Complications of endoscopic ultrasound-guided transmural drainage of pancreatic fluid collections and their management

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Abstract	The development of endoscopic ultrasound (EUS)-guided drainage techniques and lumen-apposing metal stents (LAMS) has markedly reduced the complication rate of endoscopic transmural drainage of pancreatic collections and made these procedures safer and more effective. Despite its improved safety profile, various types of complications, some even life-threatening, can occur after EUS-guided drainage of pancreatic fluid collections. Stent maldeployment/migration, bleeding, gastrointestinal perforation, and air embolism are important complications of EUS-guided drainage of pancreatic collections. Delayed complications weeks after the procedure, such as bleeding and buried LAMS due to the presence of prolonged indwelling transmural stents, have also been described. Careful patient selection, with proper assessment of the size, solid necrotic content and location of the collection, as well as an in-depth understanding of various risk factors that predict complications, are important for a safer and more effective endoscopic transmural drainage. For a better clinical outcome, it is important for the endoscopist to know about various complications of EUS-guided drainage of pancreatic collections, as well as their appropriate management strategies.

Keywords Endosonography, bleeding, pseudoaneurysm, perforation, embolism, stents

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Introduction

Acute pancreatitis (AP), especially acute necrotizing pancreatitis, is a potentially life threatening condition associated with high morbidity and mortality [1]. It is associated with the release of various pro-inflammatory mediators, such as zymogens, cytokines, and vasoactive substances that cause systemic inflammation, endothelial dysfunction, increased vascular permeability, and development of organ failure. Although the majority of patients develop mild episodes of AP (80%), 10-20% develop moderate or severe episodes of AP associated with various local and systemic complications [1]. Peripancreatic fluid collection is one of the important local complications of AP and infected collections are associated with high morbidity and mortality [1].

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According to the revised Atlanta Classification, AP is divided into 2 morphological types: acute interstitial pancreatitis (AIP) and acute necrotizing pancreatitis (ANP). AIP is associated with the formation of acute peripancreatic fluid collection (APFC) in the early course of the disease and most of these APFC cases resolve spontaneously. However, in a few patients the APFC may become encapsulated, forming an acute pseudocyst [2]. Likewise, in patients with ANP, collections developing in the early phase of the disease are termed acute necrotic collections (ANC). In contrast to APFC, a predominantly liquid collection, the ANC comprises both liquid and solid necrotic content. Over a period of time, the ANC becomes encapsulated to form a walled-off collection containing both solid and liquid necrotic debris: a walled-off necrosis (WON) [1,3,4]. Understanding this concept of "wall" is of the utmost importance from the endoscopist's perspective, as it allows the endoscopist to perform various transmural drainage procedure within a confined "walled cavity".

Advances in endoscopic technology and its accessories, especially the development of endoscopic ultrasound (EUS), have led to a phenomenal increase in the use of minimally invasive endoscopic techniques for the management of local complications of AP. The management algorithm for symptomatic pancreatic fluid collections has evolved from primarily invasive open surgical necrosectomy to a minimally invasive and now endoscopic step-up approach [5-7]. Recent studies have shown that the endoscopic step-up approach is associated with a technical success rate of up to 97-99% and clinical success rates up to 95% [6,8].

Endoscopic transmural drainage was initially carried out under endoscopic guidance, with a relatively "blind" puncture of the submucosal bulge caused by the large pancreatic fluid collection. This blind approach was associated with an increased risk of complications, especially perforation and bleeding. Furthermore, only large bulging pancreatic collections could be treated by the endoscopic approach. The development of EUS has led to these procedures being performed under imaging guidance, thereby making them more effective as well as safer. EUS-guided drainage is associated with a higher technical success rate, especially in a non-bulging collection, and a lower risk of complications, especially perforation and bleeding, because of ability to visualize the collection and collaterals [9,10]. Therefore, EUS-guided transmural drainage of pancreatic collections is currently considered as the standard-of-care treatment for such patients [11]. In addition, the development of lumen-apposing metal stents (LAMS), such as the Axios stent (Boston Scientific, Natick, MA, USA) and Niti-S Spaxus stent (Taewoong Medical, Gyeonggi-do, South Korea), has made the endoscopic drainage of pancreatic collections easier, quicker, and safer [12,13].

As a result of these phenomenal advances, the use and practice of EUS-guided transmural drainage has become widespread. At the same time, it has also become important to know about its complications, as well as their appropriate management strategies. This review discusses the currently available literature on the complications of EUS-guided transmural drainage of pancreatic fluid collections and their management.

Materials and methods

We searched the PubMed electronic database for studies published in the English language from inception till 2019, using the keywords "plastic stent" or "lumen-apposing metallic stents" or "LAMS" and "pancreatic collection". All original research articles were reviewed in detail, with more emphasis on articles with a number of patients greater than 50. Every article was searched for data on the incidence of complications, their various types, their presentation, and the management of such complications. In addition, a manual search was performed to identify other potential articles, including case reports or videos, which explored various complications of EUS-guided transmural drainage of pancreatic collections and techniques for their management.

Complications of EUS-guided transmural drainage of pancreatic collections

Although many studies have demonstrated the effectiveness of endoscopic transmural drainage of pancreatic collections, there is a scarcity of data on its complications. Developments in EUS-guided drainage techniques and LAMS have markedly reduced the complication rate of transmural drainage and made

these procedures safer and effective. Despite its improved safety profile, studies have shown that various types of complication can occur during or immediately after the procedure. Delayed complications weeks after the procedure have also been described and are due to the presence of indwelling transmural stents. Studies report varying complication rates of 5-35%, with bleeding and perforation being the most common and significant complications [6,8,14-18]. The type of fluid collection and the procedural technique usually determine the frequency of complications of EUS-guided drainage [19]. Infected fluid collections have been reported to be associated with a higher frequency of complications [20]. For ease of understanding, these complications can be divided into 2 types: complications occurring during or immediately after the procedure and delayed complications (Table 1).

Immediate or early complications

Technical difficulties

The technical success rate of EUS-guided transmural drainage of pancreatic fluid collections has been reported to range between 90 and 100% in different studies [6,8,14,21]. The presence of pancreatic fluid collection at difficult locations, such as the uncinate process, perisplenic or near the esophagogastric junction, or a distance >1 cm between the collection and the gastro-duodenal wall (Fig. 1A), are the main causes of technical difficulty during EUS-guided transmural drainage. The presence of splenic vein thrombosis with extensive collateral formation and failure to find a safe non-vascular window for needle puncture (Fig. 1B), stent deployment system malfunction, incomplete distal flange expansion of the LAMS, or a sudden gush of fluid obscuring endoscopic vision, are also documented causes for technical

Table 1 Classification of complications of endoscopic ultrasound-guided transmural drainage of pancreatic collections

During or immediately after procedure
Technical failure
Improper deployment
Bleeding
Perforation
Air embolism
Mistaking gallbladder for a fluid collection
Shearing of the guide wire by needle

Delayed complications
Bleeding
Buried stent
Compression of bile duct
Development of changes of chronic pancreatitis

failure of the procedure [6,8,14,21,22]. However, many of the above-mentioned causes can be predicted before the procedure; hence, careful selection of the patient for transmural drainage is of utmost importance.

Maldeployment/migration of stent

Maldeployment of plastic or metallic stents is one of the most common complications (incidence: 2-8%) of EUS-guided transmural drainage of pancreatic collections [21,23-25]. The maldeployment can be either external, into the gastroduodenal lumen, or internal into the collection (Fig. 2). Internal maldeployment of a plastic stent usually occurs when the stent visualization is obscured during the stent deployment. Usually, the site of puncture is in the esophagus or gastric cardia, where endoscopic visualization can be difficult at the time of final stent deployment [19]. This complication can be prevented by
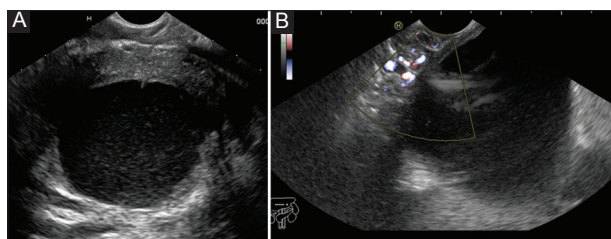

Figure 1 (A) Endoscopic ultrasound. Patient with chronic pseudocyst having the collection located more than 1 cm from the gastric wall. (B) Endoscopic ultrasound. Patient with chronic pseudocyst and splenic vein thrombosis having extensive collaterals leading to failure to find a safe non-vascular window for needle puncture
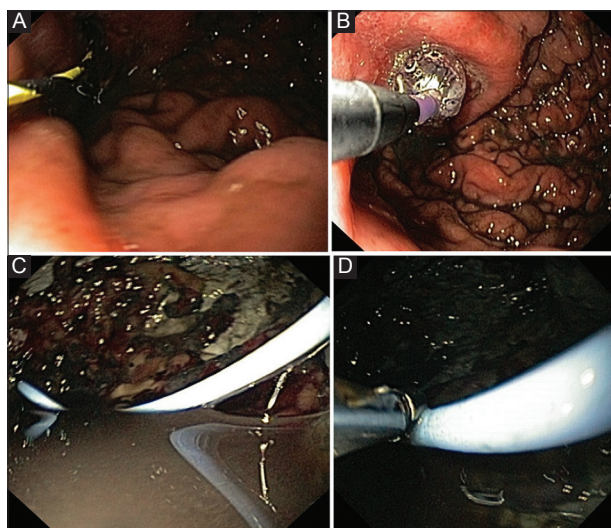

Figure 2 (A) Internal maldeployment of double pigtail plastic stent into collection. The transmural puncture site id cannulated with a guidewire using a gastroscope. (B) The transmural tract dilated with a 15 mm balloon. (C) The gastroscope inserted into the cavity. An inward migrated plastic stent is observed in the cavity, with surrounding residual fluid. (D) The stent grasped with grasping forceps and removed

gradual withdrawal and torquing of the echoendoscope during stent deployment.

Dedicated biflanged self-expanding metal stents (SEMS) also have a higher rate of maldeployment because of their shorter length. However, newer LAMS, such as the Axios stent, have a lower rate of maldeployment because of the controlled automated release of the stent. Recently, one study has shown that performing direct endoscopic necrosectomy at the time of LAMS insertion is associated with a greater chance of stent dislodgement compared to performing endoscopic necrosectomy after 1 week [25]. Maldeployment of a stent in the stomach or duodenum is easy to manage with retrieval of the stent. However, management of a maldeployed stent in the cavity is a real challenge to every endoscopist. Management of such a maldeployed stent depends upon whether the "axis" in the cystic cavity is maintained or not and whether it is associated with cyst wall perforation or not. In the absence of an "axis" in the cystic cavity and/or in the presence of an associated rupture of the cyst wall, surgery is usually required. However, if the "wire access" in the cystic cavity is maintained and the patient is stable, then endoscopic retrieval of a maldeployed stent may be attempted. The procedure usually involves balloon dilatation of the tract, followed by insertion of the endoscope into the cavity. The use of CO_2 is of the utmost importance to reduce the chances of air embolism. The proximal flange of the stent can be grasped with rat-tooth forceps and an attempt can be made to reposition the metallic stent. If only the distal flange is available for grasping, stent retrieval can be tried after inversion of the stent [26-28].

Bleeding

Bleeding is one of the most common complications of transmural drainage of pancreatic collections. Although the use of EUS is associated with better visualization of collaterals and blood vessels, its use does not completely obviate the risk of bleeding during the procedure. Bleeding can occur either at the time of the procedure or later, as a result of the development of a pseudoaneurysm. Bleeding can also occur at the time of stent removal, especially of LAMS, because of tissue overgrowth around the distal flange of the stent.

The bleeding during the procedure can occur at the site of puncture, during dilatation of the tract, or from within the cavity [19,29]. Bleeding from the point of entry can arise from small missed venous collaterals or a pseudoaneurysm within the wall of the collection that may bleed after rapid decompression of the collection (Fig. 3A) [19]. Likewise, pseudoaneurysm in the collection cavity or a blood vessel with weakened wall coursing through a collection may bleed after rapid decompression of the collection (Fig. 3B). The use of a needle knife, with or without a guidewire, is also believed to increase the risk of bleeding. Reports of the risk of bleeding vary, ranging from 1-10% in different studies [6,8,14,21].

Various checks and techniques have been suggested to decrease the risk of bleeding during EUS-guided transmural drainage. The coagulation parameters should be carefully

checked, especially in high-risk patients. Moreover, the needle knife should not be used to dilate the tract after needle puncture. An over-the-wire electrosurgical device or graded mechanical dilation should be used to enlarge the transmural tract [19]. Careful EUS examination should be performed, in particular to evaluate the entry point in detail with color Doppler. It is always advisable to relax the up–down wheel of the echoendoscope so that the transducer is not pressed against the gastro-duodenal wall. This maneuver will help in the detection of small blood vessels that otherwise would have been compressed by the pressure of the transducer.

Minor bleeding following transmural drainage is usually controlled spontaneously (Fig. 4), or may be managed using coagulation, epinephrine injection or clips [30]. Minor bleeding can also be controlled with balloon tamponade [31]. However, in the presence of a significant massive bleed or suspected arterial bleed, digital subtraction angiography followed by coil embolization of any pseudoaneurysm or abnormal bleeding vessel should be performed (Fig. 5) [32]. If bleeding is detected during the procedure and guidewire access is available, placement of a fully covered SEMS can control bleeding from the entry point by virtue of its tamponade effect [33]. An added advantage of placing a SEMS is the access to the cavity, through which subsequent necrosectomy can be performed, if required [32-35]. Endoscopic application of hemospray has also been reported as a successful method of hemostasis for bleeding following endoscopic cystogastrostomy [36]. Surgical exploration and ligation of the culprit vessel or packing of the necrotic cavity are the rescue options in case of massive life-threatening bleeding that cannot be controlled with above mentioned treatment modalities. Van Brunschot *et al* reported a systemic review of 14 studies including 455 patients who had undergone endoscopic necrosectomy [37]. They found that bleeding was the most common complication during endoscopic necrosectomy and the incidence was higher than for endoscopic transmural drainage alone. In addition, 93% patients with bleed improved with either epinephrine injection or coagulation or use of clips, while only 7% of patients required the use of angiography and embolization of the pseudoaneurysm [37].

Perforation

Perforation during EUS-guided drainage of pancreatic collections is also an important and dreaded complication (Fig. 6). Studies have reported its incidence varying from 0-4% [14,23,38]. Although perforation is usually caused by the separation of stomach and cyst wall during the procedure, cyst wall perforation may also occur from manipulation of the guidewire, especially during stent exchange. An increased distance between the two walls and transgastric drainage of a collection in a difficult location, such as the uncinate process of the pancreas, are associated with a higher risk of perforation [14]. Because of the increased distance between the uncinate process collection and the gastric wall, its transgastric drainage is associated with an increased risk
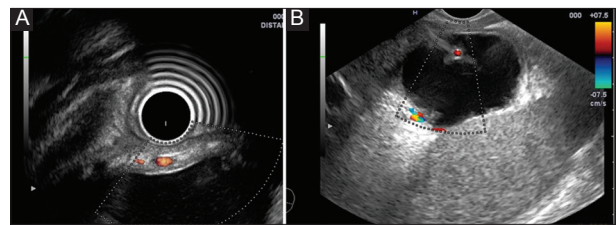
Figure 3 Endoscopic ultrasound. (A) Abnormal vessel in the wall of the pancreatic fluid collection. (B) Abnormal blood vessel running through the pseudocyst cavity
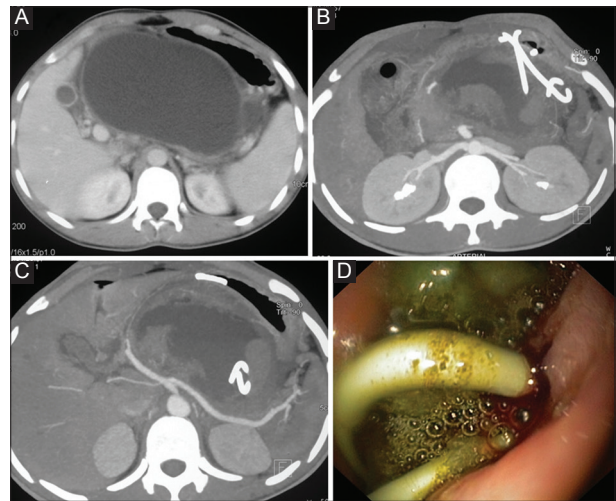

Figure 4 (A) Computed tomography (CT) of the abdomen: large walled-off necrosis. (B) Patient had gastrointestinal bleeding 48 h after endoscopic ultrasound-guided transmural drainage. CT shows residual cavity with hyperdense contents suggestive of blood. Transmural stents are seen *in situ*. (C) CT angiography: no pseudoaneurysm. (D) Endoscopy: minimal ooze of blood is seen around the stents. Bleeding stopped spontaneously after 24 h
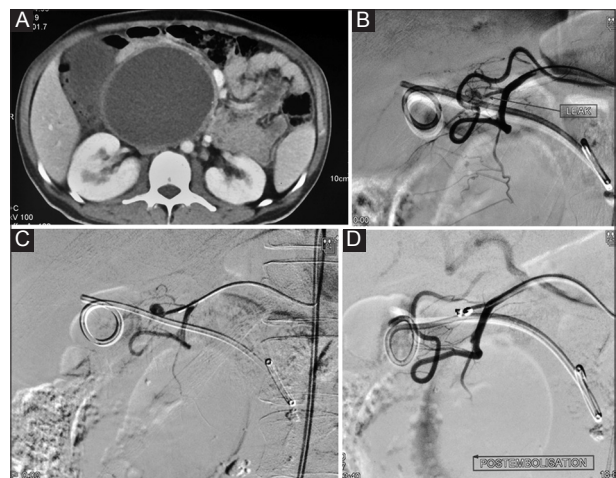

Figure 5 (A) Computed tomography: large walled-off necrosis. (B) Patient develops massive gastrointestinal bleed immediately after the procedure. Digital subtraction angiography (DSA) shows bleeding from the gastroduodenal artery around the plastic transmural stent (arrow). (C) DSA: selective cannulation of the bleeding vessel. (D) SA: successful coil embolization
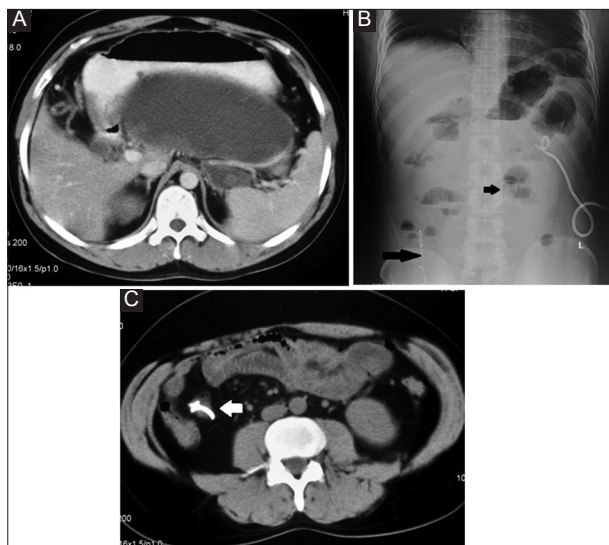
Figure 6 (A) Computed tomography (CT) of the abdomen: large walled-off necrosis. (B) Patient had increased abdominal pain 48 h after endoscopic transmural drainage with multiple plastic stents. It was accompanied by abdominal distension. Abdominal X-ray reveals air under right dome of diaphragm along with multiple air fluid levels. Both the transmural stents have migrated externally into the small bowel (arrows). Patient was managed with percutaneous drainage of walled-off necrosis and conservative management of small bowel obstruction. (C) CT: one of the migrated plastic stent is causing small-bowel obstruction (arrows)

of perforation. Other causes of perforation include the use of a non-coaxial needle knife to dilate the needle tract or a very large caliber balloon used for the initial dilation of the transmural tract.

Moreover, as most patients experience preprocedural pain due to the presence of the collection, postprocedural pain is usually neglected and the perforations can be missed. However, in cases with severe pain or a difficult procedure, an X-ray or computed tomography (CT) scan should be performed for the early diagnosis and appropriate treatment of perforation. The presence or absence of signs of peritonitis, the patient's general condition, whether the cyst has been completely emptied of its contents, and the last position of the deployed stent determine the management approach to iatrogenic perforation. If perforation is detected during the procedure, it may be possible to use a LAMS to close the defect by bridging the walls [39]. If the deployed stent lies in the retroperitoneum, or there is generalized contamination of the peritoneum with cyst fluid content and subsequent development of signs of peritonitis, immediate surgery should be performed: cysto-enterostomy with closure of the wall defect is usually associated with a good outcome. However, in the absence of any signs of peritonitis and provided the patient is in a stable condition, conservative treatment with hospitalization, nil per oral, intravenous antibiotics and intravenous hydration is associated with better outcomes in approx. 50% of patients with perforation [6,14,30,37].

Air embolism

Air embolism, though rare (incidence: <1%), is one of the fatal complications of this procedure. The risk of air embolism increases when there is a direct contact between a source of gas and the bloodstream, such as during direct endoscopic necrosectomy. A long-duration procedure or the use of air are the risk factors for air embolism during endoscopic necrosectomy [30]. The use of CO_2 is associated with a reduced risk of embolism; however, it does not completely alleviate the risk [40,41].

Delayed complications

Bleeding is also an important delayed complication of EUS-guided transmural drainage of pancreatic collections. This delayed bleeding is usually due to the formation of a pseudoaneurysm caused by an indwelling transmural stent. Bang *et al* prospectively enrolled 60 patients with a WON and randomized them to receive either LAMS or plastic stent. In the LAMS group, 3 patients had severe gastrointestinal bleeding requiring admission to the Intensive Care Unit and blood transfusion. All 3 patients had a pseudoaneurysm on CT angiography and required coil embolization. The bleeding in all these patients occurred 3 or more weeks after LAMS placement. Thereafter, the authors changed the management protocol at their center to regularly perform a CT scan at week 3 and removed the LAMS if the WON had resolved. Subsequent to this change in management protocol, no further incident of major bleed was seen. The authors hypothesized that, because of the wider diameter of the LAMS, the WON resolves rapidly and, once the necrotic cavity collapses, the stent, because of its lumen-apposing nature, gets embedded into the wall of the cavity or causes compression of surrounding structures, including the bile duct or vessels, leading to obstructive jaundice or pseudoaneurysm, respectively. The authors recommended that a CT scan should be obtained at 3 weeks post procedure and the LAMS should be removed if the WON has resolved to reduce stent-related complications [42,43]. Brimhall *et al* conducted a retrospective analysis of 249 patients with pancreatic pseudocyst or WON treated with endoscopic transmural drainage (97 with LAMS and 152 with plastic stents). Of the 249 patients, 5 had an angiographically proven pseudoaneurysm-related and 3 had a presumed pseudoaneurysm-related bleed—all of them in the LAMS group. Moreover, the frequency of bleed was significantly higher in the LAMS group compared to the plastic stent group. The authors also recommended LAMS removal within 4 weeks of deployment, especially if imaging shows resolution of the cavity [22].

Other delayed complications

Apart from bleeding, a buried stent is also an important complication of metallic stents, especially of LAMS that have

Table 2 Complications of endoscopic ultrasound-guided transmural drainage of pancreatic collections in selected studies*

Study	n	PFC type	Stent used	Technical Success (%)	Mal-deployment (%)	Bleeding (%)	Perforation (%)	Air embolism (%)	'Buried stent' (%)	Stent migration (%)	Stent blockade (%)	Infection (%)
Varadarajulu et al [14] 2011	148	48.6%-Pseudocyst 51.4%-Abscess or necrosis	DPPS	100	0	0.67 Early	1.3	0	0	0.67 Early, Spontaneous	0	2.7
Ng et al [21] 2013	55	Pseudocyst	DPPS	93	3.6	1.8 Early	1.8	0	0	5 Spontaneous	5	5
Chandran et al [49] 2015	54	72.2%-Pseudocyst 27.8%-WON	BFMS	98.1	0	5.6-Total 1.9- Early 3.7-Late	0	0	5.6	20.3-Total 7.4-During DEN 12.9- Spontaneous	5.6	7.4
Walter et al [23] 2015	61	25%-Pseudocyst 75%-WON	LAMS (AXIOS)	98	1.6	6.6 Early	1.6	0	0	9.8-Total 4.9-during DEN 4.9- Spontaneous	4.9	6.6
Rinninella et al [53] 2015	93	19.4%-Pseudocyst 55.9%-WON 4.3%-APFC 20.4%-Pancreatic abscess	LAMS (Hot AXIOS)	98.9	0	1.0 Early	2.1	0	0	1.0 During DEN	0	1.0
Vazquez-Sequeiros et al [24] 2016	211	53%-Pseudocyst 47%-WON	LAMS (AXIOS) or straight biliary stents	97	1.4	7	3	0	0	0	0	11
Siddiqui et al [54] 2016	82	17%-Pseudocyst 83%-WON	LAMS (AXIOS)	97.5	2.5	7.3	0	0	0	0	0	7.1
Sharaiha et al [48] 2016	124	WON	LAMS	100	0	1.6	0	0	0	5.6-Total 2.4-during DEN 3.2-Sponateous	5.6	5.6
Bang et al [13] 2017	60	35%-Pseudocyst 65%-WON	67%-DPPS 33%-LAMS	100	0	0	0	0	0	2.5-DPPS 10-LAMS	0	12.5-DPPS 10-LAMS
Bapaye et al [29] 2017	133	WON	46%-DPPS 54%-BFMS	100	0	8.2-DPPS All bleeding during track dilatation 2.7-BFMS All delayed bleeding due to splenic artery pseudoaneurysm	0	0	0	3.2-DPPS 2.7-BFMS	0	0
Lakhtakia et al [6] 2017	205	WON	BFMS	99	0	2.9 All Early	1.0	0	4.4	2.4 All during DEN	10.2	0
Rana et al [8] 2017	86	WON	DPPS	98.8	0	1.1	1.1	0	0	0	0	0

(Contd...)

Table 2 *(Continued)*

Study	n	PFC type	Stent used	Technical Success (%)	Mal-deployment (%)	Bleeding (%)	Perforation (%)	Air embolism (%)	'Buried stent' (%)	Stent migration (%)	Stent blockade (%)	Infection (%)
Venkatachalapathy et al [17] 2018	116	40%-Pseudocyst 60%-WON	LAMS	99	1	0.86	0	0	0.86	0.86	0.86	6.0
Petrone et al [55] 2018	67	65.6%-Pseudocyst 34.4%-WON	BFMS	98.5	1.5-LAMS	7.5-Total 4.5-Early 3.0-Delayed	1.5	0	0	7.5	3.0	1.5
Lang et al [12] 2018	103	77.7%-Pseudocyst 22.3%-WON	81.5%-DPPS 18.5%-LAMS	99	0	5-Total 1-DPPS 4-LAMS 2-Early; 3-Delayed	1-DPPS group	0	0	0	0	0
Fasullo et al [56] 2018	54	-	77.7%-DPPS 22.3%-LAMS	100	0	3.6-Total 1.8-DPPS 1.8-LAMS All early	0	0	0	11 All in DPPS group	0	0
Dayyeh et al [35] 2018	94	WON	38.3%-DPPS 61.7%-LAMS (AXIOS)	100	0	6.3-Total 5.3-DPPS group 1.0-LAMS gropu	4.2 3.4-DPPS group 1.0-LAMS group	0	0	20.2 7.4- DPPS group 12.8- LAMS group	3.2	4.3
Bang et al [42] 2018	60	WON	48.4%-(DPPS) 51.6%-(LAMS; Hot AXIOS)	-	0	DPPS group: 3.4; Late LAMS group: 16.1 3.3-Early 9.6-Late; pseudoaneurysm related 3.3-Late; during retrieval of 'buried stent'	0	0	6.4 All in LAMS group	9.6 Spontaneous	0	0
Yang et al [57] 2018	205	Pseudocyst	61%-DPPS 39%-LAMS	99.2-DPPS 97.5-LAMS	1.5	3.5	1.0	0	0	4.8-DPPS 8.8-LAMS	0	5.8
Brimhall et al [22] 2018	249	21%-Pseudocyst 79%-WON	61%-DPPS 39%-LAMS (AXIOS)	DPPS-90.1 LAMS-92.8	7- LAMS group	DPPS-3.2 0.6-Pseudoaneurysm related LAMS-15 8-Pseudoaneurysm related	3.2 in DPPS group 0 in LAMS group;	0	0	0	0	2.0 in LAMS group 3.9- in DPPS group

(Contd...)

Table 2 *(Continued)*

Study	n	PFC type	Stent used	Technical Success (%)	Mal-deployment (%)	Bleeding (%)	Perforation (%)	Air embolism (%)	'Buried stent' (%)	Stent migration (%)	Stent blockade (%)	Infection (%)
Yang *et al* [16] 2018	122	47.5%- Pseudocyst 52.5%- WON	LAMS (AXIOS and Hot AXIOS)		1.6	2.4-Total 1.6- Early 0.8-Delayed	0	0	1.6	6.6 Spontaneous	4.9	5.7
Adler *et al* [58] 2019	80	15%-Pseudocyst 85%-WON	LAMS	98.7	1.25	12.5 All early	5	0	0	-	1.25	2.5
Wang *et al* [59] 2019	160	80.6%-Pseudocyst 19.4%-WON	38.7%-DPPS 17.6%-FCSEMS 43.7%-LAMS	93.5-DPPS 96.4-FCSEMS 94.3-LAMS	5	6.9-Total 2.5-DPPS group 1.9-FCSEMS group 2.5-LAMS group	0	0	0	11.25 6.25-DPPS group 3.75-FCSEMS 1.25-LAMS	18.75 (Labelled as infection/ occlusion)	

*Original research article with sample size >50 were included in this table

APFC, acute pancreatic fluid collection; BFMS, biflanged metallic stent (Nagi stent: TaeWoong Medical Co., Ltd., Gyeonggi-do, South Korea); DEN, direct endoscopic necrosectomy; DPPS, double pigtail plastic stents; FCSEMS, fully covered self-expanding metallic stent (WallFlex, Boston Scientific); LAMS, lumen-apposing metallic stent; PFC, pancreatic fluid collection; WON, walled-off necrosis

been left *in situ* for a longer duration. The proximal flange of the LAMS (towards the gastrointestinal lumen) usually gets buried in the gastrointestinal wall by tissue hypertrophy caused by prolonged irritation. A recent study reported a higher incidence of up to 6.5% [42]. LAMS deployment near the antrum is considered to be a risk factor for a buried stent, as opposed to its deployment near the body of the stomach [44]. Moreover, according to reported cases, in patients with a buried LAMS the stent was usually *in situ* for more than 6 weeks; this again emphasizes the importance of timely LAMS removal [44-47].

The removal of buried LAMS is difficult and aggressive pulling has been associated with a risk of massive bleeding and even arterial hemorrhage requiring blood transfusion and angioembolization. The use of argon plasma coagulation or a needle knife to cut the hyperplastic gastric mucosa, followed by removal of the LAMS with rat-tooth forceps or a snare, has been reported. Alternatively, dilatation of the tract, followed by grasping the distal flange with rat-tooth forceps and removal of the LAMS by inversion can be attempted [44-47].

Blockage of stents by either food material or solid debris, leading to secondary infection, is also one of the well-recognized complications. Different studies have reported an incidence varying from 0-10% [6,16,48]. The risk of stent blockage due to debris is higher in the presence of WON than for a pseudocyst. Stent blockage is associated with a higher risk of infection of the remaining undrained collection, more time for resolution and lower clinical success rates [23,49]. Although the use of a LAMS is associated with better drainage of solid debris, it is important to remember that its use does not completely avoid this adverse effect. Once clogging of the stent is detected, de-clogging of the blocking necrotic debris should be performed using a snare, basket or stone-extraction balloon. If persistent or repeated clogging of the LAMS occurs, nasocystic drain placement can be used for better drainage and irrigation of the cystic cavity, as well as keeping the stent lumen patent. A study by Guo *et al* reported that a cyst size >15 cm is associated with a greater risk of cyst infection after a transmural drainage procedure [50]. Likewise, a study by Puri *et al* reported that the use of a nasocystic drain along with the endoscopic prosthesis is associated with a smaller risk of infection and a better clinical response compared to the use of the endoscopic prosthesis alone [51]. The morphological features of the pancreatic collection on EUS have been reported to have important therapeutic implications, with collections having a large size and more solid debris having a greater risk of secondary infection, and therefore needing more aggressive endoscopic intervention for a successful outcome [52] (Table 2).

Apart from these complications, pancreatic parenchymal calcification due to a long-indwelling transmural stent has also been reported [60]. Likewise, bile duct obstruction due to long-term LAMS has also been reported, causing jaundice and requiring intervention. [42]. Other rare complications, such as intestinal obstruction (Fig. 8C), as well as perforations including colonic perforation, have also been reported to be due to long-indwelling transmural stents [61-63].

Concluding remarks

The techniques and the accessories for EUS-guided transmural drainage of pancreatic collections have seen considerable advances in the last decade, with the procedure becoming safer and more effective. Despite its improved safety profile for EUS-guided drainage, studies have reported various types of complications, including bleeding and perforation. Delayed complications weeks after the procedure have also been described and attributed to the presence of indwelling transmural stents. Careful patient selection, with proper assessment of size, solid necrotic content and location of collection, as well as an in-depth understanding of various risk factors that predict complications, are important for safer and effective endoscopic transmural drainage. Moreover, early recognition of complications, if any, and prompt management as per structured protocol are required to limit their morbidity and mortality.

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