Review

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Current status of gastroesophageal reflux disease after sleeve gastrectomy: Still a long way to go

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SUMMARY Obesity is a public health concern that is becoming increasingly more serious around the world. Bariatric surgery has become more prevalent due to the obesity epidemic worldwide. Sleeve gastrectomy (SG) is one of the most popular procedures which is safe and efficient. Despite all its favorable features, however, there is an increasing evidence from the literature that the long-term incidence of gastroesophageal reflux disease (GERD) is likely to represent the Achilles' heel of this procedure. Management of severe reflux after SG usually requires revisional surgery. The relationship between SG and GERD needs to be better ascertained in order to prevent related complications, such as esophageal adenocarcinoma. This review attempts to elucidate the effect of SG on GERD and the postoperative management of reflux disease according to recent literature in the hope of drawing the attention of clinicians to postoperative gastroesophageal reflux and guiding the optimal management strategy associated with this "troublesome complication".

Keywords bariatric surgery, morbid obesity, sleeve gastrectomy (SG), gastroesophageal reflux disease (GERD)

1. Introduction

Obesity is becoming a worldwide health threat, and it is presently the most common and costly nutritional problem, with the prevalence of obesity and metabolic syndrome increasing to epidemic levels over the last few decades. Mean worldwide body mass index (BMI) has been steadily increasing since 1975, and current trends predict that 20% of the global population will be classified as obese (BMI ≥ 30 kg/m^2) by 2030 (*1,2*). Bariatric surgery has been associated with reduced overall mortality rates in obese patients and leads to remission of associated metabolic disorders (*3*). Sleeve gastrectomy (SG) is currently the most common bariatric procedure performed worldwide because of its advantages including the low rate of complications, the short operative time, the absence of foreign material, the lack of gastrointestinal anastomosis and malabsorption, the patient's acceptance, and the feasibility of its conversion into various other bariatric procedures (*4,5*).

However, the enthusiasm for a growing sleeve practice has been met with concerns of de novo or worsening gastroesophageal reflux disease (GERD) after the procedure (*6-8*). GERD is a disorder of the upper gastrointestinal tract that is defined by heartburn and acid regurgitation, which develops when reflux of the stomach contents causes troublesome symptoms and/or complications, according to the evidence-based consensus of the Montreal definition and the classification of GERD, issued in 2006 (*9*). Although obesity and other patient-related and environmental factors have been found to be independently associated with a higher incidence of GERD, certain anatomic and physiologic alterations resulting from SG are being recognized as potential etiologies of worsening of reflux disease (*10*). The prevalence of GERD following SG can be fairly high. Several studies have noted an incidence between 6% and 47% (*11-15*). This has prompted discussion among the surgical community with regard to the underlying pathomechanisms of GERD after SG and the postoperative management of reflux disease (*16-19*). So far, a number of new techniques have been reported to yield more encouraging results with regard to reflux symptoms after SG, but most evidence originates from retrospective studies with a small number of cases or is based on experts' opinions. The available data are limited, and very heterogeneous. As is often the case in surgery, when there are many solutions to one problem,

it is typically because no single solution is adequate for all patients. The aim of the current work is to review the contemporary literature and summarize the latest knowledge on GERD after SG in order to offer more conclusive insights into this controversial condition.

2. Obesity and GERD: The pathophysiology of GERD in obese individuals

GERD is undoubtedly a disease directly related to obesity. Overweight doubles the chance of GERD, and the prevalence of GERD symptoms in morbidly obese patients is as high as 50% (*20*). Moreover, the prevalence of GERD is proportional to the severity of obesity (*21*). The pathophysiology of GERD in obese individuals needs to be understood in order to adequately treat both GERD and obesity.

2.1. A defective gastroesophageal barrier

The most important pathophysiologic abnormality in GERD has been thought to be a decrease in lower esophageal sphincter (LES) pressure, either in the resting state or in association with a transient lower esophageal sphincter relaxation (TLESR). The number of episodes of TLESR is higher in the obese (*22,23*), and there is a correlation between the number of TLESR with BMI and abdominal circumference (*24,25*). Moreover, other studies have noted an increased basal pressure in the obese that is probably linked to compensatory mechanisms due to the increased intra-abdominal pressure (*26,27*). The angle of His is an important antireflux mechanism. The more acute this angle, the more the gastric fundus will be projected toward the esophagus as gastric distension occurs during a meal. The deposition of fat in the gastroesophageal junction, common and excessive in obese individuals, can result in an obtuse angle. Hiatal hernia (HH) is more frequent in the obese (*28*). Obese women are two and a half times more likely to have HH than non-obese women (*29*).

2.2. Inadequate esophageal clearance

Esophageal clearance is affected by the production of saliva, gravity, and esophageal peristalsis. Obese patients have decreased salivation (*30*), and esophageal peristalsis may be impaired in as much as a quarter of obese individuals. In addition, studies in obese individuals have found that sleep is associated with decreased swallowing and longer esophageal acid clearance time (*28,31*).

2.3. The trans-diaphragmatic pressure gradient

Abdominal pressure is increased in obese individuals due to the deposition of abdominal fat and its effect on gastric pressure. For each point of increase in the BMI, there is a 10% increase in intragastric pressure (*32*). Obese patients may also have a more negative intrathoracic pressure due to diaphragm elevation secondary to abdominal fat and a consequent decrease in pulmonary expansion. Negative intrathoracic pressure may also be increased by the frequent incidence of obstructive apnea. Obstructive sleep apnea (OSA) is closely associated with obesity. One can easily forget that OSA itself may be a cause of GERD due to an increase in TLESR (*33*).

2.4. Diet

Consumption of a high-fat diet increases the incidence of GERD symptoms compared to a high-fiber diet, regardless of caloric intake, due to a decrease in gastric emptying, a decrease in LES pressure, and an increase in the number of TLESRs (*34*). "Junk" foods, such as candy, chocolate, cookies, ice cream and cakes, are consumed more frequently by obese individuals and can induce reflux.

3. Mechanisms of new-onset or worsening GERD after SG

3.1. Increased intragastric pressure (IGP)

The shape of the sleeve likely plays a major role in the pathophysiology of post-SG GERD. When a gastric sleeve is created, a large, compliant stomach is converted into a long and narrow tube, resulting in a lack of gastric compliance and an increased IGP that correlates inversely with the diameter of the gastric tube and that increases when the pylorus is closed. The final shape of the sleeve also plays a role as it may encourage GERD and regurgitation when it is funnel-shaped (*35-37*). In addition, the vagovagal reflex diminishes after resection of the fundus, and the physiological postprandial relaxation of the stomach is eliminated. This results in an even higher IGP, pushing the gastric content in a retrograde direction (*38*). Moreover, a sleeve stenosis or an overly narrow SG can easily aggravate postoperative GERD symptoms. Sleeve stenosis is mostly due to postoperative edema, kinking, angulation, and/or cicatrization of the sleeve. Most stenoses are located in the middle portion of the sleeve, although they can occur at other locations (*39,40*). Sleeve stenosis is responsible for a considerable number of conversions from SG to Roux-en-Y gastric bypass (RYGB).

3.2. Disruption of the anatomical antireflux mechanisms

Several anatomical structures of the gastroesophageal junction comprise the antireflux barrier. The most important of these are the lower esophageal sphincter (LES) and the sling fibers at the cardia, along with the diaphragmatic crura. Alterations in the anatomy of either

Table 1. Possible mechanisms, preventive measures, and related preoperative examinations for GERD after SG

Proposed mechanisms leading to GERD after SG	Preventive measures	Targeted preoperative examinations
Hypotension of the lower esophageal sphincter	Maintain the integrity of the sling fibers of Helvetius at the esophagogastric junction	Symptom reporting
Blunting of the angle of His	Stapling should not be too close to the angle of His	Upper gastrointestinal radiography/CT/ Endoscopy
Decreased gastric compliance and volume (leading to increased intragastric pressure)	Avoid twisting/ narrowing of the sleeve; Do not place excessive tension on the stomach when stapling	CT/Endoscopy
Gastric shape	Attention to sleeve size and volume; Avoid a small bougie; Do not oversuture with overly big bites	Upper gastrointestinal radiography/CT/ Endoscopy
Concomitant presence of a hiatal hernia	Repair the concomitant hiatal hernia	Symptom reporting/Esophagogram/CT/ Endoscopy/High-resolution manometry
Fundal dilatation with distal narrowing	Avoid leaving an excessive posterior gastric fundus; Avoid narrowing the gastric body or pylorus	Upper gastrointestinal radiography/CT/ Endoscopy

of these are thought to be associated with the incidence of reflux symptoms (*41,42*).

Another aspect of the antireflux barrier at the gastroesophageal junction seems to be an acute Angle of His. To preserve this natural barrier during surgery, a careful dissection at the angle of His must be maintained in order to spare the sling fibers and avoid blunting the angle of His (*43*). During creation of the sleeve, the gastric sling fibers are frequently transected near the angle of His, particularly if the transection line is very close to this anatomic landmark. These sling fibers contribute significantly to the function of the LES (*44*). Disruption of these fibers can sometimes result in the herniation of part of the gastric sleeve into the posterior mediastinum (*45*). Table 1 summarizes the possible mechanisms, preventive measures, and related preoperative examinations for GERD after SG

4. Management of GERD after SG

4.1. Conservative treatment

While up to 30% of patients may experience some GERD symptoms after SG, most do not require surgery and can be treated successfully with medication (*46*). First-line therapy is similar to that used in the general population, with recommended lifestyle changes including abstinence from alcohol, cessation of smoking, and dietary modifications (*47*). Second-line therapy is the taking of medications to reduce stomach acid. Proton pump inhibitors (PPIs) are the preferred drugs for treatment of reflux, though promotility agents can also be used (*48*). If GERD symptoms persist despite maximal medical therapy, more invasive therapy should be considered.

4.2. Endoscopic interventions

4.2.1. Balloon dilation/endoluminal stent

If the cause of GERD is more of a technical nature, for example, sleeve stenosis, twisting, kinking, or cicatrization, an endoscopic or surgical intervention should be considered. Sleeve stenosis is first treated endoscopically with balloon dilation or endoluminal stent (*49*). Balloon dilation is the main form of treatment, and it has a good success rate in evident stenosis, but many technical aspects of this technique are still vigorously debated. Endoscopic stenting is the second line of endoscopic treatment, and it yields promising results when performed by an experienced surgeon (50). However, most patients refuse stenting after counseling because of its cost and risk of intolerance. The use of endoscopic stenting to treat sleeve stenosis should differ from its use to deal with leakage in terms of the duration of stenting and the limitation of the procedure to an experienced endoscopist (51).

4.2.2. Antireflux mucosectomy (ARMS)

Although no endoscopic procedure has been widely accepted as standard treatment of GERD, the ARMS procedure has come to the forefront in recent years. This effective and novel technique involves performing a mucosectomy of three quarters of the circumference at the gastro-esophageal junction (GEJ) in order to reduce the diameter due to scarring retraction (*52*). This procedure has yielded promising results in about 70% of patients with GERD in the available case series (*53,54*).

4.2.3. Endoscopic radiofrequency therapy

Endoscopic radiofrequency (Stretta) is a type of

radiofrequency ablation therapy utilizing temperature-controlled radiofrequency energy that is endoscopically delivered to the lower esophageal sphincter. The therapy is thought to increase the thickness of the muscular layer, providing an increase in the barrier mechanism of the LES and thereby decreasing acid exposure and the number of transient inappropriate relaxations of the sphincter (*55*). The device does not leave behind a permanent implant. The therapy is thought to remodel the muscles of the LES and gastric cardia. Studies have reported that the procedure is a safe and effective treatment for GERD, with a morbidity rate of less than 0.6 %, and the procedure can be performed on an outpatient basis. It has now been studied with up to a 10-year follow-up in non-bariatric patients and it has resulted in a significant improvement in quality of life and decreased use of proton pump inhibitors (PPIs) 10 years after the procedure (*56*). Complications include mucosal injury, bleeding, and perforation of the esophagus (*49*).

4.3. Surgical management

Surgical management is based on the following causes of reflux after SG: a lack of gastric compliance, increased intraluminal pressure, and the LES pressure. Technical/anatomical problems such as any narrowing or twisting during the sleeve dilation of the fundus and the persistence of hiatal hernias need to be addressed (*57*). A number of techniques can be used to mitigate the severity of reflux, either by maintaining the normal anatomic structures that limit reflux or by supplementing these structures with a plication or gastroplasty. Individuals with existing severe reflux should not be eligible for SG. New techniques that incorporate plication during the index SG have resulted in some improvement, but these involve small cases series that need to be evaluated further. The only proven method of treating intractable reflux after SG is conversion to RYGB.

4.3.1. Conversion to Roux

RYGB is still the best approach to avoid the incidence of GERD symptoms and to alleviate preoperative reflux (*58*). Conversion to RYGB effectively reduces GERD and has been found to alleviate symptoms in most patients. A RYGB limits acid production to the small gastric pouch and it reduces esophageal reflux because of the Roux-en Y anatomy, which also retains the physical activity of the esophagus and gastric pouch within the abdomen (*59*).

Several studies have confirmed that an RYGB decreases the esophagus' exposure to gastric acid. Curell *et al.* (*60*) evaluated conversion from SG to RYGB due to GERD using a prospective bariatric surgery database (2010-2018), and they found that conversion to RYGB was effective in almost all patients. They proposed that the focus should be on an exhaustive examination and aggressive approach to a hiatus. Matar *et al.* (*61*) and Lim *et al.* (*62*) obtained similar results for a RYGB for GERD. Felsenreich *et al.* (*63*) evaluated RYGB as treatment for Barrett's esophagus and reflux after SG. They concluded that RYGB is an effective therapy for patients with Barrett's esophagus and reflux after SG. In a bid to define the best practice guidelines, an international expert panel consensus statement declared that the entire panel agreed that patients who develop intractable GERD following LSG are best treated with a conversion to RYGB (*64*).

4.3.2. Magnetic sphincter augmentation (MSA)

Since the rise of SG and the known rate of postoperative GERD, MSA has been recognized as an effective treatment option for patients with GERD after SG; MSA recreates a physiological LES by means of a titanium bead ring around the gastro-esophageal junction (*65*). The device can be implanted laparoscopically, and the procedure can be done on an outpatient basis. Patients are allowed to return to a normal diet on the first day postoperatively, for as much as they can tolerate. This procedure has been found to reduce the esophagus' exposure to gastric acid, to alleviate the symptoms of GERD, and to decrease the need for antireflux medications, improving the quality of life of patients (*66*). Broderick *et al.* (*67*) reported that patients with GERD after SG had an overall satisfaction after MSA as high as 100% (13/13). A study by Kuckelman *et al.* (*68*) compared therapeutic benefits in a standard eligible group and a post-bariatric surgery group. Kuckelman *et al.* contended that MSA can provide surgeons with a new and much needed tool in their armory to combat refractory or de novo GERD developing after bariatric procedures. Although studies have suggested promising results, they have only reported on a small group of patients followed for a short period. The potential for erosion of the LINX device as well as the difficulty in dealing with these erosions surgically should also be considered (*69*). We propose the following algorithm of management for GERD after SG (Figure 1).

5. Conclusion

Obesity is associated with both symptoms and complications of GERD, and the associated risks seem to increase with increasing weight. The true incidence of clinically significant GERD following SG is unclear, but there is evidence indicating an increase in its incidence. As SG continues to be the form of bariatric surgery most often performed worldwide, further research is needed to provide clear guidance regarding the optimal preoperative evaluation of eligible patients and to ascertain technical aspects that can help to potentially

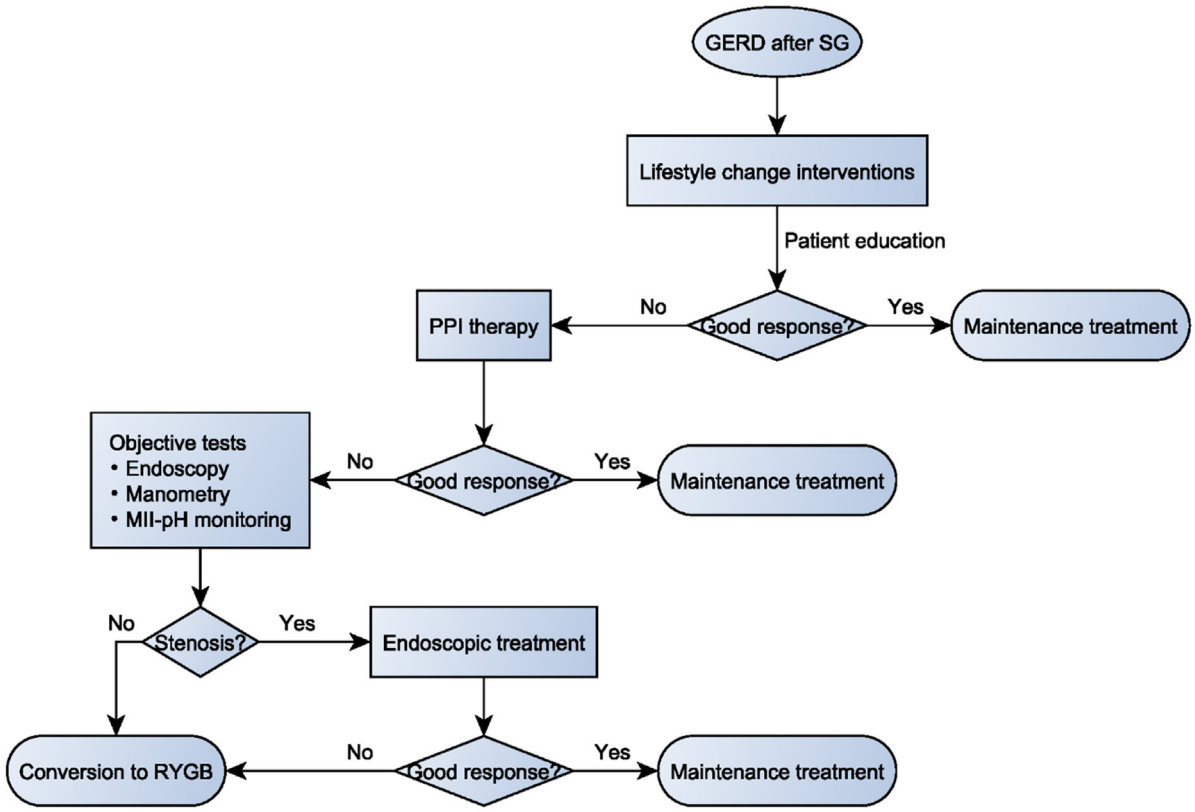

Figure 1. Current management algorithm for GERD after SG in the opinion of the authors. GERD, gastroesophageal reflux disease; SG, sleeve gastrectomy; PPI, proton pump inhibitor; RYGB, Roux-en-Y gastric bypass.

decrease the prevalence of this complication. GERD after SG is a complex problem if medical management fails. The first line of therapy is the use of antireflux medications. Currently available endoscopic antireflux procedures cannot be considered as an alternative to traditional surgical approaches in their current state, but they remain important weapons in the practitioner' s armory. The only evidence-based salvage operation for GERD after SG is RYGB. Numerous techniques have been proposed to mitigate the severity of reflux, either by maintaining the normal anatomic structures that limit reflux or by supplementing these structures with some type of plication or gastroplasty. Several of these new alternatives have yielded satisfactory results. Nevertheless, most evidence originates from retrospective studies with a small number of cases or is based on experts' opinions. The available data are limited, very heterogeneous, and need to be further evaluated.

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References

1. Blüher M. Obesity: Global epidemiology and pathogenesis. Nat Rev Endocrinol. 2019; 15:288-298.
2. Jaacks LM, Vandevijvere S, Pan A, McGowan CJ, Wallace C, Imamura F, Mozaffarian D, Swinburn B, Ezzati M. The obesity transition: stages of the global epidemic. Lancet Diabetes Endocrinol. 2019; 7:231-240.
3. Wee CC. Bariatric surgery for patients with obesity: The earlier the better. Ann Intern Med. 2020; 173:758-759.
4. Puzziferri N, Almandoz JP. Sleeve gastrectomy for weight loss. JAMA. 2018; 319:316.
5. Brajcich BC, Hungness ES. Sleeve gastrectomy. JAMA. 2020; 324:908.
6. van Rutte PW, Smulders JF, de Zoete JP, Nienhuijs SW. Outcome of sleeve gastrectomy as a primary bariatric procedure. Br J Surg. 2014; 101:661-668.
7. Dalboh A, Al-Shehri DM, Abd El Maksoud WM, Abbas KS, Alqahtani AJ, Al-Malki AQ, Al-Shahrani KA. Impact of Laparoscopic Sleeve Gastrectomy on Gastroesophageal Reflux Disease and Risk Factors

Associated with Its Occurrence Based Upon Quality of Life. Obes Surg. 2021; 31:3065-3074.
8. Yeung KTD, Penney N, Ashrafian L, Darzi A, Ashrafian H. Does Sleeve Gastrectomy Expose the Distal Esophagus to Severe Reflux?: A Systematic Review and Meta-analysis. Ann Surg. 2020; 271:257-265.
9. Vakil N, van Zanten SV, Kahrilas P, Dent J, Jones R; Global Consensus Group. The Montreal definition and classification of gastroesophageal reflux disease: A global evidence-based consensus. Am J Gastroenterol. 2006; 101:1900-1920; quiz 1943.
10. Althuwaini S, Bamehriz F, Aldohayan A, Alshammari W, Alhaidar S, Alotaibi M, Alanazi A, Alsahabi H, Almadi MA. P. Prevalence and predictors of gastroesophageal reflux disease after laparoscopic sleeve gastrectomy. Obes Surg. 2018; 28:916-922.
11. Alvarenga ES, Lo Menzo E, Szomstein S, Rosenthal RJ. Safety and efficacy of 1020 consecutive laparoscopic sleeve gastrectomies performed as a primary treatment modality for morbid obesity. A single-center experience from the metabolic and bariatric surgical accreditation quality and improvement program. Surg Endosc. 2016; 30:2673-2678.
12. Gorodner V, Buxhoeveden R, Clemente G, Solé L, Caro L, Grigaites A. Does laparoscopic sleeve gastrectomy have any influence on gastroesophageal reflux disease? Preliminary results. Surg Endosc. 2015; 29:1760-1768.
13. Moon RC, Teixeira AF, Jawad MA. Is preoperative manometry necessary for evaluating reflux symptoms in sleeve gastrectomy patients. Surg Obes Relat Dis. 2015; 11:546-551.
14. Gärtner D, Stroh C, Hukauf M, Benedix F, Manger T; Obesity Surgery Working Group, Competence Network Obesity. Sleeve gastrectomy in the German Bariatric Surgery Registry from 2005 to 2016: Perioperative and 5-year results. Surg Obes Relat Dis. 2019; 15:187-193.
15. Felsenreich DM, Prager G, Kefurt R, Eilenberg M, Jedamzik J, Beckerhinn P, Bichler C, Sperker C, Krebs M, Langer FB. Quality of life 10 years after sleeve gastrectomy: A multicenter study. Obes Facts. 2019; 12:157-166.
16. Johari Y, Wickremasinghe A, Kiswandono P, Yue H, Ooi G, Laurie C, Hebbard G, Beech P, Yap K, Brown W, Burton P. Mechanisms of esophageal and gastric transit following sleeve gastrectomy. Obes Surg. 2021; 31:725-737.
17. Patti MG, Schlottmann F. Gastroesophageal reflux after sleeve gastrectomy. JAMA Surg. 2018; 153:1147-1148.
18. Bevilacqua LA, Obeid NR, Yang J, Zhu C, Altieri MS, Spaniolas K, Pryor AD. Incidence of GERD, esophagitis, Barrett's esophagus, and esophageal adenocarcinoma after bariatric surgery. Surg Obes Relat Dis. 2020; 16:1828-1836.
19. Bou Daher H, Sharara AI. Gastroesophageal reflux disease, obesity and laparoscopic sleeve gastrectomy: The burning questions. World J Gastroenterol. 2019; 25:4805-4813.
20. Chang P, Friedenberg F. Obesity and GERD. Gastroenterol Clin North Am. 2014; 43:161-173.
21. Pandolfino JE. The relationship between obesity and GERD: "Big or overblown". Am J Gastroenterol. 2008; 103:1355-1357.
22. Wu JC, Mui LM, Cheung CM, Chan Y, Sung JJ. Obesity is associated with increased transient lower esophageal sphincter relaxation. Gastroenterology. 2007; 132:883-889.
23. Schneider JH, Küper M, Königsrainer A, Brücher B. Transient lower esophageal sphincter relaxation in morbid obesity. Obes Surg. 2009; 19:595-600.
24. Lee YY, McColl KE. Pathophysiology of gastroesophageal reflux disease. Best Pract Res Clin Gastroenterol. 2013; 27:339-351.
25. Richter JE, Rubenstein JH. Presentation and epidemiology of gastroesophageal reflux disease. Gastroenterology. 2018; 154:267-276.
26. Herbella FA, Sweet MP, Tedesco P, Nipomnick I, Patti MG. Gastroesophageal reflux disease and obesity. Pathophysiology and implications for treatment. J Gastrointest Surg. 2007; 11:286-290.
27. Valezi AC, Herbella FA, Junior JM, de Almeida Menezes M. Esophageal motility after laparoscopic Roux-en-Y gastric bypass: The manometry should be preoperative examination routine. Obes Surg. 2012; 22:1050-1054.
28. Suter M, Dorta G, Giusti V, Calmes JM. Gastro-esophageal reflux and esophageal motility disorders in morbidly obese patients. Obes Surg. 2004; 14:959-966.
29. Herbella FA, Patti MG. Gastroesophageal reflux disease: From pathophysiology to treatment. World J Gastroenterol. 2010; 16:3745-3749.
30. Côté-Daigneault J, Leclerc P, Joubert J, Bouin M. High prevalence of esophageal dysmotility in asymptomatic obese patients. Can J Gastroenterol Hepatol. 2014; 28:311-314.
31. Koppman JS, Poggi L, Szomstein S, Ukleja A, Botoman A, Rosenthal R. Esophageal motility disorders in the morbidly obese population. Surg Endosc. 2007; 21:761-764.
32. Nadaleto BF, Herbella FA, Patti MG. Gastroesophageal reflux disease in the obese: Pathophysiology and treatment. Surgery. 2016; 159:475-486.
33. Shepherd K, Hillman D, Holloway R, Eastwood P. Mechanisms of nocturnal gastroesophageal reflux events in obstructive sleep apnea. Sleep Breath. 2011; 15:561-570.
34. Mion F, Dargent J. Gastro-oesophageal reflux disease and obesity: Pathogenesis and response to treatment. Best Pract Res Clin Gastroenterol. 2014; 28:611-622.
35. F, Chand B, Grimminger P, Mikami D, Schoppmann SF, Müller-Stich B. Do we understand the pathophysiology of GERD after sleeve gastrectomy? Ann N Y Acad Sci. 2020; 1482:26-35.
36. Alhaj Saleh A, Janik MR, Mustafa RR, Alshehri M, Khan AH, Kalantar Motamedi SM, Rahim S, Patel I, Aryaie A, Abbas M, Rogula T, Khaitan L. Does sleeve shape make a difference in outcomes? Obes Surg. 2018; 28:1731-1737.
37. Wang Y, Yi XY, Gong LL, Li QF, Zhang J, Wang ZH. The effectiveness and safety of laparoscopic sleeve gastrectomy with different sizes of bougie calibration: A systematic review and meta-analysis. Int J Surg. 2018; 49:32-38.
38. Johari Y, Lim G, Wickremasinghe A, Yue H, Seah J, Ooi G, Playfair J, Laurie C, Beech P, Yap K, Hebbard G, Brown W, Burton P. Pathophysiological Mechanisms of GASTRO-ESOPHAGEAL Reflux Following Sleeve Gastrectomy. Ann Surg. 2020; doi: 10.1097/SLA.0000000000004637.
39. Ferraz ÁAB, da Silva JD, Santa-Cruz F, Aquino MR, Siqueira LT, Kreimer F. The impact of the gastric twist on esophagitis progression after sleeve gastrectomy:

Mid-term endoscopic findings. Obes Surg. 2020; 30:4452-4458.
40. Csendes A, Orellana O, Martínez G, Burgos AM, Figueroa M, Lanzarini E. Clinical, endoscopic, and histologic findings at the distal esophagus and stomach before and late (10.5 years) after laparoscopic sleeve gastrectomy: Results of a prospective study with 93% follow-up. Obes Surg. 2019; 29:3809-3817.
41. Coupaye M, Gorbatchef C, Calabrese D, Sami O, Msika S, Coffin B, Ledoux S. Gastroesophageal reflux after sleeve gastrectomy: A prospective mechanistic study. Obes Surg. 2018; 28:838-845.
42. Hesse UJ. What causes gastroesophageal reflux following sleeve gastrectomy. Obes Surg. 2020; 30:759.
43. Emile SH. Gastroesophageal reflux disease after sleeve gastrectomy: The need to predict its onset and prevent its consequences. Obes Surg. 2019; 29:2625-2626.
44. Tolone S, Savarino E, Yates RB. The impact of bariatric surgery on esophageal function. Ann N Y Acad Sci. 2016; 1381:98-103.
45. Borbély Y, Bouvy N, Schulz HG, Rodriguez LA, Ortiz C, Nieponice A. Electrical stimulation of the lower esophageal sphincter to address gastroesophageal reflux disease after sleeve gastrectomy. Surg Obes Relat Dis. 2018; 14:611-615.
46. Kindel TL, Oleynikov D. The improvement of gastroesophageal reflux disease and Barrett's after bariatric surgery. Obes Surg. 2016; 26:718-720.
47. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G. Long-term (11+years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016; 12:1778-1786.
48. Barr AC, Frelich MJ, Bosler ME, Goldblatt MI, Gould JC. GERD and acid reduction medication use following gastric bypass and sleeve gastrectomy. Surg Endosc. 2017; 31:410-415.
49. Ganz RA. A review of new surgical and endoscopic therapies for gastroesophageal reflux disease. Gastroenterol Hepatol (N Y). 2016; 12:424-431.
50. Agnihotri A, Barola S, Hill C, Neto MG, Campos J, Singh VK, Schweitzer M, Khashab MA, Kumbhari V. An algorithmic approach to the management of gastric stenosis following laparoscopic sleeve gastrectomy. Obes Surg. 2017; 27:2628-2636.
51. Vilallonga R, Sanchez-Cordero S, Umpiérrez Mayor N, Molina A, Cirera de Tudela A, Ruiz-Úcar E, Carrasco MA. GERD after Bariatric Surgery. Can We Expect Endoscopic Findings? Medicina (Kaunas). 2021; 57:506.
52. Yoo IK, Ko WJ, Kim HS, Kim HK, Kim JH, Kim WH, Hong SP, Yeniova AÖ, Cho JY. Anti-reflux mucosectomy using a cap-assisted endoscopic mucosal resection method for refractory gastroesophageal disease: A prospective feasibility study. Surg Endosc. 2020; 34:1124-1131.
53. Inoue H, Tanabe M, de Santiago ER, Abad MRA, Shimamura Y, Fujiyoshi Y, Ueno A, Sumi K, Tomida H, Iwaya Y, Ikeda H, Onimaru M. Anti-reflux mucosal ablation (ARMA) as a new treatment for gastroesophageal reflux refractory to proton pump inhibitors: A pilot study. Endosc Int Open. 2020; 8:E133-133E138.
54. Monino L, Gonzalez JM, Vitton V, Barthet M. Antireflux mucosectomy band in treatment of refractory gastroesophageal reflux disease: A pilot study for safety, feasibility and symptom control. Endosc Int Open. 2020; 8:E147-147E154.
55. Khidir N, Angrisani L, Al-Qahtani J, Abayazeed S, Bashah M. Initial experience of endoscopic radiofrequency waves delivery to the lower esophageal sphincter (Stretta procedure) on symptomatic gastroesophageal reflux disease post-sleeve gastrectomy. Obes Surg. 2018; 28:3125-3130.
56. Fass R, Cahn F, Scotti DJ, Gregory DA. Systematic review and meta-analysis of controlled and prospective cohort efficacy studies of endoscopic radiofrequency for treatment of gastroesophageal reflux disease. Surg Endosc. 2017; 31:4865-4882.
57. Crawford C, Gibbens K, Lomelin D, Krause C, Simorov A, Oleynikov D. Sleeve gastrectomy and anti-reflux procedures. Surg Endosc. 2017; 31:1012-1021.
58. Assalia A, Gagner M, Nedelcu M, Ramos AC, Nocca D. Gastroesophageal reflux and laparoscopic sleeve gastrectomy: Results of the First International Consensus Conference. Obes Surg. 2020; 30:3695-3705.
59. Carandina S, Soprani A, Montana L, Murcia S, Valenti A, Danan M, d'Agostino J, Rivkine E, Nedelcu M. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass in patients with gastroesophageal reflux disease: Results of a multicenter study. Surg Obes Relat Dis. 2020; 16:732-737.
60. Curell A, Beisani M, García Ruiz de Gordejuela A, Vilallonga R, Verdaguer Tremolosa M, González López Ó, Caubet Busquet E, Fort López-Barajas JM. Outcomes of Conversion from Sleeve Gastrectomy to Roux-en-Y Gastric Bypass Due to GERD-a Retrospective Analysis of 35 Patients. Obes Surg. 2021; doi: 10.1007/s11695-021-05541-4.
61. Curell A, Beisani M, García Ruiz de Gordejuela A, Vilallonga R, Verdaguer Tremolosa M, González López Ó, Caubet Busquet E, Fort López-Barajas JM. Outcomes of Conversion from Sleeve Gastrectomy to Roux-en-Y Gastric Bypass Due to GERD-a Retrospective Analysis of 35 Patients. Obes Surg. 2021; doi: 10.1007/s11695-021-05541-4.
62. Lim CH, Lee PC, Lim E, Eng A, Chan WH, Tan HC, Ho E, Kovalik JP, Ganguly S, Tan J. Resolution of erosive esophagitis after conversion from vertical sleeve gastrectomy to Roux-en-Y gastric bypass. Obes Surg. 2020; 30:4751-4759.
63. Felsenreich DM, Langer FB, Bichler C, Eilenberg M, Jedamzik J, Kristo I, Vock N, Gensthaler L, Rabl C, Todoroff A, Prager G. Roux-en-Y gastric bypass as a treatment for Barrett's esophagus after sleeve gastrectomy. Obes Surg. 2020; 30:1273-1279.
64. Kichler K, Rosenthal RJ, DeMaria E, Higa K. Reoperative surgery for nonresponders and complicated sleeve gastrectomy operations in patients with severe obesity. An international expert panel consensus statement to define best practice guidelines. Surg Obes Relat Dis. 2019; 15:173-186.
65. Ndubizu GU, Petrick AT, Horsley R. Concurrent magnetic sphincter augmentation and hiatal hernia repair for refractory GERD after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2020; 16:168-170.
66. Clapp B, Dodoo C, Harper B, Kim J, Castro C, Hamdan M, Grasso S, Davis B. Magnetic sphincter augmentation at the time of bariatric surgery: An analysis of the MBSAQIP. Surg Obes Relat Dis. 2021; 17:555-561.
67. Broderick RC, Smith CD, Cheverie JN, Omelanczuk P,

Lee AM, Dominguez-Profeta R, Cubas R, Jacobsen GR, Sandler BJ, Fuchs KH, Horgan S. Magnetic sphincter augmentation: A viable rescue therapy for symptomatic reflux following bariatric surgery. Surg Endosc. 2020; 34:3211-3215.
68. Kuckelman JP, Phillips CJ, Derickson MJ, Faler BJ, Martin MJ. Esophageal magnetic sphincter augmentation as a novel approach to post-bariatric surgery gastroesophageal reflux disease. Obes Surg. 2018; 28:3080-3086.
69. DeMarchi J, Schwiers M, Soberman M, Tokarski A. Evolution of a novel technology for gastroesophageal reflux disease: A safety perspective of magnetic sphincter augmentation. Dis Esophagus. 2021.

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