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REVIEW

Revisional Surgeries of Laparoscopic Sleeve Gastrectomy

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Abstract: Bariatric surgery has become increasingly common due to the worldwide obesity epidemic. A shift from open to laparoscopic surgery, specifically, laparoscopic sleeve gastrectomy (LSG), has occurred in the last two decades because of the low morbidity and mortality rates of LSG. Although LSG is a promising treatment option for patients with morbid obesity due to restrictive and endocrine mechanisms, it requires modifications for a subset of patients because of weight regain and tough complications, such as gastroesophageal reflux, strictures, gastric leak, and persistent metabolic syndrome., Revision surgeries have become more and more indispensable in bariatric surgery, accounting for 7.4% in 2016. Mainstream revisional bariatric surgeries after LSG include Roux-en-Y gastric bypass, repeated sleeve gastrectomy, biliopancreatic diversion, duodenal switch, duodenal-jejunal bypass, one-anastomosis gastric bypass, single anastomosis duodeno-ileal bypass (SAID) and transit bipartition. This review mainly describes the revisional surgeries of LSG, including the indication, choice of surgical method, and subsequent effect.

Keywords: bariatric surgery, laparoscopic sleeve gastrectomy, revisional surgery

Introduction

As a serious worldwide public health problem, obesity is associated with many chronic diseases. In fact, more than 600 million of adults were affected by obesity in 2014, and the prevalence of obesity has doubled since 1980.[1] Bariatric surgery is a highly effective and durable therapy for losing weight and performed on individuals with severe obesity. In common bariatric operations, laparoscopic sleeve gastrectomy (LSG) is well known for its perceived technical simplicity, feasibility, and safety. Initially, LSG was a component of biliopancreatic diversion with duodenal switch (BPD-DS). Subsequently, LSG has become the first stage in a two-staged operation in patients with severe obesity. Given that short-term weight loss is guaranteed in the first-stage LSG, the second stage is often discontinued. LSG has become a stand-alone primary bariatric procedure.[2] In 2014, LSG was the most common performed procedure and has maintained its predominance in 2016 (N = 340,550; 53.6%).[3] LSG can help improve metabolic syndromes, such as diabetes and hypertension, and it has the short-term satisfying outcomes of weight loss.[4] However, long-term failure rates are up to 64%.[5] Considering the long-term weight recurrence and occurrence of complications, revisional surgery is an indispensable part after LSG.

The American Society for Metabolic and Bariatric Surgery (ASMBS) categorizes reoperative surgery into corrective, reversal, and conversion procedures.[6]

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Corrective procedures are applied to a poorly constructed initial operation or the treatment of complications. Reversal procedures, as operations for restoring normal gastrointestinal anatomy, are essential for stubborn nutritional deficiencies or unbearable psychological issues. Conversion is the process of changing to another bariatric procedure for complications and inadequate response.

Currently, no set criteria for assessing the success or failure of bariatric surgery is available, and thus the necessity for revisional bariatric surgery is difficult to define. The most common indications for reoperation may be the inadequate control of weight or diabetes and occurrence of complications.

Revisional Surgeries for Weight Regain

Weight regain (WR) is defined as regaining weight to achieve a BMI >35.[7] Approximately 14% of patients[8] cannot maintain weight loss after bariatric surgery, and condition leads to the reappearance of obesity-related complications. Additionally, WR can have a devastating psychological effect, which lead to frustration, anger, and even depression, as patients feel that they failed their last option.[9]

Several factors contribute to WR. First, although the optimal bougie size is suggested to be 32F–36F,[10] the impact of bougie size on weight loss after sleeve gastrectomy (SG) remains controversial. Many studies have suggested that a thin bougie may be a protective factor against post-sleeve gastrectomy weight regain.[11–13] As we know, LSG is a restrictive operation that requires removal of most of the fundus, body and antrum of the stomach under the guidance of a probe to reduce the volume of the stomach. There is a study showing that the sleeve dilatation might contribute to weight regain, which probably because there is an incompletely excised fundus and then increasingly distend and release larger amounts of ghrelin. However, most of the current research results in this area are not very convincing[14] and the cause of gastric sleeve expansion is still under further study.[13] For WR that may be caused by sleeve expansion, banded LSG (BLSG) with a MiniMizer® ring to add restriction in LSG might be an effective preventive measure.[15,16] Moreover, a high residual gastric volume and gastric dilation are significantly and positively correlated with WR.[17–19] As for the antral dilation, the research from Emmanuel Disse shows that compared with the group without gastric dilatation, although the total gastric volume, the volume of the gastric tube, and the diameter of the gastric tube were remarkably higher in the group with gastric dilatation, the volume of the antrum was similar between the groups.[20] Besides, whether to retain the gastric antrum and the size of the retention does not seem to have a major impact on WR.[21,22] In addition to anatomical and physiological factors, WR is significantly associated with older age 5 years after LSG.[8] Many studies previously confirmed a positive effect of younger age on weight loss after bariatric surgery,[23–26] and postoperative loss-of-control eating is associated with decreased rate of weight loss after bariatric surgery.[27–29] Additionally, different groups studied the effect of pregnancy on weight loss following bariatric surgery and showed conflicting results.[30–32] Ashraf A found that the earlier the pregnancy is, the worse the effect of weight loss is.[8] Other predictors, such as ghrelin,[33] serotonin,[34] mood,[35] and follow-up support[13,36] have been introduced.

Weight-reduction measures are essential. The antiobesity drug pipeline is active and develops several new agents, including GLP-1 receptor agonists (such as semaglutide, which is being developed in oral formulations), dual-action GLP-1, glucagon receptor agonists, amylin mimetics, triple gut hormone agonists, and anti-obesity vaccines.[37] Traditionally, a conversion to duodenal switch (DS) or Roux-en-Y gastric bypass (RYGB) has been the standard of revision. DS is appropriate when the original operation is the first part of the entire operation,[38,39] whereas RYGB is suitable for patients with the complications of gastroesophageal reflux disease (GERD). However, compared with reLSG, these two types of surgery methods have higher incidence rates of postoperative complications.[40] Compared with malabsorptive procedures, this re-intervention offers several advantages, such as increased restriction; decreased gastric output; decrease in the incidence of dumping syndrome by preserving the pylorus; decreased risk of anemia, osteoporosis, and protein and vitamin deficiency (except B12 and thiamine); and reduced operative time.[41] According to the radiological studies of Braghetto et al[42–45], a 250 cm^3 threshold measured through the CT scan volume method may be a possible indication of reLSG, also known as fundectomy, and a residual volume below this threshold prompts conversion to a malabsorptive procedure. In recent years, single-anastomosis duodeno-ileal bypass (SADI), one-loop operation, has gained more attention because of its

simplified technique and comparable or even better result than conventional operations.[46,47]

With regard to weight loss outcomes in short- and midterm, BPD/DS appears to be superior to RYGB and Resleeve gastrectomy (ReSG). Given that LSG has been introduced as the restrictive part of BPD, BPD/DS seems to be the most appropriate second procedure, although the latter carries an increased risk of deficiencies, protein malnutrition, and intestinal bacterial overgrowth. Still, the fact that RYGB is technically less demanding than BPD/DS, has lower complication rates, and is less malabsorptive inclines many surgeons to opt to perform RYGB. Many documents have indicated that Re-LSG is a feasible and safe surgical approach for weight regain post-LSG, remains effective for 53.8% after 5 years, and is best used when the gastric pouch is extremely large or when the gastric tube is dilated after original LSG.[44,48–51] Besides, SADI extends the common limb length and reduce the long-term complication rate, while BPD/DS performs a better outcome than SADI when the starting BMI is high.[46,47] Further trials and meta-analyses of ReSG are necessary to prove the efficiency and compare the outcomes of Re-LSG with those of RYGB, DS, or SADI.[40,46]

Revisional Surgeries for T2DM Relapse

Many studies have demonstrated that LSG is effective in significantly resolving or alleviating obesity-related comorbidities, such as type 2 diabetes mellitus (T2DM), hypertension, and dyslipidemia and reducing the use of drugs in addition to weight loss.[52,53] The resolution rates of DM vary from 26% to 66% in the literature.[53–55] Currently, the best predictors of improvement in blood glucose control after bariatric surgery are decrease in waist circumference, better-controlled diabetes, and decrease in triglyceride levels at baseline.[56,57] Some studies have suggested that S100A8/A9 and IL-6,[58] diabetes duration, and %EWL[59] are related to persistent diabetes status post-surgery. Although T2DM after relapse is often milder, medical treatment is still needed in most cases (the amount of medicine required is usually less than the preoperative requirement).[60] Along with weight loss, incretins may play a role in diabetes remission after bariatric surgery.[61] Blocking the glucagon-like peptide-1 (GLP-1) receptor with exendin9–39 reverses the effect of bariatric surgery on β-cell function and glucose tolerance.[62] The inhibitors of dipeptidyl peptidase-4 (DPP-4), the enzyme that inactivates GLP-1, are well tolerated and weight-neutral and thus commonly used for the treatment of T2DM.[63] Whether the addition of DPP-4 inhibitors improve glucose control after RYGB and when GLP-1 levels are elevated and DPP-4 activity decreased.

Revision options are to redo SG or to convert SG to either RYGB or DS. Regarding their effects on residual T2DM, RYGB can induce considerable and persistent improvement in MetS prevalence in T2DM patients with obesity.[59,64,65] Aleassa showed clinical remission at a rate of 23.1% and improvement of 30.8% in patients converted to RYGB.[66] Recently, many studies[67–69] have shown that SG results in the same remission rates of metabolic syndrome as RYGB, although LSG seems to be inferior to laparoscopic RYGB with regard to the control of hypertension and high-density lipoprotein cholesterol[68] partly due to the greater weight loss of RYGB.[64,67,70] In Gautier's series, patients with persistent T2DM after SG show improvement after conversion to RYGB.[51] Ali and his colleagues divided T2DM into three validated severity stages for the first time for selection based on evidence-based procedures.[71] In mild T2DM (IMS score ≤25) and severe T2DM (IMS score >95), both procedures significantly improved T2DM. However, in an intermediate group, RYGB was significantly more effective than SG likely because of the more pronounced neurohormonal effects of RYGB. Adding a DS might also be a good option based on the mechanism of foregut bypass.[72] However, LSG is still a favorable choice for T2DM treatment in morbid patients with obesity and short duration of DM and good beta cell preserve.[73,74]

Revisional Surgeries for Complications of LSG

Revisional Surgeries for GERD

The pathophysiological mechanisms predisposed to gastroesophageal reflux disease (GERD) in obesity include increased intra-abdominal pressure, impaired gastric emptying, decreased lower esophageal sphincter (LES) pressure, and the high frequency of transient LES relaxation. Thus, obesity itself is an important risk factor for GERD.

The connection between LSG and GERD has always been a focus of debate among scholars. Some researchers think that LSG is an effective method of metabolic surgery and can improve GERD (especially mild GERD), whereas some studies pointed out that the incidence of GERD after LSG was higher than that after bariatric surgery.[75]

Rebecchi analyzed 18 studies that investigated 45 patients followed up for at least 12 months after surgery.[76] Six of these studies showed increased prevalence in GERD after SG, and 9 studies showed a decreased prevalence, leaving a controversy on LSG outcomes.

The physiological factors of LSG causing GERD are manifold. The possible physiological and anatomical changes that cause postoperative GERD aggravation or de novo GERD include the formation of a hiatal hernia (HH) caused by the sleeve, change in His angle, destruction of the lower esophageal sphincter, development of high intrathoracic pressures, decreasing volume, and increasing pressure in the stomach.[77,78] Csendes performed a prospective study based on the sequential clinical, endoscopic, and histologic evaluations of the foregut after LSG and confirmed the negative impact of LSG causing GERD.[79] By contrast, in long-term follow-up after LSG, changes in His angle and stomach volume, increase in stomach compliance, weight-loss and acceleration of gastric emptying that improve or resolute reflux symptoms.[80]

Given the complexity of the diagnosis of GERD and the subjectivity of patient experience,[81] as well as the lack of objective indicators after surgery, evidence of the correlation between GERD and LSG is still lacking. Some scholars have attempted to determine the relationship between LSG and GERD by the pH monitoring of gastro-oesophageal reflux before or after LSG.[82,83] However, short follow-up time and inaccurate testing methods increase confusion about this problem.

Esophagogastroscopy is considered a routine diagnostic test prior to bariatric surgery and used in detecting asymptomatic benign-like HH and premalignant or malignant lesions.[84] HH contributes to the pathogenesis of GERD,[85] and thus LSG with concomitant hiatal hernia repair (HHR) is seemingly beneficial to patients with GERD. However, an increasing amount of evidence shows that HHR is inefficient in preventing the occurrence and development of GERD after LSG.[86–88] For patients with obesity, whether receiving LSG and routine preoperative endoscopy[78,89,90] and HHR are necessary requires additional prospective studies. The good news is that LSG with anti-reflux fundoplication emerges as a new valid option for patients with GERD.[91]

Presently, PPIs can be used in treating mild patients. Other patients are suggested to undergo surgery treatment. The gold standard surgical approach for GERD is laparoscopic Nissen fundoplication plus crural closure.[92] In addition, the Linx Reflux Management System, EndoStim LES Stimulation System, Esophyx®, and MUSE™ endoscopic fundoplication devices and the Stretta endoscopic ablation system are emerging techniques for treating this disease.

Some patients with proximal gastric pouch dilatation and refractory to PPI therapy without accepting revisional bariatric surgery can consider anterior fundoplication.[93,94] For patients who are unsuitable for revision, 72% of 32 expert bariatric surgeons disagree that repairing the hiatal hernia might control symptoms according to the best practice guidelines in 2017,[95] although many scholars prefer HHR as a treatment for GERD.[72,96,97]

When PPIs are ineffective in relieving GERD symptoms, and RYGB is considered the optimal treatment approach in the absence of a correctable anatomic factor.[98] In Guan's statistics,[99] the pooled rate of revision due to GERD was 3.1%. For postoperative patients with uncontrolled GERD, RYGB is the procedure of choice.[91] After RYGB, the average esophageal acid exposure declines in a large percentage of individuals with increased acid exposure and DeMeester scores postoperation.[100] The mechanism by which RYGB alleviates GERD symptoms probably accounts for the small volume of the new gastric pouch consisting of the cardia region of the stomach and for the disappearance of bile reflux, which impairs the reservoir capacity and promotes regurgitation.[101] Conversion to RYGB cures patients from reflux well. In addition, few GERD cases treated with ligamentum teres cardiopexy (LTC) combined with the closure of the gastric crus.[102] The principle is creating an artificial valve restoring the angle of His for the reduction of hernia and prevention of reflux. Securing the esophagogastric junction (EGJ) via LTC provides mobility with hepatic movements, which occur with breathing and diaphragmatic displacement.[103] At present, the sample size of this technique is still relatively small and cannot be compared with that of RYGB. However, it is noteworthy that the symptomatology of GERD does not always disappear after RYGB treatment. As a trial reports, 23 of 80 GERD patients receiving RYGB maintained reflux after 6 months, especially in patients with previous gastric banding.[104] With more postoperative complications, LTC should be avoided in LSG patients with GERD, BPD/DS,[105,106] and One-anastomosis gastric bypass (OAGB).[107] Manabu Amiki had the same conclusion, that is, LBPD/DS or duodenojejunal bypass (DJB) as revision surgery appears to be effective for further weight loss in the medium term, and

laparoscopic RYGB appears to be effective for GERD remission.[108]

Revisional Surgeries for Strictures

Gastric sleeve stenosis is one of the most frequent complications after LSG. In a review of the published literature regarding LSG for morbid obesity, the incidence of gastric stenosis (GS) varies from 0.7% to 4%.[109] Noticeably, many of the stenosis of LSG are underdiagnosed, which means that the real percentage is higher than reported in the literature.

Two different mechanisms contribute to GS: mechanical stenosis and functional stenosis. For one thing, anatomic stenosis is generally blamed on sharp angulations of the stapler, reinforcing sutures placed over the staple line, a bougie size that is too small, or hematomas and edema. For another, the functional obstruction always occurs by misalignment of the staples, alteration of the pouch architecture, the indentation of the incisura within the gastric lumen and an excess volume of stomach from the back wall which may produce tube twisting with an axial deviation.[110,111]

Chang et al[112] improved their surgical techniques. Parallel first linear stapler firing at the antrum, making a mark with a 2 cm width at the level of the incisura angularis and leaving at least a 5 mm width of the fundus at the level of the gastroesophageal junction, prevent overnarrowing at frequent stenotic locations after LSG (the incisura angularis and gastroesophageal junction). For the most common phenomenon of GS, twisting, they fixed the greater curvature site of the sleeve gastric tube with retroperitoneal fat through suturing to maintain the axis of the whole tube and prevent possible axial distortion due to postoperative adhesion after the withdrawal of the calibrated orogastric tube. They emphasized that "standardized" LSG to prevent GS is extremely important.[112] In the International Sleeve Gastrectomy Expert Panel Consensus Statement in 2012, a collective series of >12,000 SGs performed by 24 centers worldwide, maintaining symmetric lateral traction while stapling after mobilization and takedown of short gastric vessels reduce the potential for strictures. Using an appropriately sized bougie when stapling the incisura angularis can decrease stricture formation.[10] The gastric stenosis post LSG presents classically with food dysphagia, nausea, vomiting, regurgitation, rapid weight loss or even staple line leaks after surgery.[113]

For this tough complication, a UGI contrast study should be conducted. If the results of this study are abnormal or if symptoms persist, an esophagogastroduodenoscopy should be performed with anticipation of performing a dilation. Repeated dilation can be performed as long as a patient demonstrates improvement in oral tolerance. The placement of a stent can be considered, although a stent is poorly tolerated by a patient due to pain and discomfort. Long-segment stenoses that do not respond to endoscopic techniques (most experts consider patients whose endoscopic dilation for 6 weeks has failed)[10] require revisional surgery. The surgical revision options include laparoscopic RYGB, wedge gastrectomy, or seromyotomy.[114] The first line of treatment for a stenosis is endoscopic dilatation using the Savary bougie, which is an effective, safe, and durable method for managing stenosis after LSG. Currently, laparoscopic RYGB creating a gastric pouch proximal to a stenosed gastric lumen remains the most popular and effective revisional surgery. Seromyotomy can be useful but carries a high rate of resulting in complications, such as gastric leak. Accurate technique with the parsimonious use of coagulation and possibly with the systematic use of an omental patch might lead to good results.[115] Seromyotomy[115] and median gastrectomy[116] are alternative surgical procedures. Median gastrectomy is suitable for addressing persistent stenosis within the gastric sleeve located within the midbody. This approach has a low risk of leak in contrast to seromyotomy and preserves the gastric sleeve option without a need to convert to a gastric bypass.[116]

Revisional Surgeries for Gastric Leak

Gastric leak (GL) is one of the most serious complications after LSG and the second most common cause of death after bariatric surgery.[117] The UK Surgical Infection Study Group defined "leak" as "the leak of luminal contents from a surgical join between two hollow viscera" or "a gastrointestinal leak in a suture line around the organ," laying the foundation for comparisons and clinical audits.[118] GL is considered "acute" if observed within 7 days of LSG, "early" if observed 1–6 weeks after LSG, "late" if observed after 6 weeks, and "chronic" if it has lasted >12 weeks.[10] The clinical manifestations of leakage vary. Mild patients may only have imaging manifestations, whereas severe patients develop septic shock, multisystem organ failure, and even death.

The average rate of leaks in LSG is 1.5%.[119] The two main reasons for leaks are mechanical and ischemic factors.[120] Mechanical tissular damages usually appear

within 2 days of surgery, including stapler misfiring and direct tissue injuries. In addition, the longer the staple line is, the easier it is to cause leakage. Ischemic leaks occur on the 5th or 6th postoperative day, and most leaks after LSG is operated near the gastroesophageal junction,[121,122] which is the "critical area" of ischemic pathogenesis. The major reason of ischemic leak may be the dissection of the greater curvature with the use of electrocautery or a LigaSure device, which causes gastric wall heat ischemia near the staple line.[123]

The consequences of GL are disastrous. Therefore, the early diagnosis of postoperative GL is particularly important. Patients with GL present clinical perspectives, including abdominal pain, fever, tachycardia, tachypnea, and increased white blood cell and C-reactive protein (CRP) levels. The earliest symptom is tachycardia in patients with early leak, whereas fever is the earliest symptom in patients with late leak.[123] Endoscopy is the gold standard treatment for acute staple line leaks. Once gastric leak is diagnosed, surgical supportive treatment is essential. Most early gastric leaks can be resolved by endoscopic operations, such as endoscopic stent, fibrin sealant injection, percutaneous glue, and hemoclips. Moreover, several neoteric technologies, such as the Over-the-Scope Clip system, laparo-endoscopic gastrostomy decompression, and endoluminal vacuum therapy have emerged, but their long-term effectiveness needs evidence.[124–126] In addition, GL treatment through endoscopic internal drainage coupled to prompt external drainage mobilization is controversial.[127–129] Compared with other treatments, the management of leaks following LSG is more difficult and usually need endoscopic therapies.[129] The two probable explanations are as follows: the mechanism of SG, specifically the creation of a high-pressure gastric tube associated often with a functional angular stenosis, and lack of standardization in the management of the fistula, particularly when an endoscopic approach is used.[130]

Revisional bariatric surgery is usually suitable for patients with chronic leaks, which is hard to treat through endoscopic treatment.[131] The three common revisions for chronic GL are laparoscopic Roux-En-Y Esophago-Jejunostomy (LRYEJ), RYGB, and total or near total gastrectomy with esophagojejunal anastomosis. Surgical treatment remains a difficult procedure with a high percentage of leakage but is easily tolerated by a patient and facilitates the healing of the fistula.[132] Among the three revisions, RYGB has the highest reoccurrence rate of leak,[130] and patients who underwent gastrectomy have a relatively high risk of complications related to esophagojejunal anastomosis, nutritional deficiencies, and anemia.[133] LRYEJ seems more safe and effective but with higher complications.[134] LRYEJ is a well-characterized approach that anastomoses a fistula site to a small bowel loop. It is followed by distal jejunojejunostomy for the diversion of the biliary secretions. RYGB is an option for decreasing intragastric pressure and facilitates fistula healing but should be avoided in cases of severe peritonitis and hemodynamic instability. As a major surgery mode, complete gastric resection is a salvage procedure for chronic leaks with inflammation, fibrosis, dissection, and adhesions, which cannot be cured through LRYEJ or RYGB.[135]

GL can be prevented by gently handling tissues, reinforcing the staple line[136] (or overriding sutures or buttressing materials), performing procedures by experienced surgeons,[122,137] and performing proper traction on the stomach before firing[120] and proper bougie (≥40 Fr).[138] The use of pyloric Botulinum toxin (type A) injection during LSG can reduce the incidence of GL.[139] Although the use of methylene blue test preoperatively is a conventional method in LSG, the validity of this method is still in dispute.[140,141]

Given that most GLs can be successfully treated with endoscopic techniques, the current case studies of revisions for treating GL are based on a small sample sizes, which have certain limitations. The management of post-LSG leak is multimodal, and no accepted algorithm for the diagnosis and treatment of GL has been proposed yet. In China, 84.8% of surgeons consider Roux-en-Y bypass as a salvage procedure,[142] whereas some researchers regard LRYEJ as a suitable technique after the failure of the endoscopic management of post-sleeve gastrectomy fistula.[133,134,143] The determination of surgical methods depends mainly on patient disposition.

For intractable GL after LSG, proximal gastrectomy with double tract reconstruction is a safe, feasible, and minimally invasive option.[144,145] However, as a novel revision surgery procedure, its applicability in clinical settings should be further examined before its long-term effects on weight and metabolism control in patients with obesity can be verified. A table about revisional surgery choices is listed in Table 1.

Multiple Revisional Surgeries

Revisional surgery is not a new type of surgery and can be considered after the failure after the first bariatric surgery. A new bariatric surgery is selected according to the initial operation method and postoperative situations. When

Table 1 Complications After Laparoscopic Sleeve Gastrectomy and Revision Operations

Complication	Revisional Surgery	Advantage or Indication	Shortcoming
Weight regain	DS	The original operation is the first part of the entire operation.[38,39]	Higher incidence rates of postoperative complications than reLSG.[40]
	RYGB	GERD	
	reLSG	A 250 cm3 threshold measured through the CT scan volume method.[42–45]	
	SADI	Longer common limb length;lower long-term complication rate[46,47]	A worse outcome than BPD/DS when the starting BMI is high
T2DM relapse	reLSG	Same remission rates of metabolic syndrome as RYGB.[67–69]	Inferior to RYGB with regard to the control of hypertension and high-density lipoprotein cholesterol.[68]
	RYGB	Improvement in MetS prevalence in T2DM patients with obesity.[59,64,65]	
GERD	RYGB	Absence of a correctable anatomic factor.[98]	Not always effective.
Strictures	RYGB	Creating a gastric pouch proximal to a stenosed gastric lumen	
	Seromyotomy	Useful	A high rate of resulting in complications, such as gastric leak.[115]
	Median gastrectomy	Persistent stenosis within the gastric sleeve located within the midbody; a low risk of leak in contrast to seromyotomy and preserves the gastric sleeve option without a need to convert to a gastric bypass.[116]	
Gastric Leak	LRYEJ	After the failure of the endoscopic management of post-sleeve gastrectomy fistula.[133,134,143]	
	RYGB	A salvage procedure.[142]	
	Gastrectomy	Intractable GL after LSG[144,145]	

changes in a patient's physiological anatomy are considered, revisional bariatric surgery has a higher risk of existing original or new complications than initial bariatric surgery.[146,147] Therefore, some patients inevitably undergo three or four bariatric surgeries.

Multiple bariatric operations require high technical skills and careful judgment on patients' conditions, as long-term outcomes regarding weight loss and co-morbidity resolution are usually inferior to those of primary bariatric surgery.[148] Studies on multiple bariatric surgery after LSG are few; only two statistical reports showed that RYGB is the third most effective bariatric procedure.[149,150] In addition, a case report about the failure of anastomosis gastric bypass/mini-gastric bypass rescuing in patients with GERD who underwent single-anastomosis -duodeno-ileal bypass has been published.[151] GERD after multiple bariatric surgeries might be caused by the repeated dissection of the angle of His and diaphragmatic crura and enlargement of natural orifices, such as the hiatal orifice.[152]

Patients who underwent multiple bariatric surgeries are not a minority, and multiple operations have made their situations complicated. Thus, their subsequent therapies are difficult. In addition, criteria for performing multiple bariatric surgery have not been proposed. For multiple bariatric surgery, long-term reports are needed to prove its safety and effectiveness.

LSG in East Asia

In the literature, LSG is mostly performed in western populations. LSG is a relatively new procedure and is now commonly performed in East Asia, particularly in Japan.[153] The current meta-analysis by Veeravich and his colleagues suggested that LSG is an effective procedure

for weight reduction and offers durable response for up to 5 years among Asians with obesity. The observed surgical revision rate appears to be lower than the previously reported data from other populations.[154] In a retrospective study based on prospectively collected data in South Korea, LSG and laparoscopic RYGB are effective methods that can reduce weight in the medium term and have similar surgical risks. However, most patients need revision surgery after LSG.[155] A national survey in Japan showed that the mean %TWL after LSG is 29.9%, and %TWL 20% may be the best cutoff point for diabetic remission in Japanese patients with obesity.[156] According to the results of a multi-institutional survey in Japan, hypertension remission rates by procedure is in the order of laparoscopic RYGB, LSG, LSG-DJB, and laparoscopic adjustable gastric banding (LAGB) and dyslipidemia remission rates are in the order of laparoscopic RYGB, LSG-DJB, LSG, and LAGB.[157] In the whole East Asia, some interesting bariatric and metabolic procedures have achieved excellent results. For example, LSG/DJB provides patients with significant weight loss and metabolic effects.[158] Another procedure is laparoscopic adjustable gastric banded plication, which may be a good alternative to LSG when a patient desires a restrictive and potentially reversible procedure.[159,160]

Conclusion and Outlook

Low morbidity and mortality rates associated with LSG have made it one of the most commonly used bariatric procedures worldwide and a cost-effective intervention. However, the long-term prognosis of LSG and data on revisional surgery after LSG are scarce. The main indications for revision are insufficient weight loss, GERD, strictures, GL, and persistent metabolic syndrome.[161] Laparoscopic RYGB has been described as the most reasonable treatment approach and a viable option for revisional surgery.[162]

For the resolution of aforementioned problems, novel surgeries have been proposed. In addition to novel revisional methods already mentioned above, most promising primary bariatric surgeries include endoscopic sleeve gastroplasty (ESG) and robotic-assisted laparoscopic sleeve gastrectomy (RA-LSG). Nevertheless, many articles showed that RA-LSG is related to increased supply cost,[163,164] operative time, and postoperative morbidity.[165,166] ESG seems to be promising. ESG is a minimally invasive procedure that reduces the size of the gastric reservoir and appears to be well tolerated, safe, and effective[167,168] with fewer adverse events and new-onset GERD cases than LSG.[169] Through the wide application of ESG, we can even expect bariatric surgery to become an outpatient surgery.[170]

Abbreviations

%EWL, percent of excess weight loss; BPD-DS, biliopancreatic diversion with duodenal switch; DJB, duodenojejunal bypass; DPP-4, dipeptidyl peptidase-4; DS, duodenal switch; EGJ, esophagogastric junction; ESG, endoscopic sleeve gastroplasty; GERD, gastroesophageal reflux disease; GL, Gastric leak; GS, gastric stenosis; HH, hiatal hernia; HHR, hiatal hernia repair; LAGB, laparoscopic adjustable gastric banding; LES, lower esophageal sphincter; LRYEJ, Roux-En-Y Esophago-Jejunostomy; LSG, laparoscopic sleeve gastrectomy; LTC, ligamentum teres cardiopexy; OAGB, One-anastomosis gastric bypass; RA-LSG, robotic-assisted laparoscopic sleeve gastrectomy; ReSG, revisional sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; SADI, single-anastomosis duodeno-ileal bypass; SG, sleeve gastrectomy; WR, weight regain, regaining weight to achieve a BMI >35.

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