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Endoscopic management of complications after sleeve gastrectomy: a narrative review

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Abstract

Sleeve gastrectomy (SG) has become the most widely performed bariatric procedure globally due to its technical simplicity and proven efficacy. However, complications following SG, including bleeding, leakage, fistulas, stenosis, gastroesophageal reflux disease (GERD), and hiatal hernia (HH), remain a significant concern. Endoscopic interventions have emerged as valuable minimally invasive alternatives to traditional surgical approaches for managing these complications. This review aims to provide a comprehensive overview of the endoscopic management strategies available for addressing the various complications encountered after SG, emphasizing their critical role in optimizing patient outcomes.

Keywords: Endoscopy, sleeve gastrectomy, complications, leakage, fistula, stenosis, gastroesophageal reflux disease

INTRODUCTION

Sleeve gastrectomy (SG) has emerged as a preferred bariatric procedure, lauded for its technical simplicity and efficacy in long-term weight reduction. American Society for Metabolic and Bariatric Surgery (ASMBS) data underscores its dominance in the United States, utilized both as a standalone intervention and as the initial phase of a staged approach for high-risk patients[1-3]. However, SG is not without risks, encompassing both mechanical and metabolic complications that demand comprehensive clinical understanding[4,5].

The advent of endoscopic interventions has revolutionized post-SG complication management, offering minimally invasive alternatives to traditional surgical approaches[6]. These techniques effectively address a broad spectrum of complications while minimizing surgical morbidity[7,8]. As the field of bariatric endoscopy evolves, these innovative strategies are poised to play a pivotal role in enhancing patient outcomes and quality of life.

This chapter explores endoscopic management strategies for post-SG complications, emphasizing the efficacy of minimally invasive interventions. By leveraging these advanced techniques and fostering interdisciplinary collaboration, we aim to optimize clinical outcomes and improve the long-term prognosis for SG patients.

BLEEDING

Postoperative bleeding in SG has seen a significant reduction from early incidence rates of 6%-15% to current rates of 1%-6%, attributed to advancements in surgical techniques[9-12]. Common sites of extraluminal bleeding include the extensive staple line along the sleeve conduit, omental vessels, trocar sites, and areas of liver or splenic injury[13,14]. Intraluminal bleeding is less frequent in SG compared to Roux-en-Y gastric bypass (RYGB), although both complications are relatively uncommon[15].

Patients typically present with melena, hematochezia, or hemodynamic instability necessitating blood transfusion. While most cases are self-limiting and amenable to conservative management, persistent hemodynamic instability may warrant emergency intervention[16,17]. For SG-related bleeding, radiological interventions are primarily employed for splenic or short gastric vessel bleeding, whereas endoscopic management is more commonly utilized for gastrojejunostomy bleeding in RYGB[17].

Endoscopic intervention for intraluminal bleeding post-SG presents several challenges. The everted staple line of the sleeve conduit is not easily accessible using conventional endoscopic methods. The narrow lumen restricts endoscopic manipulation, and limited suction capacity impedes visualization of the bleeding site. Additionally, CO_2 insufflation during endoscopy may complicate emergency laparoscopy if required[16].

Despite these challenges, recent advancements in therapeutic endoscopy have expanded treatment options. These techniques, now considered primary treatment modalities, include endoscopic clips, suturing, injection of epinephrine or sclerosing agents, and thermal therapies such as contact probes and argon plasma coagulation (APC)[17]. A careful risk-benefit analysis is essential when considering endoscopic intervention to ensure optimal patient outcomes and minimize the need for more invasive surgical procedures.

LEAKAGE

Staple line leakage is one of the most severe complications following SG. Historical data indicate leak rates ranging from 1.1% to 4.7%, with a leak-related mortality rate of 0.4%[18-20]. Leakage occurs when the increased intraluminal pressure exceeds the tissue and staple line strength, resulting from both mechanical/tissue factors and ischemia[21]. Researchers have attempted to identify risk factors associated with elevated intraluminal pressure leading to leakage, including bougie size, distance from the pylorus, surgical experience, and various staple line reinforcement methods[18]. Surgical technical factors contributing to leakage include inadequate stapler height, bougie size less than 40 French, excessive traction during stapling, and extensive dissection resulting in ischemia. Leakage may also occur secondary to sleeve stenosis or torsion[11]. Figure 1 illustrates two key diagnostic imaging modalities used to detect SG leaks.

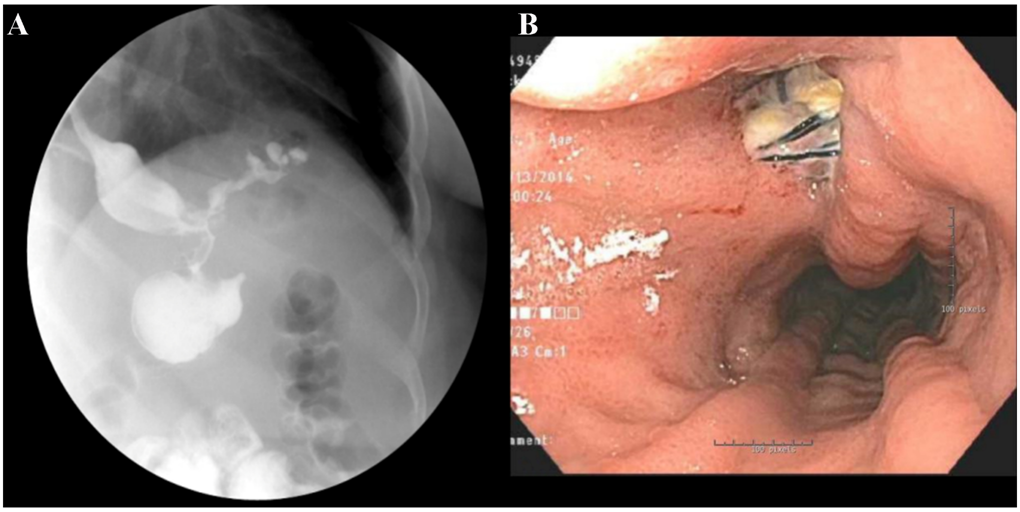

Figure 1. Sleeve leak. (A) An UGI series showing contrast extravasation; (B) Endoscopic view of the leak site with visible sutures and inflammation. UGI: Upper gastrointestinal.

Leaks primarily occur at the esophagogastric junction and angle of His, accounting for 89% of cases, and are typically diagnosed after discharge[22]. Leaks can be classified based on time of presentation or radiological findings[11,23,24]. The former categorizes leaks as acute (within 7 days), early (within 1 to 6 weeks), late (after 6 weeks), and chronic (after 12 weeks)[23]. The latter, proposed in a recent study, classifies leaks according to computed tomography (CT) scan findings into class 1 (phlegmon associated with the staple line), class 2 (fluid collection), class 3 (contrast leak), and class 4 (chronic fistula)[24]. Immediate management should be tailored to the severity of the leak. Hemodynamically unstable patients with symptomatic leakage should undergo immediate surgical intervention; however, most cases can be managed with various therapeutic endoscopic methods[23,25].

The success rate of endoscopic leak management varies depending on the time of diagnosis. For early leaks, the success rate of endoscopic treatment ranges from 74% to 85%[26]. However, the probability of successful endoscopic fistula treatment decreases over time, reaching 48.5% at 6 months and 41.7% at 12 months in a multicenter study[27].

The principles of leak management include adequate drainage, fistula closure, gastric decompression, and appropriate nutritional support[28,29]. The initial step in treating a leak is surgical, radiological, or endoscopic drainage of the abscess or fluid collection to control the infectious process[26,30]. Despite the lack of standardized treatment algorithms, endoscopic treatment has become the initial option for stable patients. However, the ASMBS position statement does not favor one treatment over another[29].

When selecting an endoscopic method, the type of leak, size of the fistula, and presence of stenosis must be evaluated[31]. Endoscopic treatment can be classified into four categories: (1) endoscopic wall closure or covering; (2) active internal drainage; (3) passive internal drainage; and (4) plugging[32]. In cases accompanied by gastric stenosis, management for decompression should also be considered[26].

For acute or early leaks, endoscopic treatment for direct wall closure or wall exclusion (covering), with or without a drainage procedure, may be attempted. These include stents, clips, and endoscopic suturing[25,26,30,32]. Among these, endoscopic self-expandable metal stents (SEMS) were first used by

Eisendrath *et al*. in 2007 and are the most common method for managing leakage after bariatric surgery[25,33,34]. According to one treatment algorithm, stents can be used depending on the size of the leak and the presence or absence of gastric stenosis[35]. Generally, if the fistula is small, only drainage or direct wall closure can be attempted. If the fistula is large or accompanied by stenosis, a stent may be considered as the first treatment[25,26,30,35,36]. The advantages of stents include a reduced number of additional procedures required, safer resumption of early oral nutrition, and a significant reduction in hospital stay[37]. The success rate of stent procedures in cases of leakage ranges from 66.7% to 95%[31,33,34,38-41].

SEMS are currently available in various configurations, including uncovered (bare metal), partially covered, and fully covered stents. However, for the management of post-bariatric surgery leaks, uncovered stents are not considered useful. Partially covered SEMS have exposed metal portions at both ends to improve adhesion by allowing tissue ingrowth[41-43]. While this reduces stent migration, it may be associated with an increased risk of stent-related adverse events, such as difficulty in stent removal, bleeding, perforation, and subsequent stricture or fistula[25,26,40-43]. Timely stent removal within 10-14 days of placement is important to reduce this risk[44].

In contrast, fully covered SEMS do not allow tissue ingrowth or overgrowth and are therefore easier to remove than partially covered stents[45,46]. Despite this advantage, fully covered SEMS are more prone to migration, which is a major factor affecting treatment strategies[26,42,43,45,46]. Reported migration rates for fully covered SEMS are up to one-third or more of patients[26,42,43,47,48]. Nonetheless, it is worth noting that stent migration is less significant after SG compared to RYGB due to the presence of the pylorus, which prevents the stent from entering the intestine and potentially requiring surgical removal. To reduce dislodgement, various strategies such as endoscopic snares, clips, and anchoring sutures are attempted[26,42,47-51].

A long, fully covered Mega stent designed to prevent migration has been developed, providing a tighter seal with a wider diameter, better fixation, and a longer bypass length covering the entire sleeve. This type of stent has demonstrated significant reductions in migration rates, with several authors reporting rates ranging from 0% to 21.6%[26,31,36,37,52]. Nevertheless, its large size and poor tolerance limit its clinical use, as it causes nausea, vomiting, and abdominal pain requiring early removal and is also associated with significant prepyloric mucosal ulceration related to the wide distal landing zone[26,31,36]. Currently, there is insufficient evidence regarding the superiority and effectiveness of any particular type of stent for treating leaks. The choice largely depends on the preference and experience of the endoscopist[26,53]. Figure 2 illustrates the process of SEMS placement through a series of fluoroscopic and endoscopic images, showcasing the various stages of stent deployment.

The duration of stent placement varies depending on the type of stent used. For fully covered stents, the recommended duration is typically 3 to 10 weeks, and many experts recommend stent removal at 6 to 8 weeks to allow sufficient time for healing[26,44,53-55]. However, when partially covered stents are used, they are usually removed within 10-14 days to prevent significant tissue ingrowth, which can lead to difficulties in stent removal and potential complications[55,56]. To illustrate this point, Figure 3 provides a striking example of tissue ingrowth in a partially covered stent after 8 weeks. This visual evidence underscores the critical importance of adhering to recommended removal timeframes to avoid such complications and ensure optimal patient outcomes.

Weekly endoscopic evaluation may be helpful in the early detection of stent dislodgement and appropriate management of subsequent complications[26,53]. Previous studies often reported an average of 1 to 7 repeat endoscopic procedures[37,53]. In cases of stent dislodgement, the stent can be repositioned or replaced with a

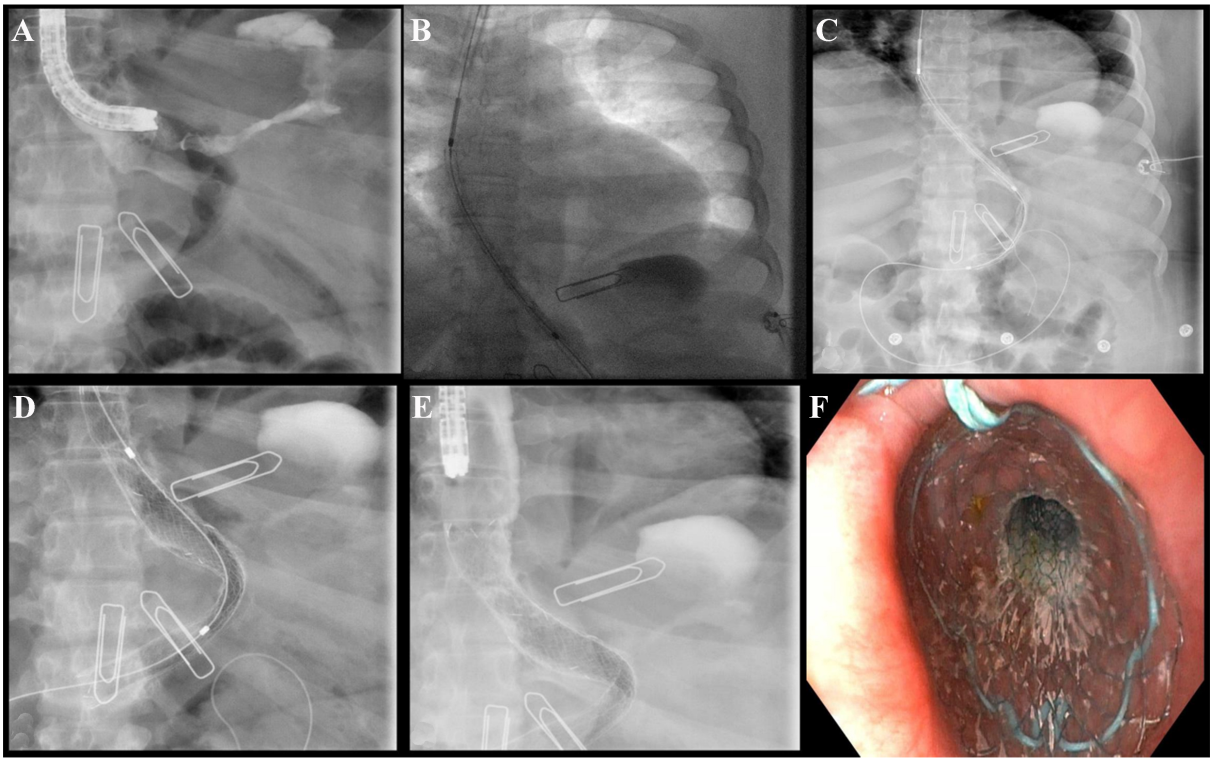

Figure 2. SEMS placement. (A) Fluoroscopy image demonstrating contrast extravasation following SG; (B) Radiographic view of external marker placement and guidewire insertion into the gastric lumen; (C) Fluoroscopic visualization of stent progression along the guidewire; (D) Stent expansion during deployment; (E) Endoscopic advancement post-stent placement; (F) Endoscopic visualization of the fully deployed stent *in situ*. SEMS: Self-expandable metal stents; SG: sleeve gastrectomy.

Figure 3. Tissue in-growth at 8 weeks.

new stent. Stents can be used in conjunction with other internal drainage or wall defect closure techniques to promote leak closure[26,30,31,37,53]. For small fistulas, endoscopic direct wall closure may be attempted using clips, tissue adhesives, or sutures in cases of acute or early leakage[11,25,26,30,32]. The choice of techniques is determined by the size and tissue condition, as well as the endoscopist's preference[26,31,53].

Generally, two types of clips are available to manage leaks: through-the-scope clips (TTSC) and over-the-scope clips (OTSC)[7,11,26,57]. Conventional TTSC, although technically more feasible, has limited use and is only employed for mildly inflamed tissue less than 1 cm[7,11,26,57]. These clips are usually applied in a consecutive, parallel manner with a suction maneuver to enhance the approximation of tissue margins. However, the potential for premature dislodgement of clips and inadequate sealing are associated with TTSC, necessitating repeat procedures or a combination of other treatment modalities[7,26]. OTSC, on the other hand, can achieve full-thickness approximation of tissue defects, providing higher strength and better sealing. While more technically challenging due to the use of suction or additional grasping tools, OTSC can be used for defects up to 3 cm and has a success rate of 70%-100% for leak management[7,11,26,58-60]. Failure of fistula closure using OTSC may occur secondary to poor tissue integrity related to ischemia or inflammation, difficulty in obtaining a right-angle endoscopic view for adequate repair, or high intraluminal pressure due to distal gastric stenosis[26,61].

Tissue sealants and plugs have also been used to manage leaks[7,11,26,31,32,53,62-64]. The advantages of this method include ease of use, absence of major complications, low cost, possibility of combination with other endoscopic treatment modalities, and the ability to repeat the treatment as needed[65]. Two types of tissue sealants are commonly used for endoscopic injections: fibrin glue and cyanoacrylate[7,26,53]. Fibrin glue rapidly forms a clot that can mechanically occlude the inner orifice and promotes healing by inducing neovascularization and fibroblast proliferation. Cyanoacrylate is a synthetic glue that works as a mechanical sealant, hardening quickly on contact with a weak base to form a cast[7,11,26,63,64]. Fibrin glue is effective, but repeat endoscopic procedures are usually required to close the fistula. Cyanoacrylate has several advantages over fibrin glue, including a longer period of hydrolysis and removal (1-6 months), the requirement of only small amounts, and a cost approximately 6 times less than fibrin glue. However, poor mechanical properties, brittleness, possible pro-inflammatory effects, and the risk of damage to the endoscope due to rapid polymerization make cyanoacrylate a suboptimal choice[63].

A sealant can be applied via a double-lumen catheter after the target area has been dried to promote clot formation. Before applying the sealant, it is recommended to use APC or a cytology brush to exfoliate the epithelium of the target area[7,26,53]. Appropriate patient selection is also important to achieve good results. Small, short, thin, and clean fistula tracts tend to close quickly[26,63]. Although sealants can be used alone or in combination with other treatment modalities, a 2015 review of the ASMBS position statement states that "in the setting of a SG staple line leak, it is rarely successful as a standalone treatment and is more commonly used in combination with other endoscopic treatment modalities"[29,65].

Endoscopic suturing techniques were first introduced by Swain and Mills in the mid-1980s and were approved by the US Food and Drug Administration for the treatment of gastroesophageal reflux disease (GERD) in 1998[66,67]. These techniques are specially designed to simulate manual suturing for all tissue types and allow for the placement of continuous or interrupted full-thickness sutures of various lengths, expanding their applications to a variety of fields, including the treatment of gastrointestinal defects such as fistulas, anastomotic leaks, and perforations[66-68]. Recently, endoscopic suturing has been used in combination with stents for anchorage to manage leaks[26,42,66-68].

As with applying a tissue sealant, the procedure begins with de-epithelialization of the edge of the leak prior to the placement of endoscopic sutures[69]. Several articles have reported on the treatment of leaks using endoscopic suturing systems with varying success rates[67,70-74]. However, data on the successful closure of leaks and fistulas after SG using direct endoscopic suturing are still limited[26,67]. In summary, although the treatment of leaks with endoscopic suturing is safe and somewhat successful, long-term clinical success without combination with other treatment modalities is more compromised than immediate or short-term outcomes[26,67,74].

Drainage procedures are crucial in treating leaks under any condition because the presence of fluid accumulation or debris needs to be removed from the leak cavity to promote healing[26]. For the treatment of late-stage and chronic leakage, endoscopic wall closure or covering procedures are less effective, and therefore endoscopic drainage procedures are recommended[75]. Drainage can be divided into two types: active and passive[32]. Nasocystic drainage is a form of active drainage that involves a drainage device with active intermittent suction and is used when there are large collections that require repeated irrigation to remove pus and debris. Because this catheter can cause significant discomfort, catheter placement is usually performed only for a short period and is often combined with transfistulary drainage[26,30,32,76].

Transfistulary double pigtail stent (DPS) or endoscopic internal drainage (EID) is a form of passive drainage used for prolonged placement to induce re-epithelialization and stimulate tissue growth, keeping the fistula tract open and promoting drainage into the gastric lumen. This results in the collapse of the abscess cavity and closure of the leak[11,26,32,76]. The stent is delivered via an orifice that places one end inside the cavity to drain and the other end in the gastric lumen to prevent migration. It should be replaced every 4-6 weeks until fully healed[25,77]. Clinical success rates vary from 70% to 85%[26,76-80]. Figure 4 illustrates the step-by-step process of EID, while Figure 5 showcases a radiographic view of a combined approach, showing the simultaneous use of a DPS for internal drainage and an over-the-scope clip for defect closure. This combination exemplifies how endoscopic techniques can be synergistically employed in complex cases.

Donatelli *et al.* reported the use of DPS for leak management combined with enteral nutrition [endoscopic internal drainage with enteral nutrition (EDEN)], a treatment modality that had a 95% success rate[81]. DPS offers several advantages in leak management. First, it can be applied to both acute/early and chronic/late leakage[26,76,77,79,82]. Second, despite the need to perform endoscopy multiple times, there appears to be a cost-saving effect due to ease of management, shortened hospitalization period, and early enteral nutrition[77,80,82-84]. Third, it is generally well tolerated, with minimal patient discomfort and few complications[11,77,79,80,84]. However, significant complications related to DPS, mainly associated with drain migration, have been reported. Migration can occur into the abdominal cavity at the time of placement or later and can usually be managed endoscopically[83,84]. A series of rare but potentially life-threatening cases have been reported, including massive splenic hemorrhage, splenic abscess, and portal vein gas, suggesting the need for close follow-up and early removal in case of drain migration[84-88].

Endoscopic or endoluminal vacuum therapy (EVT) is a technique that rapidly controls leak-related sepsis by absorbing fluids through the application of negative pressure to the defect area using an electronically controlled vacuum device along with a polyurethane sponge placed at the end of a drainage tube inserted through an endoscope. Several studies have reported this effective and feasible treatment modality, which allows stepwise closure of the defect and sufficient drainage in the infected area, reducing the risk of contamination or superinfection, accelerating granulation tissue formation, and promoting tissue perfusion[26,89-92]. Success rates reported in previous studies range from 84% to 100%[26,89-94].

EVT can be used alone or in combination with other treatment modalities and is also used as a means of support in conjunction with surgical revision[90,91]. Like other endoscopic treatment methods, EVT requires repeated endoscopic sessions because the sponge generally needs to be replaced every 3 to 5 days, depending on the lesional findings and clinical course[11,91]. Compared to stents, EVT showed a higher success rate, lower mortality, and a lower incidence of stricture[91,94-98]. However, although the observed efficacy of EVT

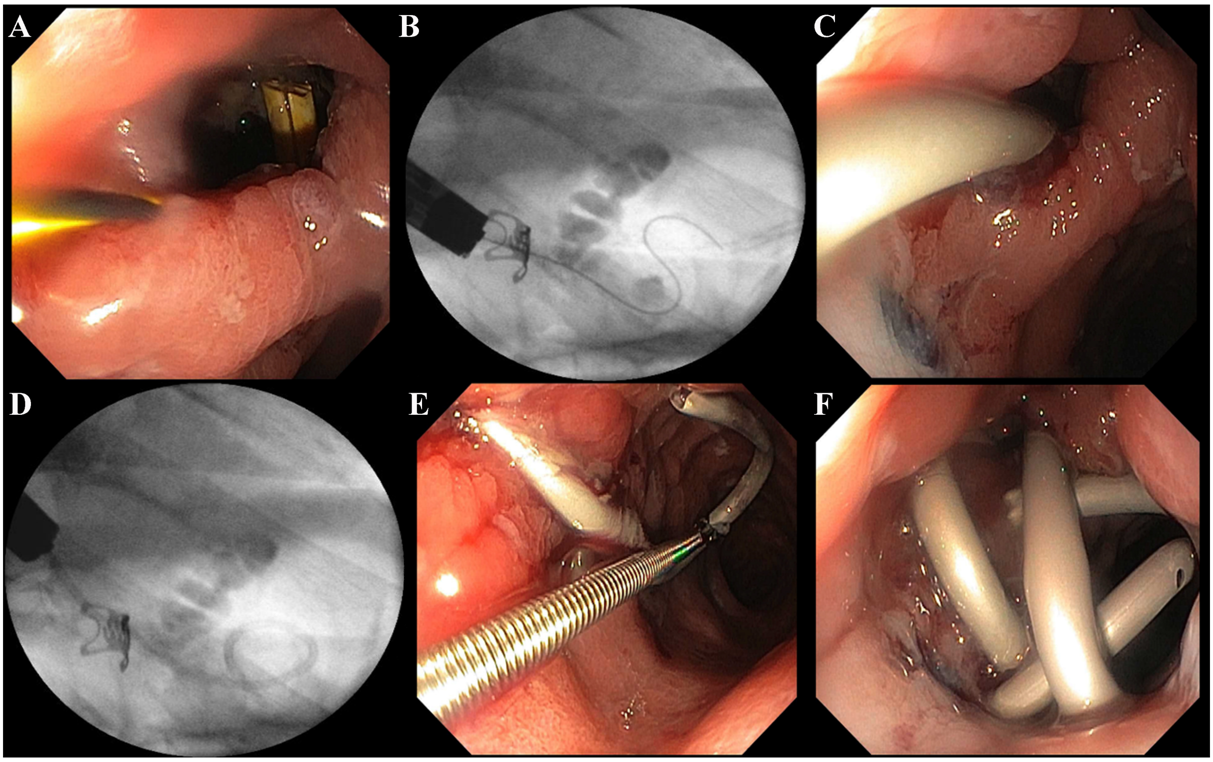

Figure 4. EID. (A) Endoscopic view of fistula with intra-abdominal drain and guidewire introduction into gastric lumen; (B) Fluoroscopic visualization of guidewire placement and OTSC application; (C and D) DPS advancement along guidewire through fistular tract into intra-abdominal cavity for internal drainage; (E and F) Endoscopic view of DPS deployment within gastric lumen. EID: Endoscopic internal drainage; OTSC: over-the-scope clips; DPS: double pigtail stent.

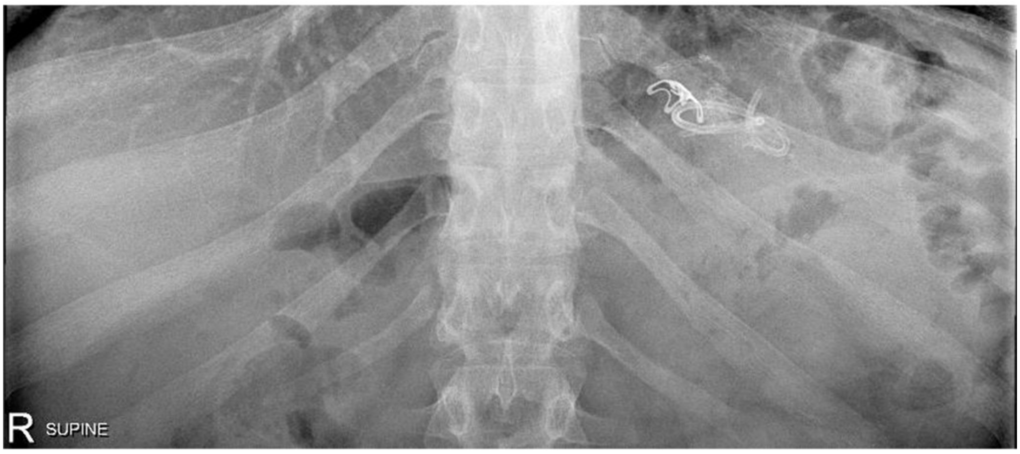

Figure 5. Leakage management using DPS and OTSC. DPS: Double pigtail stent; OTSC: over-the-scope clips.

was slightly lower than EID, EID was associated with a significantly longer treatment duration[99]. Combinations with different treatment modalities, such as EVT with SEMS and EVT with OTSC, have been reported in complex cases[96].

Endoscopic septotomy is a relatively new technique that divides the septum separating the perigastric cavity from the gastric cavity using a needle knife or APC, allowing communication between both cavities to equalize cavity pressure and promote secretion into the stomach. These changes ultimately lead to the collapse of the cavity and clinical resolution[26,100,101]. It was initially attempted for chronic leaks with leak sizes greater than 10 mm, where an endoscope can be passed into the cavity to overcome the limitations of diversion therapy, which has poor clinical success when the sinus tract is well established, and the fistula is large or chronic[102,103]. Septotomy is usually combined with balloon dilation of the distal sleeve stenosis to promote drainage[100,102,103].

Reported clinical success rates in case series range from 80% to 100%, and the concept and mechanism of EID suggest that septotomy is an excellent treatment option for the management of fistulas after SG[26,100,101,103-108]. However, it should be performed at least one month after surgery, when a stable septum has formed[104]. Additionally, while the septum is prone to bleeding due to inflammation, bleeding tends to occur less frequently when APC electrocautery is used[26,100,103].

FISTULA

A fistula, often used synonymously with the term leak, is an abnormal communication between two epithelialized surfaces. Fistulas can be categorized as internal, connecting an abdominal organ to another organ, or external, extending from an abdominal organ to the body surface. Chronic fistulas typically arise from long-standing, untreated leaks and are characterized by epithelialized tracts surrounded by unhealthy tissue, which adversely affects spontaneous closure and treatment success[26,75,109]. Various endoscopic approaches and devices, including closure, covering, and drainage modalities, have been employed in the management of fistulas, with varying degrees of efficacy[75,109,110].

Biomaterial plugs have emerged as a promising option for the treatment of long-standing and refractory fistulas[26,53,111]. The Surgisis AFP plug (Cook Biotech, West Lafayette, IN), an acellular matrix biomaterial derived from porcine small intestine, has demonstrated success in promoting the closure of leaks and fistulas by stimulating fibroblast proliferation[53,112]. Initially developed for the management of anal fistulas, this biomaterial has shown promising results in the treatment of enterocutaneous fistulas following bariatric surgery[111,112]. The plug can be inserted either endoscopically or percutaneously, and multiple plugs can be placed adjacent to a large-diameter fistula[26,53,111]. Studies evaluating the use of sealant plugs for fistula closure in bariatric patients have reported an overall success rate of 80%[26].

Cardiac septal defect occluder (CSDO) is an innovative technique that has shown favorable outcomes in the management of gastrointestinal disruptions. This double-disc, self-expanding closure device, constructed from nitinol and interwoven polyester, promotes occlusion and tissue ingrowth. Several studies have reported the off-label use of CSDO for the treatment of late and chronic leakage, with a technical success rate of 100% and a clinical success rate of 77.3%[26,109,113]. While CSDO appears to be an effective alternative for the management of chronic fistulas, research data are still limited. To promote more widespread use, further studies are necessary to validate previously reported results and clarify the indications for this technique[110,114].

STENOSIS

Stenosis or obstruction flowing SG is one of the most common complications, with an incidence ranging from 0.1% to 3.9%, along with leakage. It can manifest as nausea, vomiting, regurgitation, dyspepsia, retrosternal burning pain, early satiety, abdominal pain, and rapid weight loss. Endoscopic and fluoroscopic examinations are essential for confirming the diagnosis of stenosis. There are two distinct types of stenosis:

functional (helix stenosis) and mechanical[26,115-118].

Functional stenosis, the most prevalent type, is caused by abnormal rotation, kinking, and twisting of the sleeve associated with unequal traction of the anterior and posterior gastric walls during stapling. This may result in a sharp angulation or indentation at the incisura of the remnant stomach, creating a flap valve that impedes proper gastric emptying. Complete obstruction preventing endoscope passage is uncommon in this condition[26,115-118].

The second, less frequent type is mechanical stenosis, which can occur anywhere proximal to the sleeve and is typically described on endoscopy as a stricture or mucosal narrowing, rendering endoscope passage difficult or impossible[26,115-118]. Over-sewing the staple line or using an excessively small bougie may contribute to the development of this narrowing or stricture[25,119].

Prompt identification and treatment are crucial, as upstream pressure from the stenosis contributes to the development and prolongation of gastric leaks. Treatment options for stenosis include observation/expectant management, endoscopic balloon dilation (EBD), stent insertion, stricturotomy, and revisional surgery[26,120].

The endoscopic management of sleeve stenosis has been extensively discussed in the literature, with several authors proposing treatment algorithms involving staged balloon dilation and long-term placement of fully covered SEMs in cases where dilation fails[118,121-124]. However, the clinical success rates of endoscopic treatment for stenosis are heterogenous, ranging from 44% to 100%[115,120,121,125].

EBD is the cornerstone of stenosis treatment, but many technical details, such as balloon size, duration, and the number of sessions, remain controversial, with no established guidelines to suggest optimal dilation parameters[123,124]. Nonetheless, a large meta-analysis examining the efficacy of EBD for the treatment of sleeve stenosis reported an overall success rate of 76%[124]. A significant contributing factor of the success of EBD may be the physician's expertise with the type of balloon used. Few studies have compared multiple balloon types, but evidence suggests that larger achalasia balloons provide a more robust dilation compared to through-the-scope controlled radial expansion (CRE) balloons[116,122,124]. However, a meta-analysis found that neither balloon type nor initial balloon dilation size affected the overall EBD success rate. Although anecdotal reports from multiple studies may indicate the potential advantages of achalasia balloons, the selection of the specific balloon type may be contingent upon its availability and the extent of the stenotic segment[116,124]. A significant limitation in the existing literature is the failure of most studies to report the length of the stenotic segment, thereby impeding comprehensive analysis[124,126].

The debate regarding routine repeated dilation versus on-demand dilation for EBD persists. It is generally accepted that repetitive EBD is more efficacious in treating stenosis. According to the studies, the likelihood of success decreases significantly beyond the third dilatation with the same balloon size. However, switching to a larger balloon size after three failed attempts may increase success rates in subsequent dilations[124]. A main concern regarding the use of larger balloons is the risk of perforation. However, the reported serious adverse event rate is only 0.9%. To mitigate the risk associated with EBD, a meticulous endoscopic evaluation is crucial prior to the procedure. This evaluation serves not only to delineate the characteristics of the stenosis but also to detect any structural abnormalities that may predispose to perforation. Undoubtedly, precise positioning of the balloon is paramount, as it enhances the likelihood of successful dilation while concurrently minimizing the potential for perforation[124].

In cases where stenosis persists despite multiple attempts at EBD, the placement of stents may be warranted. A few studies have explored the utilization of SEMS as the sole treatment modality for stenosis, reporting a pooled success rate of 95.5%[117,127-130]. A meta-analysis demonstrated that the endoscopic deployment of SEMS yielded a success rate of 70%, and the inclusion of stents as a subsequent therapeutic option following EBD elevated the overall endoscopic success rate from 76% to 78%[124]. Notably, no instances of stent migration were reported, and the rate of other adverse events was insignificant. However, the use of SEMS for stenosis management remains an understudied area, and further comparative studies are necessary to establish the optimal treatment strategy[124,127].

A novel technique, termed endoscopic tunneled stricturotomy, has recently been described by De Moura *et al.*, which draws upon the principles of per-oral endoscopic myotomy[131,132]. The underlying cause of helix functional stenosis is anatomic, arising from the spiral configuration of the sleeve, which consequently leads to increased luminal pressure at the narrowed segment. To address this issue, Zundel *et al.* have employed endoscopic needle cautery incisions in all four quadrants of the muscle layer, following pneumatic dilation, aiming to achieve more sustained results in certain patients as an adjunctive method[118,133]. Although limited case studies have reported successful outcomes with this approach, it could potentially serve as an alternative option after the failure of conventional treatments. However, further research is necessary to establish its overall efficacy and safety profile[131,132].

GERD

GERD is a significant concern following SG, with both de novo cases and exacerbation of pre-existing symptoms reported. The etiology is multifactorial, involving disruption of anatomical anti-reflux mechanisms, decreased gastric compliance, elevated gastric pressure, and alterations in gastric anatomy such as strictures, angulations, or torsion of the gastric tube, and/or the persistence of a significant portion of the gastric fundus[134,135].

Clinical manifestations range from asymptomatic cases to both typical and atypical GERD symptoms. Endoscopic findings may include non-erosive reflux disease (NERD), esophagitis, and Barrett's esophagus (BE)[134]. Long-term studies, such as the Finnish Sleeve versus Bypass (SLEEVEPASS) Randomized Clinical Trial and the Swiss Multicenter Bypass or Sleeve Study (SM-BOSS) Trial, reveal high rates of GERD symptoms, proton pump inhibitor (PPI) dependency, and endoscopic abnormalities post-SG. The SLEEVEPASS trial reported a 31% prevalence of esophagitis and 4% incidence of de novo BE at 10 years post-SG[136,137]. The ASMBS recommends routine endoscopic screening for BE at 3 years post-SG and subsequent surveillance every 5 years, regardless of symptomatology. This recommendation is supported by studies indicating that many patients with endoscopic abnormalities may be asymptomatic[138].

While GERD symptoms post-SG are prevalent, conservative management is often efficacious, with revisional surgery indicated in only 3.1% of cases[134,139]. Emerging endoscopic anti-reflux treatments, such as the Stretta procedure and anti-reflux mucosectomy (ARM), are being proposed as alternatives to traditional surgery[140]. The Stretta procedure, utilizing radiofrequency ablation to augment lower esophageal sphincter (LES) function, has demonstrated efficacy in mitigating esophageal acid sensitivity and reducing gastroesophageal junction (GEJ) distensibility in general GERD cases[140,141]. However, preliminary trials in post-SG patients have yielded suboptimal outcomes, suggesting potential limitations in this specific cohort[142]. Conversely, ARM, involving partial circumferential mucosectomy at the GEJ, has shown high feasibility and efficacy rates of up to 83.3% in alleviating refractory GERD symptoms in post-bariatric patients with confirmed acid reflux[140,143]. Despite current limitations, ongoing research is expected to yield additional validated evidence and novel approaches, potentially refining GERD management in the context of bariatric surgery.

HIATAL HERNIA

Hiatal hernia (HH) is a common finding in SG patients, but the development of de novo HH postoperatively is less characterized[144,145]. Intrathoracic sleeve migration (ITSM), the herniation of the gastric sleeve into the thoracic cavity, occurs in 5%-35% of cases, with one study reporting up to 72.5%[146,147]. Clinical presentation may involve reflux-related symptoms, which can confound diagnosis due to reflux being a common obesity co-morbidity, or dysphagia and pain in cases of sleeve incarceration[146].

The etiology of de novo HH is multifactorial. Contributing factors include surgical techniques (dissection of the angle of His and left diaphragmatic pillar, fat pad removal), anatomical changes (tubular sleeve shape, division of phrenogastric and phrenoesophageal ligaments), and postoperative factors (negative intrathoracic pressure, rapid weight loss, crural fat atrophy). These changes can lead to GEJ migration, forming a type I HH and reducing LES pressure, a key factor in GERD development. Many of these mechanisms are inherent to SG technique and non-modifiable[147].

The management of ITSM may involve cruroplasty, conversion to RYGB, conversion to one anastomosis gastric bypass, or re-sleeve and gastropexy, depending on the results of the diagnostic workup and the condition of the diaphragmatic pillars during surgery[146]. Although there is currently no suitable endoscopic management option for ITSM, it is essential to recognize this underreported complication of SG and consider its implications in the management of post-bariatric surgical patients[146,147].

ENDOSCOPIC FAILURE

Surgical intervention is warranted when endoscopic techniques fail or hemodynamic instability occurs. The approach is tailored to the specific complication, ranging from simple drainage to complex reconstruction. Common procedures include Roux-en-Y bypasses (esophago-jejunal or gastro-jejunal) and, occasionally, fistulo-jejunal anastomoses. This array of surgical options enables targeted management of postoperative complications[148]. Acute complications, such as staple line failures, may warrant immediate reoperation. Later revisions typically address problems like stenosis or medically refractory GERD[149]. Figure 6 illustrates various scenarios of endoscopic failure, including intra-abdominal abscess formation, uncontrolled leakage, pathological connections between abdominal and thoracic cavities, and gastro-bronchial fistula, emphasizing the need for surgical intervention in complex cases.

Clinical evidence suggests that persisting with multiple endoscopic interventions may be suboptimal. Timely progression to surgical management could potentially reduce patient discomfort and overall healthcare expenses[150]. This approach balances conservative care with prompt surgical intervention when necessary, aiming to optimize patient outcomes and healthcare efficiency.

CONCLUSION

In conclusion, while SG has become the most popular bariatric procedure worldwide, complications remain a significant concern. A concerted effort to standardize surgical techniques and adopt evidence-based recommendations for minimally invasive treatments is ongoing, with the goal of optimizing patient outcomes. Healthcare professionals must possess a fundamental understanding of common complications and available treatment options, and a multidisciplinary team with specialized experience in bariatric surgery is best equipped to manage the complex needs of post-bariatric surgical patients. As endoscopic modalities continue to advance, they offer an increasingly important minimally invasive treatment option for addressing post-bariatric surgical complications.

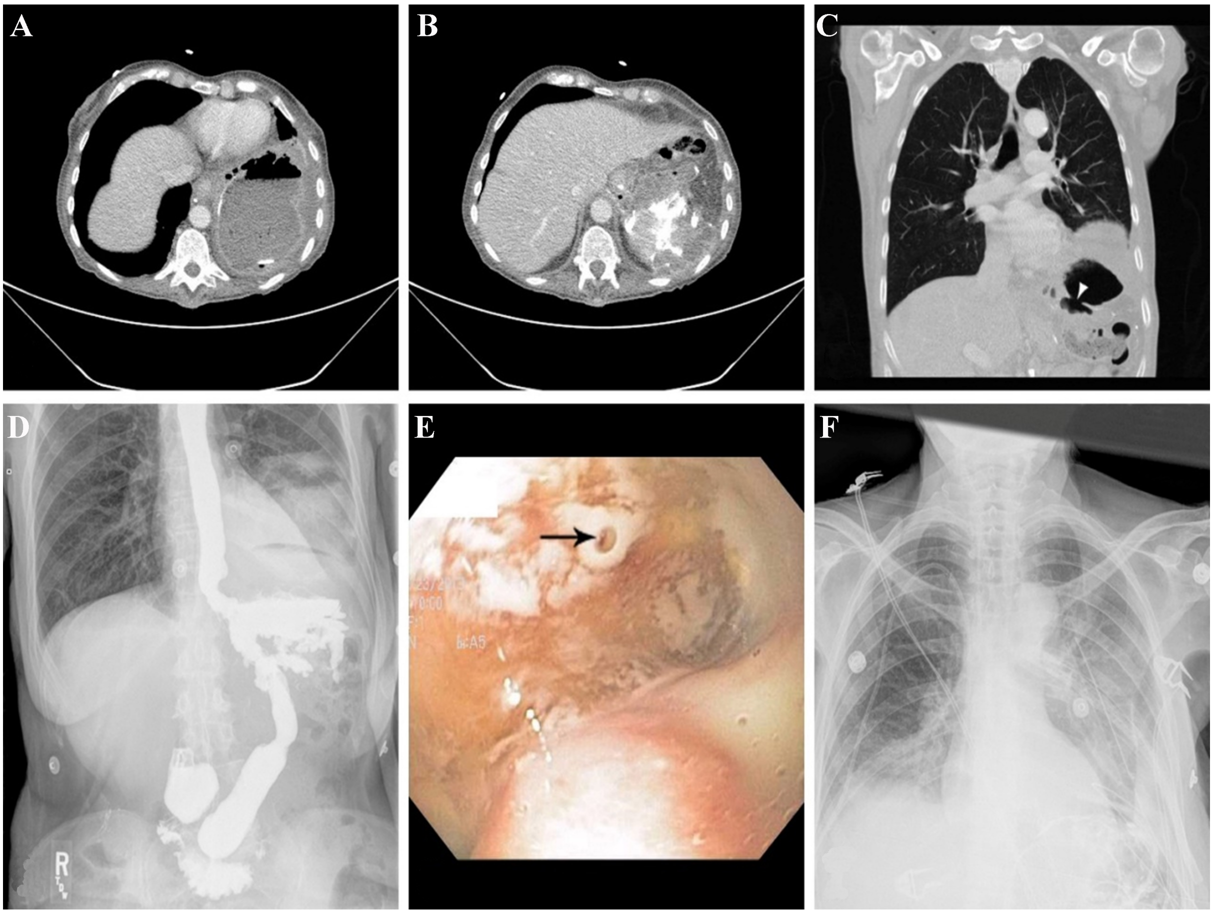

Figure 6. Endoscopic failure. (A) Large intra-abdominal abscess formation following SG; (B) Uncontrolled leakage following endoscopic management; (C) Pathological connection between abdominal and thoracic cavities due to abdominal abscess; (D and E) Gastro-bronchial fistula; (F) After resolution. SG: Sleeve gastrectomy.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study, data acquisition, data interpretation, drafted and revised the manuscript: Lee S
Made substantial contributions to the conception and design of the study, provided critical input to the revision, and commented on previous versions of the manuscript: Dang J
Made substantial contributions to the conception and design of the study, commented on previous versions of the manuscript, and gave final approval of the version to be published: Kroh M
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Conflicts of interest

Dang J is the Junior Editorial Board Member of the journal *Mini-invasive Surgery*, while the other authors have declared that they have no conflicts of interest.

Ethical approval and consent to participate

The Cleveland Clinic Foundation (CCF) institutional review board confirmed no formal ethical approval is required under current policies. This study does not require individual patient consent, in accordance with the Institutional Review Board (IRB) policies of CCF.

Consent for publication

Not applicable.

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