc* 2017;29:83–90.
32. Muniraj T, Jamidar PA, Nealon WH, et al. Endoscopic management of pancreatic fluid collections. *J Clin Gastroenterol* 2017;51:19–33.
33. van Brunschot S, Fockens P, Bakker OJ, et al. Endoscopic transluminal necrosectomy in necrotising pancreatitis: Aa systematic review. *Surg Endosc* 2014;28:1425–1438.
34. Jagielski M, Piatkowski J, Jackowski M. Early endoscopic treatment of symptomatic pancreatic necrotic collections. *Sci Rep* 2022;12:308.
35. Teoh AYB, Dhir V, Kida M, et al. Consensus guidelines on the optimal management in interventional EUS procedures: results from the Asian EUS group RAND/UCLA expert panel. *Gut* 2018;67:1209–1228.
36. ASGE Standards of Practice Committee, Muthusamy VR, Chandrasekhara V. The role of endoscopy in the diagnosis and treatment of inflammatory pancreatic fluid collections. *Gastrointest Endosc* 2016;83:481–488.
37. Mukai S, Itoi T, Sofuni A, et al. Expanding endoscopic interventions for pancreatic pseudocyst and walled-off necrosis. *J Gastroenterol* 2015; 50:211–220.
38. Biedermann J, Zeissig S, Bruckner S, et al. EUS-guided stent removal in buried lumen-apposing metal stent syndrome: a case series. *VideoGIE* 2020;5:37–40.
39. Bang JY, Hawes RH, Varadarajulu S. Lumen-apposing metal stent placement for drainage of pancreatic fluid collections: predictors of adverse events. *Gut* 2020;69:1379–1381.
40. Khan S, Chandran S, Chin J, et al. Drainage of pancreatic fluid collections using a lumen-apposing metal stent with an electrocautery-enhanced delivery system. *J Gastroenterol Hepatol* 2021;36:3395–3401.
41. Miwa H, Sugimori K, Tsuchiya H, et al. Safe removal of lumen-apposing metal stent using argon plasma coagulation after EUS-guided cyst gastrostomy (with video). *Endosc Ultrasound* 2021;10:309–310.
42. Seerden TC, Vleggaar FP. Endoscopic removal of buried lumen-apposing metal stents used for cystogastrostomy and cholecystogastrostomy. *Endoscopy* 2016;48(Suppl 1):E179.
43. Irani S, Kozarek RA. The buried lumen-apposing metal stent: is this a stent problem, a location problem, or both? *VideoGIE* 2016;1:25–26.
44. Simons-Linares CR, Chittajallu V, Chahal P. Stent gone rogue: endoscopic removal of a 3-year-old embedded cystogastrostomy stent. *VideoGIE* 2020;5:548–551.
45. Bang JY, Varadarajulu S. Stent tracker app: novel method to track patients with indwelling lumen-apposing metal stents. *Endosc Ultrasound* 2018; 7:69–70.
46. Wang WL, Wu ZH, Sun Q, et al. Meta-analysis: the use of carbon dioxide insufflation vs. Room air insufflation for gastrointestinal endoscopy. *Aliment Pharmacol Ther* 2012;35:1145–1154.
47. Guzman-Calderon E, Chacaltana A, Diaz R, et al. Head-to-head comparison between endoscopic ultrasound guided lumen apposing metal stent and plastic stents for the treatment of pancreatic fluid collections: a systematic review and meta-analysis. *J Hepatobiliary Pancreat Sci* 2022;29:198–211.
48. Amato A, Tarantino I, Facciorusso A, et al. Real-life multicentre study of lumen-apposing metal stent for EUS-guided drainage of pancreatic fluid collections. *Gut* 2022;71:1050–1052.
49. Li J, Zhang Q, Zhou A, et al. Comparative outcomes of endoscopic ultrasound-guided lumen-apposing mental stents drainage for pancreatic pseudocysts and walled-off necrosis: case series and meta-analysis. *Chronic Dis Transl Med* 2021;7:157–168.
50. Chandrasekhara V, Barthet M, Deviere J, et al. Safety and efficacy of lumen-apposing metal stents versus plastic stents to treat walled-off pancreatic necrosis: systematic review and meta-analysis. *Endosc Int Open* 2020;8: E1639–E1653.