Heliyon 82 (2022) e08857

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Radiological stent placement of post sleeve gastrectomy leak: efficacy, imaging features and post-procedure complications

Giovanni Scavone [a,*], Giuseppe Caltabiano [a], Corrado Inì [b], Federica Castelli [a], Daniele Falsaperla [b], Antonio Basile [b], Luigi Piazza [c], Antonio Scavone [a]

[a] Department of Diagnostic Radiology, Neuroradiology and Interventional Radiology, "Garibaldi Centro" Hospital, Piazza Santa Maria di Gesù, 5, 95124 Catania CT, Italy
[b] Department of Radiodiagnostic and Radiotherapy Unit, University Hospital Policlinico "G.Rodolico-San Marco", Via Santa Sofia 78, 95123, Catania, Italy
[c] General and Emergency Surgery Department, "Garibaldi Centro" Hospital, Piazza Santa Maria di Gesù, 5, 95124 Catania CT, Italy

ARTICLE INFO

Keywords:
Sleeve gastrectomy
Bariatric surgery
Obesity
Radiological stent placement
Imaging

ABSTRACT

Laparoscopic sleeve gastrectomy (SG) is the most commonly performed bariatric procedure. The primary and insidious early post-SG complication is the gastric leak (GL). In literature, there are many studies describing the endoscopic stent placement as treatment of GL and few studies about stent placement performed by interventional radiology under fluoroscopic guide. Our aims were to describe the radiological stent placement technique, to compare endoscopic and radiological stent placement, to illustrate normal diagnostic features and summarise the incidence of complications after stent placement, removal, and their imaging features. This was a single centre retrospective study of 595 patients who underwent SG between 2011 and 2019. Inclusion criteria: patients who developed GL after SG and treated with gastro-oesophageal stent placement by endoscopy or interventional radiology; availability of medical history and imaging studies; follow-up time after stent removal (1 year). The rates of technical success, clinical success and complications after stent placement and removal were collected and compared between the two methods of stent positioning. A total of 17/595 (2.8%) patients developed a radiologically diagnosed GL after SG. The type II-III GLs (15/17) were treated with endoscopic or radiological stent placement. 9/15 (60%/Group A) patients underwent gastro-oesophageal stenting by interventional radiology and 6/15 (40%/Group B) were treated with endoscopic stent placement. The technical and clinical success rate was 100% for both groups. Stent migration occurred in 22% and 27% for Group A and B respectively. Post-extraction stenosis was the main late complication, occurring in 22% in Group A and 0% in Group B. Gastro-esophageal stent placement performed by interventional radiologists is a valid "mini-invasive" treatment for GL. This procedure is not inferior to endoscopic positioning regarding efficacy, periprocedural and postprocedural complication rate. It's necessary to be familiar with radiological findings after stent placement and removal. Computed tomography (CT) scan is the main radiological technique to identify stent placement complications. Upper gastrointestinal (UGI) series are the first radiological procedures used to detect late complications after stent removal.

1. Introduction

Obesity is a disease that reduces life expectancy, in addition to the increased morbidity and mortality [1, 2, 3]. Bariatric surgery is considered more effective than non-surgical treatments for obesity. It produces significant loss of weight compared with the common medical management and lifestyle changes and has a higher impact on obesity-related comorbidities [4].

According to the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) Registry (calendar years 2014–2018), which describes the principal surgical practices, laparoscopic sleeve gastrectomy (SG) is the most commonly performed bariatric procedure, followed by laparoscopic Roux-en Y gastric bypass (RYGB) and laparoscopic mini/one anastomosis gastric bypass (MGB/OAGB) [5, 6].

SG is a restrictive bariatric procedure. In this surgical technique, greater curvature of the gastric fundus, body, and proximal antrum are removed, leaving the pylorus intact; the gastric volume is therefore reduced by 70 % (Figure 1) [7].

SG is equally effective, safer and technically easier to perform than other bariatric procedures, such as RYGB [8, 9]. The American Society for

* Corresponding author.
E-mail address: gioscavone@hotmail.it (G. Scavone).

https://doi.org/10.1016/j.heliyon.2022.e08857
Received 29 October 2021; Received in revised form 12 January 2022; Accepted 25 January 2022

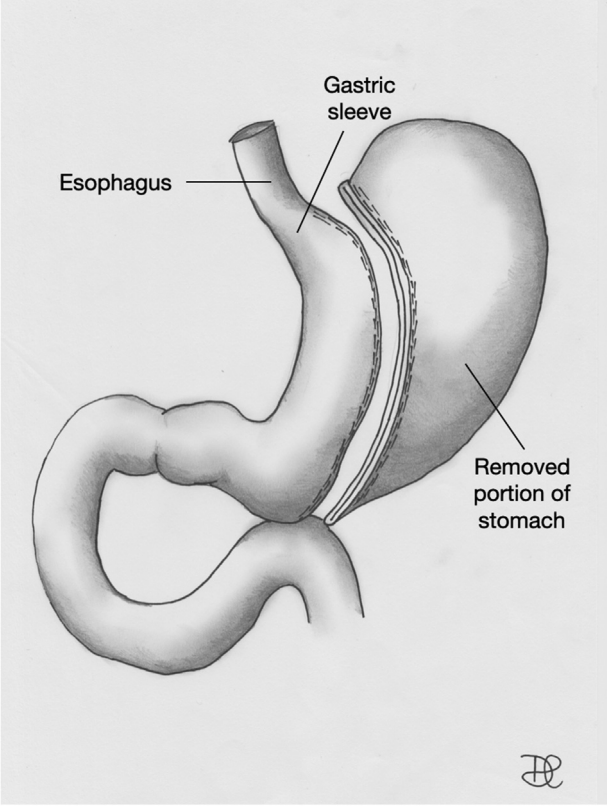

Figure 1. Anatomical changes resulting from Sleeve Gastrectomy. Courtesy of Daniele Carmelo Caltabiano.

Metabolic and Bariatric Surgery position statement concludes that SG provides significant and durable weight loss, improvements in medical co-morbidities, improved quality of life, with low complication and mortality rates in obese patients [10].

The primary and insidious early postoperative complication in SG is leak, occurring in 1%–8% of cases, leading to significant morbidity [11, 12, 13]. The gastric leak (GL) originates mainly from the proximal staple line near the gastro-oesophageal junction (GEJ) and it can result from technical failure or vascular injury, with a higher risk (2.9%) in super-obese patients (body mass index >50 kg/m^2) [14]. The GL can be classified on the basis of the morphology and on the time passed after surgery. GL can be morphologically distinguished as contained and well localized, with no evidence of massive spreading of gastric contents into abdominal cavity and without systemic symptoms (type I), extensive or with abscess (type II) and complex with internal subdiaphragmatic or gastrocutaneus fistula (type III) [15]. According to the time of onset, GL can be divided into "acute" (within 7 days of the procedure), "early" (1–6 weeks after the procedure), "late" (6–12 weeks after the procedure) and "chronic" (>12 weeks after the procedure) [16].

Radiological evaluation for GL can be performed with water-soluble contrast upper gastrointestinal imaging (UGI) and computed tomography (CT) with oral and intravenous contrast medium administration.

Several approaches are described to treat patient with postoperative GL including observation, endoscopic suturing or sealing, reintervention, percutaneous drainage and endoscopic or radiological stenting [17, 18, 19, 20, 21, 22, 23, 24, 25]. In most cases, the type of leak and the clinical condition of the patient are the main factors that define the chosen treatment option. Up to date, in literature, there are many studies describing endoscopic management and its results, although there is lack of studies about stent placement by interventional radiology and the diagnostic features [19, 20].

The aims of this paper were to describe the radiological stent placement technique and to compare endoscopic and radiological stent placement; to illustrate normal diagnostic features and summarise the incidence of radiologically identified complications after stent placement, removal, and their imaging features.

2. Materials and methods

This was a single centre retrospective study of 595 patients (F 423, M 172; mean age 41,2 years, range 18–70 years) who underwent SG between 2011 and 2019. All procedures were performed by expert surgeons who had completed the 'learning curve' (over 50 cases).

In the postoperative period, all patients were evaluated with clinical and laboratory tests and radiological examinations to detect possible complications after surgery, in particular GL. UGI series were performed on the third day after the procedure to exclude a GL or obstruction, before starting oral intake. CT was not performed routinely, but only in clinically stable patients with a clinical suspicion of early post-procedure complications, such as GL, haemorrhage, abscesses or lesions in other intra-abdominal organs. Indications for abdomen or chest-abdomen CT scans were abdominal pain, tachycardia, tachypnoea, dyspnoea, chest pain, fever, leucocytosis, hypotension and vomiting. The CT technique includes both oral (Gastrografin®, Bayer 370 mg/ml) and intravenous contrast medium administration. Chest CT was also recommended in order to exclude other causes of pain, such as pulmonary embolism, pleural effusion or lung infection.

Contained GLs (type I) detected were treated with simple medical therapy, clinical and radiological observation. Extensive and complex GLs detected were treated with endoscopic or radiological stent placement. The stents used were self-expandable fully covered double-bump metal stent with radiopaque markers at both ends (Taewoong Niti-S Beta Esophageal Stent). The patients with stent placement have received a semi-liquid diet while the stent was in place.

Percutaneous drainage was carried out for each fluid collection >3 cm [26]. Ultrasound (US) or CT guidance for the placement of the access needle was used (depending on the dimension and location of the collection). The drainage tube, a locking pigtail catheter with multi-side-hole at the distal loop and range in size from 8 to 12 Fr, was left in place, periodically flushed with saline, until drained material was less than 20 ml/day or there was no more collection on follow-up imaging. Stent placement and percutaneous drainage were performed by expert interventional radiologists during the same session.

Low dose CT with oral contrast medium administration was performed on the third day after the stenting procedure to exclude a stent migration with reappearance of GL, stent sweeping or stenosis due to mucosal hypertrophy and to detect other chest and abdominal complications, such as pleural effusion and abscesses.

The stent migration was treated by endoscopic replacement and a low dose CT with oral contrast medium administration was performed on the third day after this procedure to confirm the correct stent replacement and to exclude the GL reappearance. The stent sweeping was evaluated with simple clinical observation and a low dose CT with oral contrast medium administration was recommended seven days later to confirm the correct stent placement.

The stent placed either by radiologists or endoscopists were left in place for 3–4 weeks. The stent retrieval was carried out using an Endoscopy. The proximal portion of the stent was removed using a sheath passing through the mouth.

All the patients were evaluated for a period of time of at least 1 year following the stent removal to exclude late complications, such as post-extraction stenosis, defined as a narrowing of the gastric lumen associated with symptoms of upper gastrointestinal tract obstruction; UGI series were performed only in clinically suspected patients. Main indications for UGI series were vomiting, dysphagia and gastro-oesophageal reflux. Endoscopic dilatation was carried out in cases of symptomatic stenosis documented after stent removal.

Inclusion criteria of this retrospective study were: patients who developed GL after SG treated with gastro-oesophageal stent placement;

availability of medical history and imaging studies; follow-up time after stent removal of at least 1 year.

Patients who underwent gastro-oesophageal stenting were divided into two groups based on whether placement was performed by interventional radiologists under fluoroscopic guidance (Group A) or by endoscopists (Group B). Technical success rate was defined as the ability to complete deployment of the stent with no immediate imaging evidence of persistent leak. Clinical success was defined as resolution of gastric leak by stent deployment without the need for further intervention measured at 1-year. The rates of technical success, clinical success, and complications after stent placement (including periprocedural ones) and removal were collected and compared between the two groups.

Our retrospective study was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; all the data used were anonymized or maintained with confidentiality. Informed consent was waived because of the retrospective design of the study.

2.1. Radiological stent placement

Radiological stent placement was performed by an interventional radiologist in the angiographic room. The patient lay supine or in left anterior oblique position. Emptying the stomach with a nasogastric tube before the procedure can be useful to make it acquire a cylindrical shape and make it easier to reach the pylorus.

A 5 Fr Bern catheter (100 cm length, Boston Scientific, USA) lubricated with jelly, inserted on a 0.35 hydrophilic wire (180 cm length, Terumo, Japan) is advanced through the mouth into the stomach under fluoroscopic guidance. The passage through the hypopharynx should be performed carefully as the wire and the catheter could accidently get into the larynx and proceed in the airways. Asking the patient to swallow while advancing the wire help to enter the oesophagus avoiding the laryngeal lumen. After reaching the esophagogastric junction, the leak is documented by injecting radiopaque oral contrast media through the catheter under fluoroscopic check. The site of the leak is then marked by fluoroscopy.

The catheter is advanced into the duodenum and the hydrophilic wire is exchanged for a 260-cm Amplatz Super Stiff wire (Boston Scientific, USA). A preloaded stent delivery system, whose proximal part is lubricated with jelly, is passed over the guidewire to the chosen position. The Niti-S Beta stent (length 200 mm, body diameter 24 mm, Prion Medical BV) is a self-expandable fully covered double-bump metal stent with radiopaque markers at both extremities. The introducing sheath is slowly withdrawn over the pusher and the stent is released under fluoroscopic check to secure the correct placing. The stent delivery system is removed, and the catheter is reinserted over the wire until it reaches the upper extremity of the stent. The correct expansion of the stent and the exclusion of the leakage is checked by a second injection of radiopaque oral contrast media. The catheter is finally withdrawn from the mouth (Figure 2).

2.2. Endoscopic stent placement

Endoscopic stent placement was performed by endoscopist. Under sedation, the Niti-S Beta stent (length 200 mm, internal diameter 24 mm, Prion Medical BV) is introduced over a delivery device passed on a guidewire positioned in the duodenum or proximal jejunum. The proximal pole of self-expandable fully covered stent was placed above the

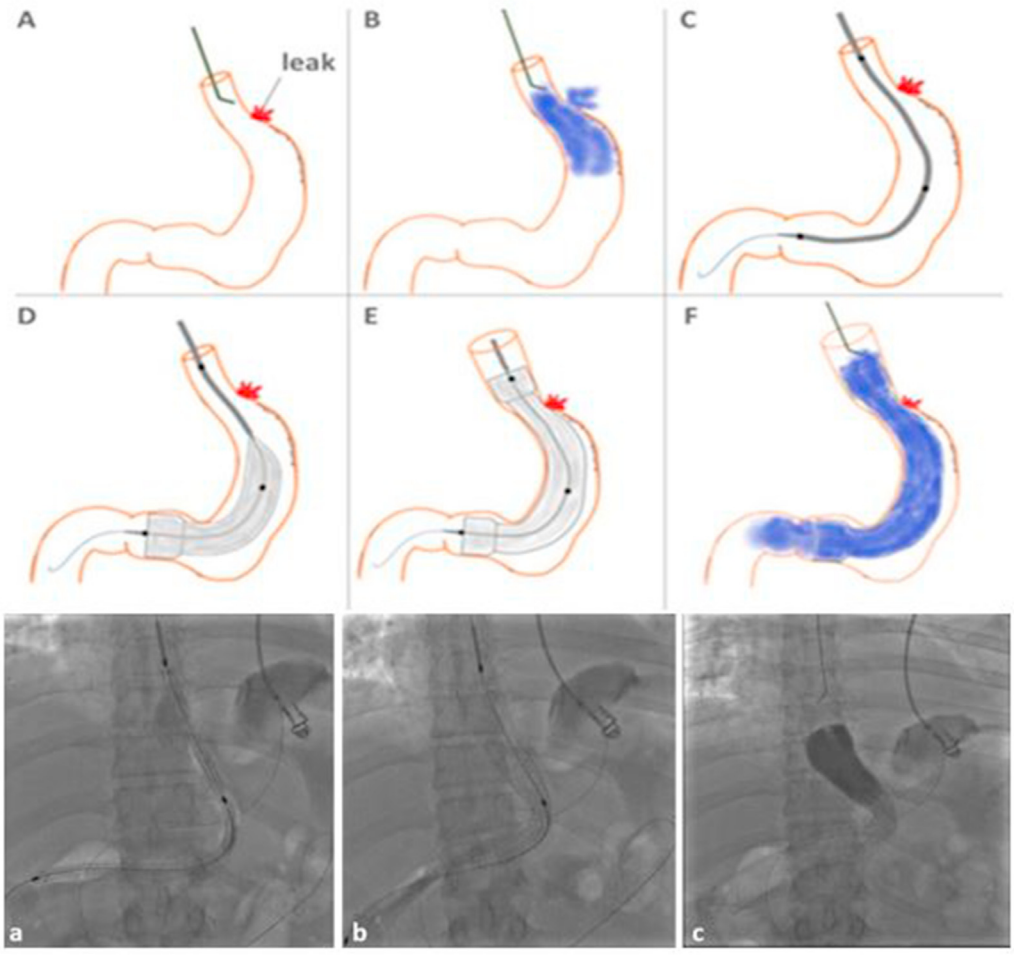

Figure 2. Anatomical drawings (A–F) made to schematize the stent placement steps: (A) catheter insertion at the superior esophagogastric junction (B) injection of contrast medium from the catheter with documentation of the leak; (C) the stent delivery system, equipped with radiopaque markers, is positioned through the supportive guide; (D–E) the stent is released under fluoroscopic guidance to exclude the leak; (F) final check with contrast medium from the proximal end to document correct expansion and positioning of the stent. Fluoroscopic images (a–b) show the Niti-S Beta stent deployment through its delivery system passed over the guidewire to the chosen position. Fluoroscopic image (c) shows the final check after stent placement with correct expansion of the stent documented by normal passage of contrast media administered with a hydrophilic catheter advanced through the mouth.

region of pathological leak; the distal extremity of stent was placed distal to sleeve resection. Under fluoroscopic or endoscopic guidance the exact location of the stent was then documented. A radiological study was performed the day after stent placement to confirm the correct location of the stent and to assess possible complications or persisting leakage. The stent was endoscopically removed after 3–4 weeks (using an endoscopic forceps) based on the decision of the endoscopist.

3. Results

Between 2011 and 2019, a total of 17/595 (2.8%) patients (female 14, male 3; mean age 38.1 years, range 22–49 years) developed a radiologically diagnosed GL after SG. Only 1/17 GL was detected using UGI, confirmed by a CT scan examination; other GLs (16/17) were identified using CT scans.

Based on the time of diagnosis 70% (12/17) GLs were “acute”, 24% (4/17) "early" and 6% (1/17) "late". 12% GLs (2/17) were morphologically type I, 82% (14/17) type II and 6% (1/17) type III. 100% (17/17) of leaks appeared in the proximal third of the stomach, close to the gastro-oesophageal junction. The most common clinical presentation was abdominal pain (16/17, 94%) followed by tachycardia (10/17, 59%), fever and/or sepsis (6/17, 35%). The demographic and clinicopathological characteristics of patients with GL after SG are summarized in Table 1.

Patients with type I GLs (2/17) were treated with medical therapy (proton-pump inhibitors, antibiotics), they received exclusive parenteral nutrition and underwent clinical and radiological follow-ups; the clinical success was 100%. The type II and III GLs (15/17) were treated with endoscopic or radiological stent placement based on immediate availability of interventional radiologists or endoscopists. 9/15 (60% - Group A) patients underwent gastro-oesophageal stenting by interventional radiology under fluoroscopic guidance (Table 2) and 6/15 (40% - Group B) patients were treated with endoscopic stent placement (Table 3). The mean procedure times was 28.8 min (range, 25–34 min) for radiological stent placement and 32 min (range, 26.5–39 min) for endoscopic stent placement. The technical success of stent placement was 100% for both endoscopic and radiological approaches with no intraprocedural complications or symptomatic reflux and a good tolerance of all patients to the stent. Some patients suffered transient nausea or retrosternal discomfort.

Table 1. Demographic data and clinicopathological features of enrolled population.

Patient	Gender	Age	Body mass index (kg/m^2)	GL type	Symptoms
1	Female	49	51	Acute Type II	Abdominal pain, tachycardia, sepsis
2	Female	33	48	Acute Type II	Abdominal pain, tachycardia, sepsis
3	Female	46	46	Early Type II	Abdominal pain, sepsis
4	Female	24	55	Acute Type II	Tachycardia
5	Male	47	54	Acute Type II	Abdominal pain
6	Female	35	53	Acute Type II	Abdominal pain, tachycardia
7	Female	23	48	Early Type II	Abdominal pain, tachycardia
8	Female	36	52	Early Type II	Abdominal pain, tachycardia
9	Female	41	50	Acute Type II	Abdominal pain, tachycardia, fever
10	Male	22	51	Acute Type II	Abdominal pain
11	Male	38	49	Acute Type II	Abdominal pain, tachycardia
12	Female	41	50	Acute Type II	Abdominal pain, tachycardia
13	Female	47	48	Acute Type II	Abdominal pain
14	Female	35	53	Acute Type II	Abdominal pain, tachycardia
15	Female	43	57	Late Type II	Abdominal pain, fever, vomiting
16	Female	47	46	Early Type I	Abdominal pain, fever
17	Female	40	56	Acute Type I	Abdominal pain

9/15 (60%) patients underwent percutaneous drainage of abdominal fluid collection together with oesophageal stenting, with no perioperative complications.

All patients were evaluated with low dose CT with oral contrast medium administration on the third day after stent placement to detect a stent migration with reappearance of GL, stent sweeping, stenosis due to mucosal changes (hypertrophy) and other chest and abdominal complications, such as pleural effusion and abscesses. Asymptomatic stent migration occurred in 3/15 (20%) patients in caudal direction, in particular it was diagnosed in 2/9 (22%) and 1/6 (27%) after radiological and endoscopic placement respectively. No stent migration occurred in cranial direction and no specific symptoms were observed. All stent migrations were treated by endoscopic replacement and low dose CT with oral contrast medium administration performed on the third day after the procedure confirmed the correct stent replacement and no GL reappearance.

Asymptomatic stent sweeping occurred in 3/15 (20%) patients, in particular, it occurred in patients treated with radiological stent placement 3/9 (33%) and none after endoscopic stent placement.

No stent sweeping required additional replacement. Clinical observation and a low dose CT with oral contrast medium administration performed seven days later have been adequate to exclude the stent migration and the need for replacement.

Mucosal hypertrophy represents an inflammatory change in the inner layer of gastric wall and occurred in 1/15 (6%) patient after radiological stent placement, close to the distal edge of the stent. This mucosal hypertrophy required no endoscopic or surgical interventions and no specific symptoms or stenosis were associated.

All patients underwent endoscopic stent removal after 3–4 weeks (mean duration 24 days, range 21–32 days) with no intraprocedural complications and clinical follow-up at 3, 6 and 12 months. If patients showed symptoms of late complications, such as post-extraction stenosis, UGI series were performed. In total, 7/15 patients underwent UGI scans: stenosis at the level of the proximal stent margin occurred in 1/15 (6%) patient after stent placement, esophageal spasms without significant stenosis occurred in 2/15 (13%) patients, 4/15 (26%) patients had a negative UGI scan examination. The only post-extraction stenosis was treated with endoscopic balloon dilatation. The technical success was 100% and none of the patients reported a symptomatic gastro-oesophageal reflux and required other surgical procedures.

Comparing Group A and Group B, both demonstrated a clinical and technical success rate of 100%. Among the early complications after stent placement, stent migration occurred in 2/9 (22%) patients in Group A and 1/6 (16 %) in Group B. Post-extraction stenosis was the main late complication, occurring in 1/9 (22%) in Group A and 0/6 (0%) in Group B (Tables 2, 3).

4. Discussion

GL represents one of the most fearful complications after SG [27, 28]. The pathogenesis of the GL can be considered multifactorial, being influenced both by mechanical factors, such as tension on the staple line and increased endoluminal pressure, and by vascular factors, such as locoregional ischaemia and inflammation [14]. Aurora et al reviewed 29

Table 2. Patients treated with radiological stent placement for gastric leak after sleeve gastrectomy: technical success, clinical success, procedure time, placement duration, complications and collateral findings.

Patient	Technical success	Clinical success	Procedure time (minutes)	Placement duration (days)	Complications	Collateral findings
2	Yes	Yes	26	28	Migration	-
3	Yes	Yes	31.5	26	-	Mucosal hypertrophy
4	Yes	Yes	28	30	Stenosis	Sweeping
5	Yes	Yes	34	21	-	Sweeping
6	Yes	Yes	29	28	Migration	-
9	Yes	Yes	25	25	-	-
11	Yes	Yes	31	21	-	-
12	Yes	Yes	27	22	-	Sweeping
13	Yes	Yes	28.5	21	-	-

Table 3. Patients treated with endoscopic stent placement for gastric leak after sleeve gastrectomy: technical success, clinical success, procedure time, placement duration, complications and collateral findings.

Patient	Technical success	Clinical success	Procedure time (minutes)	Placement duration (days)	Complications	Collateral findings
1	Yes	Yes	28	32	Migration	-
7	Yes	Yes	26.5	21	-	-
8	Yes	Yes	35	23	-	-
10	Yes	Yes	33	26	-	Esophageal spasms
14	Yes	Yes	39	21	-	-
15	Yes	Yes	31	21	-	-

studies with a total of 4888 patients who underwent SG: the risk of GL was 2.4% globally, mostly located in the esophagogastric junction (89%) and a higher risk (2.9%) was reported for super-obese patients (body mass index >50 kg/m^2) and for Bougie size of <40Fr [14]. The clinical presentation of stapled line leaks varies widely from asymptomatic forms to peritonitis with septic shock and the most frequent symptoms are abdominal pain, fever, tachycardia, and tachypnoea [29]. The overall leak rate of our series was 2.8% and 100% of leaks appeared on the left side and just inferior to the gastro-oesophageal junction. Abdominal pain (94%), tachycardia (59%), fever and sepsis (35%) were the major manifesting signs. The findings of our study are consistent with previous reports.

GL management depends on the patient's clinical condition and the local availability of "minimally invasive" treatments. Stenting helps to heal the leak both by decreasing the endoluminal pressure in the gastro-oesophageal tract and by preventing peritoneal contamination through the lesion [30]. The simultaneous drainage of perivisceral collections reduces the local inflammation and the tissue damage, facilitating the healing of the leak. A wide experience is reported in literature about the endoscopic treatment of GL [17, 18, 30]. However, few studies report the efficacy and post-procedure complication ratio of stent placement by interventional radiology [19, 20].

In our series, the technical success rate of stent placement was 100% for both endoscopic and radiological approach with no intraprocedural complications or symptomatic reflux and a good tolerance of all patients to the stent with only transient nausea or retrosternal discomfort. Although not well demonstrated, it is conceivable that the insufflation of air required for performing the endoscopy, especially in patients with acute leak, could further stress the staple line by increasing the endoluminal pressure; radiological positioning, instead, not requiring insufflation, is less traumatic for the gastrointestinal tract and avoids excessive tension on the staple line.

In a recent meta-analysis by Okazaki et al. on 187 endoscopic placements, migration occurred in 28.2% of cases, with rates ranging from 31.5% to 27.1% depending on the type of stent used [18]. In our study, the migration rate after radiological positioning (22%) is not higher than the rate reported in literature by endoscopists.

Up to date, there are very few studies reporting radiological gastro-oesophageal stent placement for treating GL after SG; Guzaiz et al. described their monocentric experience in 12 patients demonstrating a 100% success rate but a high migration rate (50%), could be partially due to the use of shorter stents [19].

Serra et al. have described radiological stent placement in a case series of 2 patients who underwent SG with GL with a successful healing of the leak in both cases, using a coated self-expandable stents and an uncovered Wallstent. Then they removed the stent in 6–8 weeks. This strategy allows bypassing pathological site of leakage with minimal discomfort for patients [20].

The risk of stenosis or stent migration does not seem related to the chosen positioning methodology. The factors that most influence this risk

Figure 3. Normal post-stent placement CT imaging: after oral contrast medium administration CT image shows passage of oral contrast through gastro-oesophageal stent, fat stranding (black arrow) and gas (white arrow) around gastric pouch and in perisplenic region.

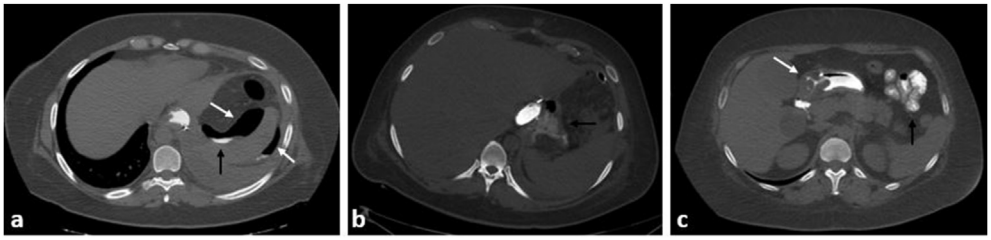

Figure 4. Axial CT image after oral contrast medium administration (a) shows a stent migration characterised by significant extraluminal gas in the abdominal cavity (white arrow) and extraluminal passage of oral contrast (black arrow) for persistent leak at the gastro-oesophageal junction. Axial CT image after oral contrast medium administration (b) shows a stent sweeping characterised by little extraluminal passage of oral contrast circumscribed by the surrounding tissues (black arrow) without extraluminal peritoneal contrast spreading. Axial CT image after oral contrast medium administration (c) shows a mucosal hypertrophy close to the distal edge of the stent characterised by focal wall thickening (white arrow) and regular passage of oral contrast in the lumen of the small bowel (black arrow).

seem to be the type of stent chosen and the stent placement duration [31, 32]. The use of partially covered stents is associated with less risk of migration than fully covered metal stents and plastic stents [19]; however retrieval may become difficult requiring modified techniques due to tissue ingrowth and fibrotic reaction in the uncovered part of the stent. This change leads to increase in the risk of proximal mucosal injury or residual stenosis upon removal of the stent [33, 34]. A self-expandable fully covered double-bump metal stent was used and a range of 3–4 weeks for stent placement was enough to exclude the GL in patients treated. Previous studies recommend maintaining stent for a period of 3–12 weeks since early stent removal (before 3 weeks) showed persistence of the leak despite treatment [19].

The utility of routine radiological imaging is controversial in the bariatric surgery literature, especially because often radiologists are unfamiliar with possible post-surgical complications. Many patients are young and may present non-specific symptoms; nevertheless, a diagnostic investigation should always be advisable. As reported in literature, in our study cohort, low dose CT with water-soluble oral contrast medium administration (Gastrografin®) was performed on the third day after the stent placement to detect stent migration, stent sweeping or stenosis due to mucosal hypertrophy and to identify other chest and abdominal complications. In normal post-stent placement CT imaging, rapid passage of oral contrast through gastro-oesophageal stent, fat stranding and gas around gastric pouch may be observed (Figure 3).

The most frequent early placement complication was stent migration, identified with CT in about 20% of our study cohort; this data appears to be lower than that reported in the literature, where stent migration rate occurred in more than a third of cases [20]. The stent migration is characterised by significant extraluminal gas in the abdominal cavity and extraluminal passage of oral contrast for persistent leak at the gastro-oesophageal junction (Figure 4a). This early complication requires stent replacement. Even if partially covered stents have a lower rate of migration, they are difficult to remove increasing the risk of complication. Several approaches are described to prevent stent migration: endoscopic stent suturing to the oesophageal wall or anchoring the stent with metal clips. However further studies are needed to standardize these procedures [18, 22].

Stent sweeping and mucosal hypertrophy are not considered stent placement complications but only collateral post-procedural findings because they do not require additional treatments and generally are asymptomatic. In our experience, CT identified stent sweeping in 20% of patients, caused by passage of oral contrast between esophageal wall and stent and characterised by little extraluminal passage of oral contrast circumscribed by the surrounding tissues without extensive peritoneal contrast spreading (Figure 4b). Clinical observation and a further CT are adequate to exclude the appearance of stent migration and the need for replacement. Mucosal hypertrophy close to the distal edge of the stent was identified with CT in 6% of patients, characterised by focal wall

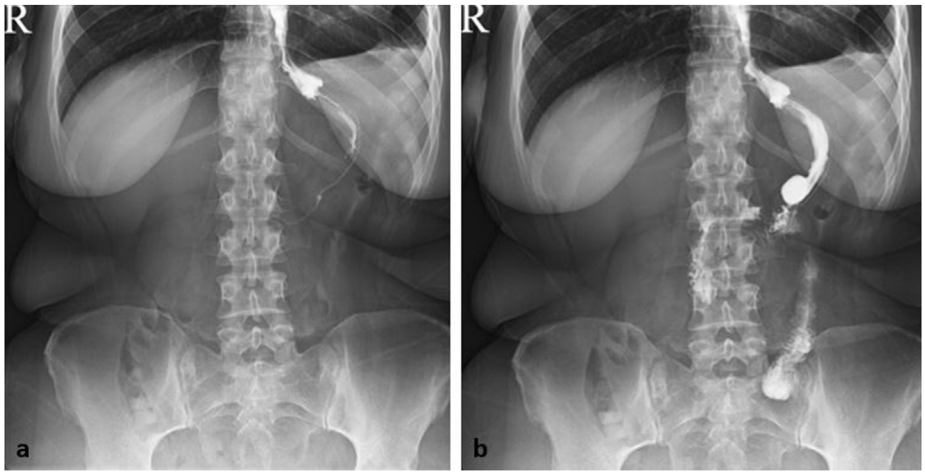

Figure 5. Normal post-stent removal UGI imaging: after oral contrast medium administration UGI images show gastric pouch tubular configuration, rapid passage of oral contrast with opacification of jejunal loops.

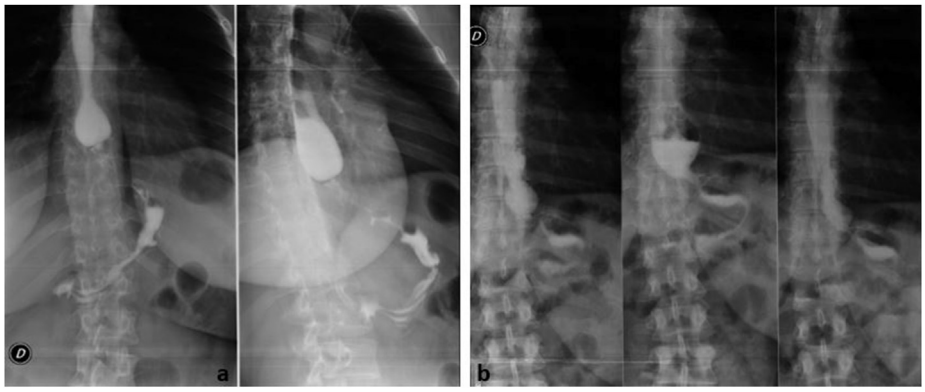

Figure 6. UGI images (a) in patient with vomiting and dysphagia, show a stenosis at the level of the proximal stent margin with abnormal distension of esophageal lumen and absent passage of oral contrast into the intestinal lumen. UGI images (b) in patient with dysphagia and regurgitation, show esophageal spasms without significant stenosis with "corkscrew or rosary bead esophagus".

thickening, regular distension of gastro-oesophageal lumen and passage of oral contrast in the small bowel (Figure 4c).

UGI series are the main radiological technique to detect late complications after stent removal in patients with suspected clinical symptoms; UGI series allow to provide dynamic imaging of oral contrast medium progression and to identify proximal or distal stenosis [15]. In the normal post-stent removal UGI imaging, gastric pouch typically has a tubular configuration and a rapid passage of oral contrast is observed (Figure 5). A stenosis at the level of the proximal stent margin occurred in 6% of patients after stent removal and was treated with endoscopic balloon dilatation. Vomiting, dysphagia and esophago-gastric reflux are common clinical presentations and radiological findings of stenosis may include abnormal distension of esophageal lumen and slow or absent passage of oral contrast in the small bowel (Figure 6a). Esophageal spasms without significant stenosis occurred in 13% of patients and identified with UGI series. Esophageal spasms is a transient physiological alteration and are not considered a post-removal stent complications since it does not require additional treatments. Dysphagia and regurgitation are main clinical presentations and UGI findings may include "corkscrew or rosary bead esophagus" appearance (Figure 6b).

5. Conclusion

Gastro-oesophageal stent placement under fluoroscopic guidance performed by interventional radiologists is a valid “mini-invasive” treatment for GL. This procedure is not inferior to endoscopic positioning regarding efficacy, periprocedural and postprocedural complication rates. The choice between the two methods may depend on local availability and presence of expert operators. Interventional radiology allows for positioning of the gastroesophageal stent and the performance of percutaneous drainage of fluid collections during a single procedure. Other advantage is to perform intraprocedural radiological study after stent deployment to confirm exclusion of gastric leak. The clinical success is most influenced by type of stent chosen (length, diameter, partially/fully covered) and stent placement duration.

In clinical practice, it is necessary to be familiar with the radiological features of non-pathological stent placement and post-removal complications. CT scan is the main radiological technique to identify stent placement complications. UGI series are the first radiological procedures used to detect late complications after stent removal. Further studies on the outcome and safety of radiological stent positioning are desirable to better underline specific indication and contraindication for this approach.

Declarations

Author contribution statement

Giovanni Scavone, Giuseppe Caltabiano and Corrado Inì: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Federica Castelli, Daniele Falsaperla, Antonio Basile, Luigi Piazza and Antonio Scavone: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

[1] R.S. Ahima, in: R.S. Ahima (Ed.), Obesity Epidemiology, Pathogenesis, and Treatment: a Multidisciplinary Approach, first ed., Apple Academic Press, New York, 2014.

[2] L. Sjöström, K. Narbro, C.D. Sjöström, K. Karason, B. Larsson, H. Wedel, T. Lystig, M. Sullivan, C. Bouchard, B. Carlsson, C. Bengtsson, S. Dahlgren, A. Gummesson, P. Jacobson, J. Karlsson, A.K. Lindroos, H. Lonroth, I. Naslund, T. Olbers, K. Stenlof, J. Torgerson, G. Agren, L.M. Carlsson, Swedish Obese Subjects Study. Effects of bariatric surgery on mortality in Swedish obese subjects, N. Engl. J. Med. 357 (8) (2007) 741–752.

[3] A. Romero-Corral, V.M. Montori, V.K. Somers, J. Korinek, R.J. Thomas, T.G. Allison, F. Mokadam, F. Lopez-Jimenez, Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: a systematic review of cohort studies, Lancet 368 (9536) (2006) 666–678.

[4] E. Ravussin, D.H. Ryan, Expert panel report: guidelines (2013) for the management of overweight and obesity in adults, Obesity 22 (S2) (2014) S41–S410.

[5] G. Scavone, F. Castelli, C.D. Caltabiano, M.V. Raciti, C. Ini', A. Basile, L. Piazza, A. Scavone, Imaging features in management of laparoscopic mini/one anastomosis gastric bypass post-surgical complications, Heliyon 7 (8) (2021 Aug), e07705.

[6] G. Scavone, D.C. Caltabiano, F. Gulino, M.V. Raciti, A. Giarrizzo, A. Biondi, L. Piazza, A. Scavone, Laparoscopic mini/one anastomosis gastric bypass: anatomic features, imaging, efcacy and postoperative complications, Updat. Surg. (2020).

[7] R.T. Yehoshua, L.A. Eidelman, M. Stein, S. Fichman, A. Mazor, J. Chen, H. Bernstine, P. Singer, R. Dickman, N. Beglaibter, S.A. Shikora, R.J. Rosenthal, M. Rubin, Laparoscopic sleeve gastrectomy—volume and pressure assessment, Obes. Surg. 18 (9) (2008) 1083–1088.

[8] J.P. Buwen, M.R. Kammerer, A.C. Beekley, D.S. Tichansky, Laparoscopic sleeve gastrectomy: the rightful gold standard weight loss surgery procedure, Surg. Obes. Relat. Dis. 11 (6) (2015) 1383–1385.

[9] S.B. Kumar, B.C. Hamilton, S.G. Wood, S.J. Rogers, J.T. Carter, M.Y. Lin, Is laparoscopic sleeve gastrectomy safer than laparoscopic gastric bypass? a comparison of 30-day complications using the MBSAQIP data registry, Surg. Obes. Relat. Dis. 14 (3) (2018) 264–269.

[10] M. Ali, M.E. Chaar, S. Ghiassi, A.M. Rogers, American Society for Metabolic and Bariatric Surgery updated position statement on sleeve gastrectomy as a bariatric procedure, Surg. Obes. Relat. Dis. 13 (10) (2017) 1652–1657.

[11] G. Cesana, S. Cioffi, R. Giorgi, R. Villa, M. Uccelli, F. Ciccarese, G. Castello, B. Scotto, S. Olmi, Proximal leakage after laparoscopic sleeve gastrectomy: an analysis of preoperative and operative predictors on 1738 consecutive procedures, Obes. Surg. 28 (3) (2017) 627–635.

[12] C. Jurowich, A. Thalheimer, F. Seyfried, M. Fein, G. Bender, C.T. Germer, C. Wichelmann, Gastric leakage after sleeve gastrectomy-clinical presentation and therapeutic options, Langenbeck's Arch. Surg. 396 (7) (2011) 981–987.

[13] M.M. Hutter, B.D. Schirmer, D.B. Jones, C.Y. Ko, M.E. Cohen, R.P. Merkow, N.T. Nguyen, First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass, Ann. Surg. 254 (3) (2011) 410–422.

[14] A.R. Aurora, L. Khaitan, A.A. Saber, Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients, Surg. Endosc. 26 (6) (2012) 1509–1515.

[15] G. Al Hajj, R. Chemaly, Fistula following laparoscopic sleeve gastrectomy: a proposed classification and algorithm for optimal management, Obes. Surg. 28 (3) (2018) 656–664.

[16] R.J. Rosenthal, , International Sleeve Gastrectomy Expert Panel, A.A. Diaz, D. Arvidsson, R.S. Baker, N. Basso, D. Bellanger, C. Boza, H. El Mourad, M. France, M. Gagner, M. Galvao-Neto, K.D. Higa, J. Himpens, C.M. Hutchinson, M. Jacobs, J.O. Jorgensen, G. Jossart, M. Lakdawala, N.T. Nguyen, D. Nocca, G. Prager, A. Pomp, A.C. Ramos, R.J. Rosenthal, S. Shah, M. Vix, A. Wittgrove, N. Zundel, International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases, Surg. Obes. Relat. Dis. 8 (1) (2012) 8–19.

[17] X. De Aretxabala, J. Leon, G. Wiedmaier, I. Turu, C. Ovalle, F. Maluenda, C. Gonzalez, J. Humphrey, M. Hurtado, C. Benavides, Gastric leak after sleeve gastrectomy: analysis of its management, Obes. Surg. 21 (8) (2011) 1232–1237.

[18] O. Okazaki, W.M. Bernardo, V.O. Brunaldi, C.C.C. Junior, M.K. Minata, D.T.H. de Moura, T.F. de Souza, J.M. Campos, M.A. Santo, E.G.H. de Moura, Efficacy and safety of stents in the treatment of fistula after bariatric surgery: a systematic review and meta-analysis, Obes. Surg. 28 (6) (2018) 1788–1796.

[19] N. Guzaiz, M. Arabi, A. Khankan, R. Salman, M. Al-Toki, S. Qazi, A. Alzakari, M. Al-Moaiqel, Gastroesophageal stenting for the management of post sleeve gastrectomy leak. A single institution experience, Saudi Med. J. 37 (12) (2016) 1339–1343.

[20] C. Serra, A. Baltasar, L. Andreo, N. Pérez, R. Bou, M. Bengochea, J.J. Chisbert, Treatment of gastric leaks with coated self-expanding stents after sleeve gastrectomy, Obes. Surg. 17 (7) (2007) 866–872.

[21] G.H. Loo, R. Rajan, N.R.K. Nik Mahmood, Staple-line leak post primary sleeve gastrectomy. A two patient case series and literature review, Ann Med Surg (Lond). 44 (2019; Jul 2) 72–76.

[22] T.C.C. Boerlage, G.P.M. Houben, M.J.M. Groenen, K. van der Linde, A.W.J.M. van de Laar, M. Emous, P. Fockens, R.P. Voermans, A novel fully covered double-bump stent for staple line leaks after bariatric surgery: a retrospective analysis, Surg. Endosc. 32 (7) (2018) 3174–3180.

[23] S.G. Leeds, J.S. Burdick, Management of gastric leaks after sleeve gastrectomy with endoluminal vacuum (E-Vac) therapy, Surg. Obes. Relat. Dis. 12 (7) (2016) 1278–1285.

[24] M. Gjeorgjievski, Z. Imam, M.S. Cappell, L.H. Jamil, M. Kahaleh, A comprehensive review of endoscopic management of sleeve gastrectomy leaks, J. Clin. Gastroenterol. 55 (7) (2021 Aug 1) 551–576.

[25] G. Donatelli, A. Spota, F. Cereatti, S. Granieri, I. Dagher, R. Chiche, J.-M. Catheline, G. Pourcher, L. Rebibo, D. Calabrese, S. Msika, C. Dammaro, H. Tranchart, P. Lainas, T. Tuszynski, F. Pacini, R. Arienzo, J.-M. Chevallier, N. Trelles, A. Lazzati, L. Paolino, F. Papini, A. Torcivia, L. Genser, K. Arapis, A. Soprani, B. Randone, D. Chosidow, J.-L. Bouillot, J.-P. Marmuse, J.-L. Dumont, Endoscopic internal drainage for the management of leak, fistula, and collection after sleeve gastrectomy: our experience in 617 consecutive patients, Surg. Obes. Relat. Dis. 17 (8) (2021 Aug) 1432–1439.

[26] H.W. Charles, Abscess drainage, Semin. Intervent. Radiol. 29 (4) (2012) 325–336.

[27] K. Sarkhosh, D. Birch, A. Sharma, S. Karmali, Complications associated with laparoscopic sleeve gastrectomy for morbid obesity: a surgeon's guide, Can. J. Surg. 56 (5) (2013) 347–352.

[28] S. Moon Han, W.W. Kim, J.H. Oh, Results of laparoscopic sleeve gastrectomy (LSG) at 1 year in morbidly obese Korean patients, Obes. Surg. 15 (2005) 1469–1475.

[29] M.F. Márquez, M.F. Ayza, R.B. Lozano, M. Del mar Rico Morales, J.M. García Díez, R.B. Poujoulet, Gastric leak after laparoscopic sleeve gastrectomy, Obes. Surg. 20 (9) (2010) 1306–1311.

[30] A.M. Burgos, I. Braghetto, A. Csendes, F. Maluenda, O. Korn, J. Yarmuch, L. Gutierrez, Gastric leak after laparoscopic-sleeve gastrectomy for obesity, *Obes. Surg.* 19 (12) (2009) 1672–1677.

[31] T.C.C. Boerlage, G.P.M. Houben, M.J.M. Groenen, K. Van der Linde, M. Emous, P. Fockens, R.P. Voermans, A novel fully covered double-bump stent for staple line leaks after bariatric surgery: a retrospective analysis, Surg. Endosc. 32 (7) (2018) 3174–3180.

[32] F. Garofalo, M. Noreau-Nguyen, R. Denis, H. Atlas, P. Garneau, R. Pescarus, Evolution of endoscopic treatment of sleeve gastrectomy leaks: from partially covered to long, fully covered stents, Surg. Obes. Relat. Dis. 13 (6) (2017) 925–932.

[33] P.G.A. Van Boeckel, A. Sijbring, F.P. Vleggaar, P.D. Siersema, Systematic review: temporary stent placement for benign rupture or anastomotic leak of the oesophagus, Aliment. Pharmacol. Ther. 33 (12) (2011) 1292–1301.

[34] S.H. Arif, A.A. Mohammed, Esophageal stricture as a complication of stentplacement for leak after sleeve gastrectomy, J. Surg. Case Rep. 2019 (12) (2019; Dec 23) rjz353.