

Complications of staple line and anastomoses following laparoscopic bariatric surgery

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Abstract

With over 600 million people being obese, and given the scientific demonstration of the advantages of surgical treatment, bariatric surgery is on the rise. The promising long-term results in terms of weight loss, and particularly in relation to comorbidities and the control/cure rate, mean that the number of procedures performed in all countries remains high. However, the risk of potentially complex or fatal complications, though small, is present and is related to the procedures *per se*. This review is a guide for bariatric and/or general surgeons, offering a complete overview of the pathogenesis of anastomosis and staple line following the most common laparoscopic bariatric procedures: sleeve gastrectomy, gastric bypass, and mini-gastric bypass. The review is divided according to the procedure and the complications (leak, bleeding and stenosis), and evaluates all the factors that can potentially improve or worsen the complication rate, representing a "unicum" in the present literature on bariatric surgery.

Keywords Bariatric surgery, complications, laparoscopic, staple line, prevention, leaks, stenosis, bleeding

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Introduction

The number of bariatric operations performed worldwide is continuously rising. Based on the last International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) survey in 2014, a total of 579,517 procedures involving sleeve gastrectomy (SG) or the Roux-en-Y gastric bypass (RYGB), which represent the two most popular techniques (45.9 and 39.6%, respectively), have been performed [1]. The worldwide mini-gastric bypass (MGB) trend has reached a plateau, with the exception of the Asia/Pacific region. The current report on the number of MGB procedures could be underestimated, since the USA and Canada did not provide any data [1].

Each operation predisposes to specific postoperative complications because of the presence of multiple sequential or crossing staple lines and anastomoses (gastro-entero;

entero-entero). The most frequent postoperative complications after bariatric surgery are bleeding, leaks, and stenosis of the anastomosis. Knowledge of the clinical presentation, together with the postoperative anatomy, is crucial for the prevention, early diagnosis and proper management of those potentially life-threatening complications. The aim of this review is to evaluate the complications of the staple line and anastomoses in the most common bariatric procedures, evaluating for each the risk factors and the prevention strategies.

SG: staple-line complications

Major surgical complications, such as bleeding, leakage and gastric stenosis, occur in about 5% of cases in large series [2]. The mean incidence of leakage, which usually occurs in the upper portion of the staple line, is 2.1% (1.1-5.3 %) [2]. Leak is the second most common cause of death after SG, with an overall reported mortality rate of 0.4% [3].

Staple-line leak: pathogenesis and prevention

Pathogenesis of leakage after SG can be attributed to mechanical or ischemic causes [4]. Many factors, either technical or patient-related, can predispose to leakage. According to Baker *et al* [5], stapler misfiring or direct tissue injuries are categorized as "mechanical-tissular" causes and usually appear within 2 days of surgery (early leak). The mechanical factors are usually related to the intrinsic characteristics of the long

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staple line (approx. 20 cm). The phenomena of tissue creep, stress relaxation, and shear stress are dependent upon one common factor, which is time. Hence, optimal stapling should allow adequate time for tissue compression and creeping while preventing excessive tensile stress. Usually, waiting at least 15 sec before firing helps to optimize this concept and allow adequate pre-cut compression time [5]. The choice of adequate cartridge is essential and many studies have been published on this topic, showing a great variability in the stomach wall thickness, related to the portion of the stomach (from antrum to fundus), sex, and the procedures (primary or revisional). Based on the latest evidence, proper cartridge selection among the several options offered on the market by the two major brands (Ethicon Echelon™ Stapler-Echelon Flex™ Endopath® Stapler, Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA; and Covidien Endo GIA™ Reloads with Tri-Staple™ Technology-Covidien, Dublin, Ireland) is challenging in the absence of routine intraoperative measurement of gastric wall thickness. The appropriate cartridge “colors” using the Stapler-Echelon Flex™ Endopath® Stapler at the antrum, midbody, and fundus in both patient groups (male/female) seem to be black, black, and blue, respectively [6]. In contrast, with the Endo GIA™ Tri-Staple™ the appropriate cartridge colors appear to be black, black, and purple respectively, although the black cartridge for the antrum with this technology is completely appropriate in only 1 of every 6 female patients [6]. Despite the evidence, many surgeons use different colored cartridges, or use the same color for the entire staple line in combination with different kinds of stapler reinforcement (suture, glue, buttress materials). In the absence of current guidelines, the only assumption is that 81% of the panel experts of the international consensus summit for SG believe that it is not appropriate to use staples with a closed height less than that of a blue load (1.5 mm open) on any part of the SG [7]. When using these devices to create a long staple line, the surgeon must search for and remove the migratory “crotch” staple [5]. Failure to notice and remove this crotch staple may result in a staple misfire.

It is strongly recommended to maintain an adequate distance from the gastroesophageal junction in order to avoid ischemic complications related to the transection of the segmental vascularization of this area, where the majority of leaks occur (Fig. 1), although the ischemic theory of leak is not so strongly confirmed by the recent literature [8].

The choice of bougie size (between 32 and 40 Fr) could worsen the leak rate by creating an overpressure inside the pouch. A meta-analysis of Parikh *et al*, including 198 leaks in 8922 patients, revealed that the risk of leak decreased with a bougie ≥ 40 Fr, with no difference in percentage excessive weight loss between a bougie < 40 Fr and a bougie ≥ 40 Fr up to 36 months [9]. This strong evidence supports the use of ≥ 40 Fr bougies to decrease the leak rates, with controversial effects on weight loss [9-11].

The distance from the pylorus varies from 2-6 cm and is related to a variable leak rate attributed to the higher intragastric pressure obtained after antral resection. Increasing the size of the resected antrum might be associated with better short- and mid-term weight loss results, but could increase the leak rate [11-13]. Recalling that the bougie is only an inferior

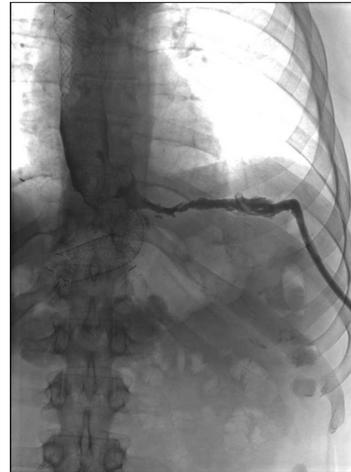


Figure 1 Sleeve gastrectomy: leak

resecting limit, the principal rule for avoiding overpressure in the sleeve is the critical orientation of the created sleeve, respecting the *incisura* and the staple-line orientation, together with a correct choice of bougie [4]. The creation of a gastric tube that is not cylindrical in shape results in high pressure, especially at the most proximal corner of the staple line (Laplace's Law) and thus results in a higher probability of leak in the proximal third of the tubular stomach. A spiral-shaped staple line can result in functional obstruction; in addition, stapling too close to the *incisura* can result in anatomical narrowing, creating a high-pressure system; both are preventable causes of leak that can potentially result in a high-pressure system [4].

The leak rate is also related to the surgical experience, as reported by Noel *et al* [14]. The authors analyzed their experience in two groups, Group A (first 900) and Group B (last 900 laparoscopic SG [LSG]), showing a critical decrease in leak rate from 2% to 0.2%, ($P=0.001$).

Regarding staple-line reinforcement (SLR) as a leak-reducing option, several tools have been proposed, including the following: oversewing, absorbable synthetic buttress material (synthetic glycolide trimethylene carbonate copolymer Gore®Seamguard® Bioabsorbable Staple Line Reinforcement), biologic cross-linked buttressing (bovine pericardium strips, Peri-strips Dry® and PSD Veritas®Baxter), biologic non-cross-linked buttressing (absorbable) (porcine small intestinal submucosa, Surgisis Biodesign®), thrombin matrix (Flo Seal®, Baxter Healthcare), and fibrin glue (Tisseel, Baxter Healthcare). The current high-level evidence showed that absorbable buttress materials applied on adequate cartridges appear to offer safer and more effective control of staple-line bleeding and leak (1.09% with Gore®Seamguard® [2] vs. 1.83% with Peri-strips Dry® [15]) and an increased cost compared with non-reinforced staple lines, but at the same time single-center experience in a large population demonstrated excellent results using fibrin glue as SLR (0%) [16], as well as the inverting absorbable suture (Lembert's suture) (0%) [17]. Berger *et al* published the first report from the metabolic and bariatric surgery accreditation and quality improvement program (MBSAQIP), which evaluated the outcomes of

189,477 patients who underwent SG with or without SLR [10], and demonstrated a negative effect of SLR on leak rate: 0.96% vs. 0.65% (odds ratio [OR] 1.20, 95% confidence interval [CI] 1.00-1.43). Placement of drains does not facilitate the detection of leak and/or abscess and they do not appear to eliminate the reoperation rates for these complications, which usually occur after the patient's discharge [18].

A leak after SG represents a complex condition, hard to solve and potentially life threatening, with a high additional cost. Prolonged hospitalization in the ICU accounted for the majority of hospital costs (58.9%), with a total cost of €304,290 [19].

In conclusion, based on evidence in the literature, measures for the prevention of leak include the following:

- Use a bougie size ≥ 40 Fr
- Begin the gastric transection 5-6 cm from the pylorus
- Use appropriate cartridge colors from antrum to fundus
- Perform a proper staple line
- Remove the crotch staples
- Maintain proper traction on the stomach before firing
- Stay at least 1 cm away from the angle of His and 1.5 cm from the *incisura*
- Reinforce the staple line (buttress, glue and Lember's suture)

Staple-line bleeding: pathogenesis and prevention

A long stapler line is mostly responsible for postoperative bleeding in 0-20% cases, with a re-operation rate of 1.4% for major bleeding [20] (Fig. 2), while intraluminal bleeding is uncommon. Modifiable factors should be investigated and corrected before surgery. Comorbidities, such as liver disease (non-alcoholic fatty liver), coagulopathy, hypertension and super-obesity, increase the bleeding risk and should be carefully evaluated and treated preoperatively when possible [21,22]. Patients who are candidates for SG as a revisional procedure, mainly after adjustable gastric band



Figure 2 Sleeve gastrectomy: staple-line bleeding. Re-laparoscopy

failure or complications, represent a high-risk subset. Based on a "sleeve bleed calculator" published this year [23], the authors concluded that the protective factors for hemorrhagic complications were no history of obstructive sleep apnea (OR 0.22; 95CI 0.05-0.94) and no history of hypertension (OR 0.38; 95%CI 0.14-1.05), while a low level of expertise in bariatric surgery (OR 2.85; 95%CI 1.08-7.53) and no staple-line reinforcement (OR 3.34; 95%CI 1.21-9.21) were associated with a higher risk of hemorrhagic complications. Another intraoperative bleed control protocol has been published recently by De Angelis *et al*; it involves an adjustment of the systolic blood pressure to 140 mmHg and a simultaneous reduction of the pneumoperitoneum to 10 mm/Hg in order to identify the possible silent bleeding; the authors reported a post-operative bleeding rate of 0% [24]. The SLR seems to play a central role in bleeding, as was indicated by two high-level evidence papers: in 2015, Shikora published a meta-analysis that assessed four SLR options (no reinforcement, oversewing, bovine pericardial strips, and absorbable polymer membrane), showing bleeding rates of 1.16% and 2.09% with reinforcement (bovine pericardial strips and absorbable polymer membrane, respectively) compared with 4.94% and 2.41% for the no-reinforcement technique and the oversuture, respectively [15]. Recently, Berger, evaluating the outcomes of 189,477 patients undergoing LSG with or without SLR, showed a positive effect of SLR on bleed rate: 0.75% vs. 1% (OR 0.74; 95%CI 0.63-0.86) [10]. There is evidence that using fibrin glue (bleed rate 0.3%) [16] and inverting suture (0.1%) [17] leads to excellent results; these need to be re-evaluated in large populations and based on multicenter experience. Placement of drains does not facilitate the detection of bleeding. Furthermore, they do not seem to reduce the reoperation rates for these complications. It is possible that patients with previous laparoscopic adjustable gastric banding and intraperitoneal bleeding could benefit from placement of a drain that will remain for more than 5 days [18].

In conclusion, based on the evidence in the literature, the adequate prevention of bleeding includes the following:

- Reinforce the staple line (buttress, glue and Lember's suture)
- Choose an adequate cartridge
- Control hemostasis with low intra-abdominal pressure and increased systolic blood pressure (≥ 140 mmHg)

Staple-line stenosis: pathogenesis and prevention

Staple-line stenosis occurs in 0.7% to 4% of patients who undergo LSG and often causes nausea, vomiting, epigastric pain and reflux; if untreated, it can lead to readmission [25]. It has been suggested that mechanical gastric can be caused by retraction of scar, oversewing of the staple line, overtraction of the greater curvature during stapling, or small hematomas or leaks that heal as scar tissue [25]. Sharp angulation or a spiral of the gastric sleeve could result from an incomplete gastric sleeve stenosis, or from other mechanisms such as asymmetrical

lateral traction, with stapling leading to twisting of the gastric tube via a volvulus-like mechanism [25-27]. The site of stenosis is most often at the *incisura angularis* or gastroesophageal junction [26,28] (Fig. 3). When a stenosis occurs, it is usually one of two types: a functional one (passage of the endoscope is possible but the sleeve is twisted with various degrees of rotation, requiring the scope to be passed through the gastric lumen—the so-called helix stenosis) or a mechanical one (when the passage of the endoscope is very difficult or impossible) [26]. Stricture and kinking may be avoided by keeping a safe distance between the *incisura angularis* and the edge where the staples are applied. In agreement with Manos *et al*, we believe that left-hand stapling offers the proper direction “to respect the *incisura angularis*” [26]. During left-hand stapling, the device will be parallel with the lesser curvature and not perpendicular,



Figure 3 Sleeve gastrectomy: mid-gastric stenosis

as is the case when performing right-hand stapling. Keeping the staple line straight by resecting symmetrically anterior and posterior walls of the stomach represents the main factor for avoiding staple line twisting [26].

In conclusion, in the majority of cases staple-line stenosis represents a technical error related to incorrect traction of the stomach during stapling, or an inappropriate distance from the *incisura*. Table 1 presents a summary of the complications.

Gastric bypass: staple-line complications

The most common anastomotic complications after RYGB are bleeding, stenosis and fistula. These complications occur predominantly at the gastrojejunal (G-J) anastomosis, with the following incidence ranges: bleeding 1-4% [28,29], stenosis 3-28% [28-30], and leaks 0.1-5.8% [28,29]. Several studies have shown the leak-associated mortality to reach 37.5-50% [28-30].

Staple-line leak: pathogenesis and prevention

The incidence of anastomotic leaks ranges from 0.1-5.8% [28,29]. Patients may present with any combination of abdominal pain, persistent tachycardia, shortness of breath, fever, hypotension, and unexplained sepsis. The leaks most commonly occur at the G-J anastomosis [28,29] but can also occur at the gastric pouch stapler line, gastric remnant, or jejunojunostomy. This is usually an early complication (most commonly within 1 week after surgery). In 2016 Varban *et al* [31] published a retrospective analysis of the Michigan Bariatric Surgery Collaborative, including 16,258 patients who underwent RYGB, and reported the following results: according

Table 1 Summary of staple-line complications after laparoscopic sleeve gastrectomy (SG)

	Incidence	Pathogenesis	Prevention
Leak	2.1% (1.1-5.3%)	Narrow tube (<40 Fr bougie); Distance from AOH (<1 cm); Twisted/stenotic tube; Staple misfiring	Bougie size ≥ 40 Fr; Distance from the pylorus 5-6 cm; Appropriate cartridge colors from antrum to fundus; Straight staple line; Crotch staples removal; Distance from AOH at least 1 cm and 1.5 cm from the <i>incisura</i> ; Staple-line reinforcement (buttress, glue and Lembert's suture)
Bleeding	0-20%	Patient-related factors: Liver disease, coagulopathy, hypertension, super-obesity, revisional surgery Surgeon-related factors: Low level of expertise, no staple-line reinforcement	Staple line reinforcement (buttress, glue and Lembert's suture); Appropriate cartridge colors from antrum to fundus; Bleeding check with low intra-abdominal pressure and increased systolic blood pressure (≥ 140 mmHg)
Stenosis	0.7-4%	Oversewing of the staple line; Overtraction of the greater curvature during stapling; Small hematomas or leaks that heal as scar tissue	Symmetric/lateral traction of the stomach during stapling; Distance of 1.5 cm from the <i>incisura</i>

AOH, angle of His

to the univariate analysis, cases with an increased blood transfusion requirement (OR 4.3; 95%CI 1.00-1.01, P=0.0015), conversions from laparoscopic to open surgery (OR 10.00; 95%CI 1.17-85.59; P=0.0356), the use of buttressing material (OR 3.35; 95%CI 1.61-6.99; P=0.0013), and Covidien stapler brand (OR 2.02; 95%CI 1.08-3.76; P=0.0268) were associated with a significantly higher rate of anastomotic leak. Conversely, the use of fibrin sealant over the G-J anastomoses was associated with a significantly lower rate of leaks (OR 0.37; 95%CI 0.17-0.79; P=0.0099). After multivariate analysis, only the use of buttressing material continued to be associated with a higher rate of leaks (OR 8.79; 95%CI 2.49-31.01; P=0.0007), whereas the use of fibrin sealant was associated with a decrease in the likelihood of leaks (OR 0.11; 95%CI 0.03-0.41 P=0.0013) [31]. Contrary to those results regarding fibrin sealant, Ibele *et al*, in a retrospective study evaluating 529 patients (429 fibrin sealant group vs. 104 no), found a leak rate of 0.9% vs. 1.9% (P=0.2) [32]. Furthermore, regarding SLR, Shikora *et al* [15], in a recent meta-analysis evaluating the advantages of SLR in gastrointestinal surgery, showed that the leak rate in gastric bypass decreased progressively using SLR, reporting the following percentages: no SRL=2.60%, oversuture=2.44%, glycolide copolymer=1.88%, bovine pericardium=1%. As recently reported in a meta-analysis that compared different kind of G-J anastomosis [33], no significant differences were observed in leak and reoperation rate. Compared with circular (CSA), hand-sewn (HAS) anastomosis had a similar risk of leak (OR 1.65; 95%CI, 0.61-4.48; P=0.33; and reoperation (OR 0.50; 95%CI 0.10-2.54; P=0.40). Compared with LSA, HSA also had a similar risk of leak (OR 1.46; 95%CI 0.72-2.96; P=0.29), and reoperation (OR 1.03; 95%CI 0.52-2.04; P=0.94) (Table 2) [33].

In conclusion, leaks after RYGB are not influenced by the type of G-J anastomosis, but can be positively influenced by the use of fibrin glue.

Staple-line bleeding: pathogenesis and prevention

Bleeding usually takes place in the early postoperative course (within the first hours to days) [28]. The bleeding

after RYGB can originate at one of five potential staple lines: the gastric pouch, excluded stomach, Roux limb staple line, gastrojejunostomy, and jejunojunction. Staple-line bleeding occurs at the transected tissue edges or at the sites where staples penetrate the tissue. In order of frequency, the sites of staple-line bleeding are 40% from the gastric remnant staple line, 30% from the G-J staple line, and 30% from the jejunojunction staple line [28]. Interestingly, a meta-analysis comparing open versus laparoscopic RYGB noted that the frequency of bleeding was higher in the laparoscopic RYGB (LRYGB) series (1.8% vs. 0.7%) [34]. Some hypotheses to explain this greater incidence of bleeding in the LRYGB in the minimally invasive surgery era are the overuse of chemoprophylaxis for deep vein thrombosis and the decreased in the practice of oversewing the staple lines. Two types of postoperative hemorrhage have been noted to occur following LRYGB: intraperitoneal or intraluminal [28]. The latter usually occurs as a late complication, while intraperitoneal bleeding occurs in the early postoperative course. As with any bleeding associated with surgery, early diagnosis is crucial. The clinical signs and symptoms are critical in determining the most appropriate steps for managing this life-threatening complication.

There are some potential methods for the prevention of staple-line bleeding. One method is to use a linear stapler with a shorter staple height. For example, using a white linear stapler load (2.5 mm) instead of a blue stapler load (3.5 mm) for the creation of the jejunojunction, or a blue stapler load instead of a green stapler load (4.8 mm) for the creation of the gastric pouch [28]. The shorter staple height provides more compression of the tissues and hence results in better hemostasis. However, a shorter staple height does not completely prevent staple-line bleeding and it can increase the risk of leaking due to inadequate tissue approximation [28]. Another method for prevention of staple-line bleeding is the use of SLR. In a recent meta-analysis published by Shikora *et al*, the authors concluded that the use of SLR guaranteed a lower incidence of bleed events, particularly using bovine pericardium (1.28% vs. 3.13% without SLR vs. 3.10% using oversuture vs. 3.02% using glycolide copolymer) [15].

Technical factors seem to be related to the incidence of

Table 2 Summary of staple-line complications after laparoscopic gastric bypass

	Incidence	Pathogenesis	Prevention
Leak	0.1-5.8%	No differences related to the type of anastomosis (circular, hand-sewn, linear) Controversial effect of reinforcement (protective/worsening)	Fibrin glue on G-J anastomosis; Appropriate cartridge
Bleeding	1.3-3.1%	Patient-related factors: liver disease, coagulopathy, hypertension, super-obesity, revisional surgery Surgeon-related factors: No staple-line reinforcement, mechanical circular anastomosis	Staple-line reinforcement (buttress, glue); Linear or hand-sewn technique
Stenosis	3-28%	Local factors (ischemia, scar formation, and tension of the G-J anastomosis); G-J anastomosis technique; Marginal ulcer	G-J anastomosis >21 mm; linear or hand-sewn technique; Quit smoking and NSAID (marginal ulcer prevention)

G-J, gastro-jejunal; NSAID, non-steroid anti-inflammatory drugs

postoperative bleeding from the G-J anastomosis, as was demonstrated by Jiang *et al*, in a recently published meta-analysis evaluating the outcomes of HSA vs. circular CSA or linear LSA anastomosis [33]. Compared with CSA, HSA (OR 0.48; 95%CI 0.31-0.74; $P=0.001$; Fig. 4) was associated with significantly less postoperative bleeding. There was no significant difference between HSA and LSA (OR 1.27; 95%CI 0.77-2.10; $P=0.34$) [33]. A recent report by Ichter *et al* [35] showed that using an EEA™ stapler reinforced with absorbable synthetic material yielded excellent results in terms of bleeding rate (0% in 125 cases) compared with the not-reinforced group. Fibrin sealant seems to be a valid option for reducing postoperative bleeding, as was reported by Silecchia *et al* in 2008 [36]. This multicenter randomized trial compared two groups of patients undergoing RYGBP, with or without fibrin sealant, and reported a 0% rate of bleeding from the G-J anastomosis in patients receiving fibrin sealant. The authors commented that the overall reintervention rate for early postoperative complications (anastomotic leak, internal hernia, and anastomotic bleeding) was significantly higher in the group that did not receive fibrin sealant ($P=0.02$). Recently, Ibele *et al* [32] found that 1.7% of patients in the sealant group experienced symptomatic postoperative bleeding requiring transfusion of ≥ 2 units of blood, compared to 4.8% in the group that did not receive sealant ($P=0.05$), despite a high incidence of stricture in patients treated with fibrin sealant on the G-J anastomosis (11.3 vs. 5.8%; $P=0.04$).

In conclusion, staple-line bleeding after RYGB can be controlled with the use of SLR or fibrin sealant, while a circular G-J anastomosis carries a potential risk for intraluminal bleeding.

Staple-line stenosis: pathogenesis and prevention

Symptomatic narrowing and stenosis of the G-J anastomosis (incidence: 3-28%) takes several weeks to a few months to develop and render the patient symptomatic [28]. It is typically followed by such symptoms as dysphagia, nausea, vomiting,

and gastroesophageal reflux (Fig. 4). The etiology remains uncertain, but it seemingly depends on local factors (ischemia, scar formation, and tension of the anastomosis) and on the technique used to create the G-J anastomosis (i.e. hand-sewn, circular versus linear stapler, and size of stapler) [28,33]. For example, Nguyen *et al* reported a higher rate of stenoses using a 21 mm (26.8%) compared to a 25 mm (8.8%) circular stapler, with no effect on weight loss [37]. Another factor that has been shown to reduce the incidence of strictures is the hand-sewn construction of the gastrojejunostomy. Comparative studies of a circular mechanical anastomosis versus a hand-sewn anastomosis showed significantly greater stenosis rates in the circular stapler group (31% vs. 3%) [30]. Linear staplers are also used for construction of the gastrojejunostomy, with the reported stricture rate being between 3.1% and 6.8%—lower than the rate quoted for circular staplers [30]. Despite the recently published data, a meta-analysis comparing the outcomes between hand-sewn vs. mechanical G-J anastomosis showed no difference in terms of postoperative stricture [33]. Interesting, applying fibrin sealant to the staple line, particularly to the anastomosis, seems to worsened the stricture rate, as recently reported by Ibele *et al* (11.3% with vs. 4.8% without fibrin sealant $P=0.04$) [32]. A central role in the pathogenesis of stenosis is played by the marginal ulcers, which have an incidence of between 0.6% and 16% [30]. Several previous studies attempted to define potential risk factors for the development of marginal ulcers, but it still remains a controversial topic [30,38]. There is currently no evidence for an association between the development of marginal ulceration after RYGB and the presence of *Helicobacter pylori* (*H. pylori*) infection [30]. *H. pylori* appears rather to cause an injury to the gastric mucosa preoperatively that potentiates the formation of marginal ulcer after gastric bypass. Therefore, *H. pylori* eradication is recommended prior to surgery. Other causes include smoking and alcohol consumption; use of non-steroid anti-inflammatory drugs (NSAID); diabetes; excess acid exposure due to creation of a too-large gastric pouch, to dilatation of the gastric pouch over time, or to the presence



Figure 4 Gastric bypass: stenosis at gastrojejunal anastomosis

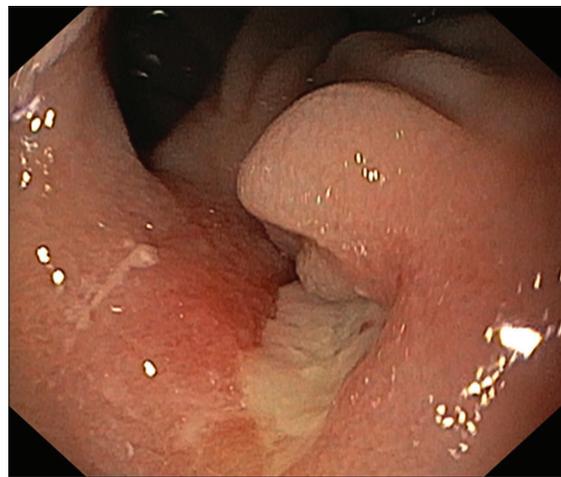


Figure 5 Recurrent marginal ulcer at gastrojejunal anastomosis after fibrin healing

of a gastrogastic fistula; presence of foreign bodies, such as non-absorbable sutures or staples; and local factors, such as ischemia, or tension at the G-J anastomosis [30,38]. Even if marginal ulcers are multifactorial, the development of early marginal ulcer is more likely to be associated with local factors (ischemia, postoperative inflammation, stenosis, or foreign body) while late marginal ulcers are likely to be related to an increased acid exposition of the G-J anastomosis developing over time (Fig. 5) [30,38-39]. Zollinger-Ellison syndrome also has to be ruled out. In their review of 3430 procedures of RYGB, Felix *et al* identified 35 cases of perforation (1%) with a median time to perforation of 18 months (range 3-70 months) [40]. Wendling *et al* have recently described the most delayed onset of perforated ulcer found in the literature, occurring 98 months after the original surgery [41]. In the study by Felix *et al* the incidence of smoking was significantly higher and the use of NSAID and steroids was common in patients presenting with a perforated ulcer [40].

In conclusion, stenosis has an incidence related to the technique (circular stapler vs. hand-sewn vs. linear), the G-J outlet diameter (smaller = better weight loss result vs. high stenosis incidence) and the developing of a marginal ulcer (quitting smoking is always a good indication for patients who are candidates for RYGB). A summary of the complications is shown in Table 2.

MGB: staple-line complications

Laparoscopic MGB is an emerging surgical method that was first reported by Rutledge in 2001 [42]. Thousands of procedures have been performed worldwide [43-46], and the efficacy of MGB regarding weight loss and the improvement of comorbidities, as well as its safety, have been reported [43]. Based on a published systematic review, minor early postoperative complication rates ranged from 3.6-7.5%, whereas major early postoperative complication rates ranged from 0-7% [47,48].

Staple-line leak: pathogenesis and prevention

The leakage incidence is reported to be between 0.8% and 1.6%, with a rare report of a high percentage of 4.08% when performed as a revisional procedure [47,48]. A report of experience from over 1500 cases [45] cited a very low incidence (0.1%), probably explained by the technical differences compared with RYGB: a long pouch that is not under pressure and a large anastomosis without tension. A major study was published in 2016 by Genser *et al* [49], evaluating the results of 2321 MGB procedures (62% primary and 38% revisional), focusing particularly on leak presentation after more than 8-year experience. The authors reported an incidence of 1.5%: 57% from undetermined origin, 32% from the gastric tube and 11% from the G-J anastomosis. No leaks were found from the excluded stomach. The authors concluded that there was no statistical difference in terms of leak rate between revisional

and primary procedures ($P=0.21$), or between one-stage and two-stage procedures [49].

In conclusion, the leak rate after MGB does not appear to be related to any particular technical factor, such as bougie size, choice of cartridge, and/or to patient-related factors such as revisional procedures and comorbidities, and the main prevention measures are similar to those indicated before for SG and RYGB, apart from SLR.

Staple-line bleeding: pathogenesis and prevention

Major bleeding (0.2-28.6%) is the most commonly reported complication and in 0.3-0.58% of these cases reoperation and/or endoscopic/radiologic interventions are required [47,48]. The high percentage of bleeding reported by Copăescu *et al* may reflect the small sample size and represent only the initial experience of that center, given that the learning curve for MGB spans 30 cases [50]. Apart from the latter report, the maximum reported bleeding rate is 3.5%. Because of the abundant blood supply in the gastric tube, bleeding after MGB can originate at one of three potential staple lines: the long gastric pouch, the excluded stomach and the G-J anastomosis. Intraluminal acute bleeding represents a rare complication (0.6%) [48], particularly because the G-J anastomosis is performed with a linear stapler that allows immediate checking inside the lumen and treatment when necessary. The majority of the reported cases did not use SLR, and it is notable that the bleeding rate was comparable to, and sometimes lower than, those obtained using SLR in SG or RYGBP. This review, based on the available literature, cannot offer evidence from well-powered studies, but in our opinion the measures to prevent bleeding are the same as for SG and RYGBP: adequate devices (cartridges), adequate hemostatic control (intra-abdominal and systolic pressure), and the use of hemostatic devices based on personal choice.

Staple-line stenosis: pathogenesis and prevention

Anastomotic stricture after MGB occurs rarely, in a percentage between 0.1% and 1%, and is rarely reported in the literature [48]. The presence of a 45-60 mm linear side-to-side anastomosis helps to avoid this complication, and the majority of surgeons use a similar technique [42-48], also because the weight loss related to the procedure is due more to a metabolic than to a restrictive effect. Carbajo, in a large series with long-term follow up (1200 patients, 70% followed for 12 years), performed a G-J anastomosis of 2-2.5 cm in length, reporting 6 stomal stenoses (0.5%) [46]. No case of stenosis related to the gastric pouch has been reported in the literature, there are reports of stenosis of the gastric reservoir [51].

In conclusion, despite the ample experience, it is hard to establish strong evidence and recommendations. The prevention of stenosis is based on the size of the G-J anastomosis (not less than 2.5 cm), on respect for the distance from the greater curvature (not less than 2 cm to avoid gastric reservoir occlusion), and to symmetric, lateral traction of the stomach

Table 3 Summary of staple-line complications after laparoscopic mini-gastric bypass

	Incidence	Pathogenesis	Prevention
Leak	0.8-1.6%	Not different from SG factors	Not different from SG and RYGB factors No evidence about use of reinforcement
Bleeding	0.2-28.6%	Not different from SG and RYGB No evidence about use of reinforcement	Adequate devices (cartridges) Adequate hemostatic control (intra-abdominal and systolic pressure) Hemostatic devices based on personal choice No evidence about use of reinforcement
Stenosis	0.1-1%	Asymmetric traction during pouch creation; Narrow G-J anastomosis	Size of G-J anastomosis (not less than 2.5 cm); Adequate distance from the greater curvature (not less than 2 cm to avoid gastric reservoir occlusion) Symmetric, lateral traction of the stomach during vertical transection (as previously reported for SG)

G-J, gastrojejunal; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy

during vertical transection (as previously reported for SG). A summary of the complications is shown in Table 3.

Concluding remarks

This review shows how to prevent complications of the staple line and anastomoses during bariatric surgery, providing an evaluation of all factors that could potentially increase the rate. To reduce the complication rate it is mandatory to consider the patients' comorbidities and the following technical pitfalls: a. type of procedure (primary vs. revisional); b. use of a stapler with adequate cartridges; and c. reinforcement of the staple line/anastomoses (advantages not demonstrated for MGB). Respecting these basic rules, based on substantial experience, will help maintain low complication rates, compared with other abdominal surgeries, in these complex patients.

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