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The Management of Intractable Gastroesophageal Reflux Following Sleeve Gastrectomy: A Narrative Review

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Abstract

Purpose of Review Laparoscopic sleeve gastrectomy (LSG) is currently the most commonly performed bariatric surgery in the world and is widely considered safe and effective for weight loss in the obese population. However, intractable gastroesophageal reflux disease (GERD) following LSG poses a clinical challenge, with significant impact on quality of life and the potential for development of Barrett's esophagus This review aims to provide clinicians with a systematic approach to investigating and managing patients with intractable GERD following LSG.

Recent Findings Management of GERD following LSG requires thorough clinical, anatomical and functional assessment in order to accurately diagnose GERD. Management should then be tailored to the patient in an integrated approach, with medical, endoscopic and/or operative interventions. Medical therapy includes PPIs and lifestyle therapy and are well established for GERD in the post-LSG population but limited in efficacy for severe disease. Endoscopic treatments such as anti-reflux mucosectomy and endoscopic radiofrequency ablation are novel, and benefits are still unclear. Operative interventions include conversion to Roux-en-Y gastric bypass with or without hiatal hernia repair, one anastomosis gastric bypass, duodenal switch, hiatal hernia repair or insertion of a Linx ™ device. These options have predominantly been studied in weight-loss failure post-LSG, with emerging evidence now in the treatment of intractable GERD following LSG.

Summary A three-pronged assessment including clinical factors, anatomical evaluation and functional studies are required to accurately diagnose intractable GERD following LSG. Following this, individualised management with medical therapy, endoscopic and/or operative interventions should be considered with the patient within a multidisciplinary healthcare setting.

Keywords Obesity · Laparoscopic sleeve gastrectomy · Gastro-esophageal reflux · Management

Introduction

Global rates of obesity continue to rise, resulting in a significant public health and economic burden [1]. Bariatric surgery remains the most effective method of producing lasting weight loss and reducing the incidence and progression of obesity-related diseases [2]. Laparoscopic sleeve gastrectomy (LSG) is currently the most common bariatric procedure performed worldwide. It is a technically straightforward and safe procedure which results in effective weight loss and reduction in obesity-related comorbidities, which accounts for its popularity with both patients and surgeons [3].

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There are concerns for the potentiation of symptomatic gastro-esophageal reflux disease (GERD) following LSG. GERD is associated with significantly reduced quality of life and increased risk of premalignant conditions such as Barrett's esophagus in the first decade following LSG [4–8]. Following LSG, the incidence of GERD may be as high as 57% within 10 years post-operatively [5]. Rates of de novo GERD following LSG have been reported to range from 16 to 47% [9–11]. The heterogeneity of results is likely impacted by the array of varying definitions and diagnostic methodology used in the literature, which include various combinations of clinical history, patient questionnaires, pH and manometry measurements and/or endoscopic evaluation [12, 13]. In accordance with the 2018 Lyon Consensus, the diagnosis of GERD requires summative findings from clinical history, questionnaire data, pH studies (distal esophageal acid exposure time > 6%) and endoscopy (advanced grade erosive esophagitis, long-segment Barrett's esophagus or peptic strictures). Further adjunctive diagnostic evidence can be gathered from biopsy findings, high resolution manometry (HRM) studies and novel impedance metrics [14]. Intractable, or refractory GERD is poorly defined by major international groups, however has been defined in the literatures inadequate symptom response after at least 8 weeks of twice-daily proton pump inhibitor (PPI) therapy [15].

One of the major risk factors for the development of GERD is obesity itself. Multiple pathophysiological mechanisms account for this. Obesity, as measured by an increased body mass index (BMI) results in a subsequent increase in intra-abdominal and intra-gastric pressure, and therefore an increased gastro-esophageal pressure gradient [16]. Increased BMI is also associated with a mechanically defective lower esophageal sphincter (LES), increased transient LES relaxation, esophageal dysmotility and hiatus hernia occurrence [17–19].

In addition to the bariatric surgery patient population's inherent risk factor of obesity, LSG may predispose to de novo GERD. Following LSG, the gastro-esophageal junction anatomy is modified, resulting in widening of the angle of His and thus increasing the propensity for GERD [17]. Final sleeve morphology has also been thought to play a role, with a dilated proximal stomach (superior pouch) and narrowed mid-stomach (incisura stenosis) being demonstrated on gastrograffin studies of patients who experienced GERD post-LSG [20]. There is also frequently a necessary disruption of the phreno-esophageal ligament during LSG, which may cause LES dysfunction, and result in herniation of the stomach into the thoracic cavity [21]. In addition to these anatomical factors, objective pH and HRM studies have demonstrated elevated fasting esophageal acid exposure, hypotension of the LES, and reduced gastric volume and compliance resulting in raised intragastric pressures and therefore raised gastro-esophageal pressure gradients, which all contribute to the development of GERD post-LSG [1, 22–27]. There is an interplay of these factors with the weight loss patient experience following LSG, which alleviates some of the aspects of GERD, with reduced gastric acid output, increased gastric transit, and lowering of intra-abdominal pressures [28].

With the obesity epidemic, the treatment and management of intractable GERD post-LSG becomes increasingly essential. The aim of this review is to provide healthcare professionals working within a bariatric multidisciplinary team with a framework of management options for patients with intractable GERD following LSG.

Methods

A literature search was conducted on the MEDLINE and PubMed electronic databases for articles published from 2000 to 2023 to include data relevant to the laparoscopic surgery era. The search strategy used combinations of the keywords "overweight", "obesity", "sleeve gastrectomy", "gastro-oesophageal reflux", "investigations", "treatment" and "therapy". Abstracts were screened for relevance. Specialist society publications and guidelines were screened including the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO), the British Obesity and Metabolic Surgery Society (BOMSS) and the American Society for Metabolic and Bariatric Surgery (ASMBS). We included English language articles and human studies only. There were no exclusions on article type. Abstracts, review articles, letters and editorials were included.

Results

Investigations Directing Management

The diagnosis of post-LSG GERD in clinical practice is based on patient symptoms, response to medical therapy, and investigations that aim to establish or refute, or provide supportive evidence the diagnosis. It is recognized that there is heterogeneity in the assessment of GERD post-LSG. A combination of clinical, anatomical, and functional assessment is often employed, and this reflects the complexity of the postoperative upper gastrointestinal tract, as well as GERD pathophysiology and its phenotypes.

Clinical Assessment and Acid Suppression

The use of clinical history and questionnaires in the assessment of typical GERD symptoms (heartburn and regurgitation) have been evaluated and though subjective, form an accessible and low-cost option of assessment. The subjective nature of clinician evaluation, even in the context of specialist gastroenterologists, had a sensitivity and specificity of symptoms-based GERD diagnosis of 67% and 70% respectively, in a blinded study when compared to objective investigations [29]. An array of questionnaires are used for GERD assessment of symptom severity and quality of life. These validated questionnaires may be specific to GERD, such as the Reflux Disease Questionnaire (RDQ), Gastroesophageal Reflux Disease Symptom Assessment Scale (GSAS), Carlson Dent self-administered questionnaire or generic such as the Short Form Health Survey (SF-36) [30, 31]. The accuracy of these questionnaires has been reported as being similar to clinical diagnosis, with a sensitivity of 62% and specificity of 67% noted in the prior mentioned blinded study [29, 32].

Acid suppression with a trial of PPI is a pragmatic approach to patient management but does not equate to GERD diagnosis. This approach has been favoured for its availability and simplicity [33]. However, the sensitivity and specificity of GERD diagnosis with a trial of empirical PPI was noted at 71% and 44% when compared to objective assessment [29]. This low specificity is related to the mechanism of action of PPIs, with lower response rates noted in patients with atypical symptoms such as chest pain, cough, etc. The other potential reasons for failure of PPI response relate to the heterogeneity of GERD, with persistent weakly acid, bile, or gas reflux, or in those with esophageal mucosal hypersensitivity [34].

Anatomical Assessment

Morphological abnormalities of the post-LSG stomach contribute to the incidence of GERD and should be excluded through anatomical assessment. Other findings of these investigations may form supporting evidence for the diagnosis of GERD [14]. These abnormalities include esophageal dilation, hiatal hernia, neofundus or a retained fundus, sleeve dilation, antral dilation, and incisura stenosis and angulation, or a combination of these [35–38]. The anatomical assessment for these factors generally involves a barium swallow, esophagoduodenoscopy (EGD), computed tomography (CT), or combination of these investigations.

Barium swallow is an imaging study that involves swallowing barium-contrast in conjunction with either an x-ray series or with fluoroscopy. In the context of post-LSG GERD assessment, the flow of contrast from the esophagus, through to the stomach and duodenum, and anatomy of the gastric sleeve can be inspected. In this respect, it can also provide a certain degree of subjective functional information. Despite its availability and low cost, BS may have a poor sensitivity in detecting anatomical abnormalities. It is associated with a low sensitivity (30%) of detecting gastric sleeve stenosis [38]. This investigation has also been less accurate in hiatal hernia diagnosis in a recent meta-analysis, although with no studies relating to post-LSG specifically were included [39].

Esophagoduodenoscopy and biopsy is often used in GERD symptoms evaluation post-LSG. There are proponents of routine preoperative EGD to detect pathology that may alter the choice of bariatric surgery, such as reflux oesophagitis, Barrett's esophagus, hiatus hernia or undiagnosed malignancy [36, 40, 41]. Certainly, high-grade oesophagitis (LA grades C or D), long segment Barrett's esophagus or peptic strictures are considered confirmatory evidence for GERD [14, 42]. EGD can also detect associated morphological abnormalities post-LSG such as hiatal hernias and diagnose sleeve stenosis with concurrent therapeutic intervention [38, 43]. Though it is recognised that EGD findings may be discordant with the patient's symptoms, or when used as a screening test in an asymptomatic population [37].

More recently, CT imaging has been utilized to assess post-LSG GERD symptoms due to availability and its role in assessment of other potential postoperative symptoms. Intrathoracic staple-line migration at 1-year post-LSG has been correlated with GERD symptoms ($p < 0.05$, OR = 4.25) [44]. In a small case series assessing post-LSG patients with weight regain and/or upper gastrointestinal symptoms, CT was more sensitive than other conventional assessments for morphological alterations [35]. CT was more sensitive than barium swallow in detection of hiatal hernia (100% vs 57.1%, $p = 0.04$), and more sensitive than EGD for sleeve dilation (100% vs 43.7%, $p < 0.05$), and antral dilation (100% vs 52.6%, $p < 0.05$). Furthermore, another recent series demonstrated a higher sensitivity with CT and hiatal surface area measurements (94.6%) when compared with ECG (75.3%), barium swallow (70.9%), or high-resolution esophageal manometry (HRM) (80.4%) [45].

Functional Assessment

The functional assessment of GERD symptoms following LSG involves a complex interplay of esophageal function relating to the main anti-reflux mechanisms of the upper gastrointestinal tract and surrounding structures, as well as the nature of the reflux burden. This assessment is generally performed through a combination of HRM and 24-h pH impedance monitoring.

Whilst HRM was designed to objectively assess esophageal motility, there are several overlapping components to are attributed this GERD symptoms. A HRM catheter with up to 36 pressure sensors spaced 1 cm apart is placed in the past the gastroesophageal junction with a series of dry and liquid swallows. HRM has also largely replaced conventional manometry due to increased diagnostic accuracy, and its ability to assess anatomical landmarks and pressurization patterns [46]. Objective studies in HRM post-LSG assesses esophageal bolus clearance, esophagogastric junction basal pressure, LES length, basal and relaxation pressures, gastric pressure, and the presence of hiatus hernia [27, 42, 47, 48].

Though an association between GERD and esophageal peristalsis impairment has been shown in several studies, whether this amounts to a causal relationship is unclear [47]. The burden of reflux disease also correlates with the degree of esopahgeal dysmotility, as impaired peristalsis results in reduced reflux clearance [49]. Though there is significant heterogenity in the studies available in the current literature on post-LSG HRM, there appears to be an association with impaired esophageal peristalsis, slowed esophageal transit, and an increase in proximal intragastric pressure (Fig. 1) [47]. Detection of hypotensive EGJ, esophageal hypomotility, and or the presence of a HH provides supportive evidence for GERD diagnosis [14]. Figure 2 demonstrates the preoperative and postoperative HRM of a patient with GERD, 5-years following LSG, who underwent a HHR. A 3 cm HH is seen in the preoperative image through the LES migrating proximal to and separating from the external diaphragmatic crura. The postoperative image shows restoration of the LES complex, where these two components are inseparable.

The gold standard for detection and characterization of reflux episodes is ambulatory pH monitoring. Currently this is available as either transnasal catheter-based 24-h pH monitoring or wireless pH monitoring (up to 96 h) (Bravo® pH mointoring) using a transoral pH capsule introduced to the distal esophagus during EGD [32]. The addition of impedance electrodes allows for assessment of reflux burden, including weakly acidic and alkaline reflux, and liquid and gaseous reflux. Among the pH monitoring metrics,

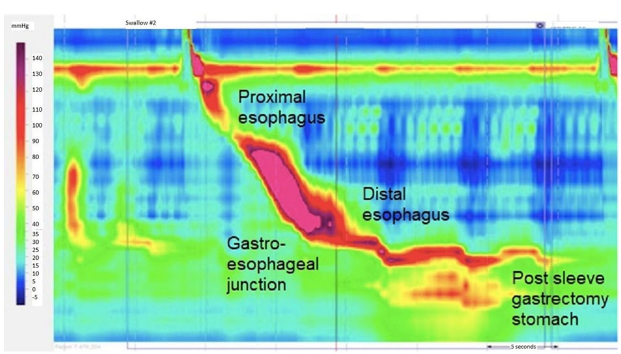

Fig. 1 This figure shows a pressure tomography plot during a normal swallow, measured using a 36-channel high-resolution manometry system, of a patient with reflux symptoms post sleeve gastrectomy. High intra-gastric pressure (up to 90 mmHg) is demonstrated in this image, a consistent finding associated with reflux post sleeve gastrectomy. Time is on the horizontal axis and length along the esophagus and stomach on the vertical axis. Pressure magnitude is encoded in color corresponding the scale shown on the left. High-pressure regions are denoted by the red end of the spectrum

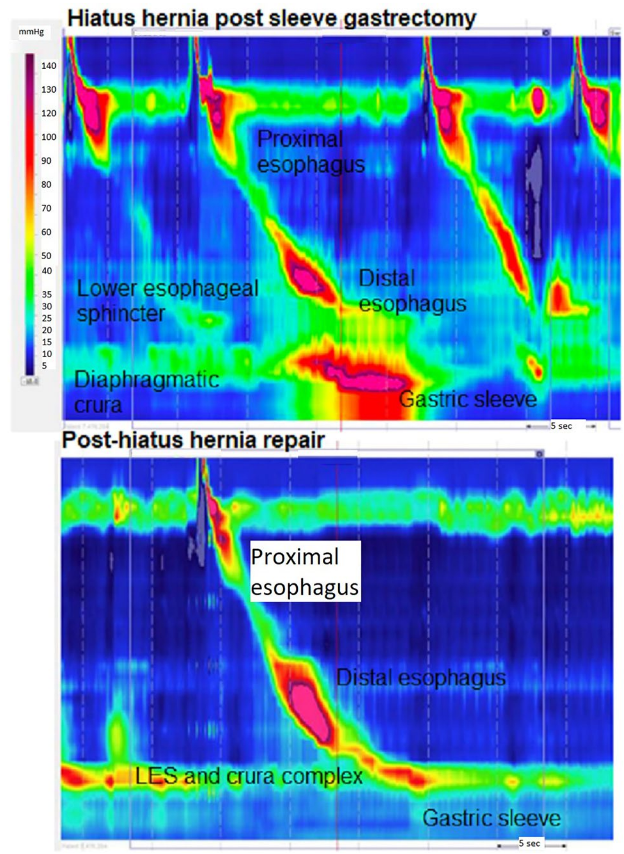

Fig. 2 Preoperative and postoperative high-resolution esophageal manometry in a patient with severe reflux 5-year post sleeve gastrectomy, before (above) and after (below) hiatus hernia repair. The 3 cm hernia is demonstrated by a separation of the lower esophageal sphincter (LES) proximal to the diaphragmatic crura distally. The sphincter and crura are inseparable in a single complex following repair. Time is on the horizontal axis and length along the esophagus and stomach on the vertical axis. Pressure magnitude is encoded in color corresponding the scale shown on the left. High-pressure regions are denoted by the red end of the spectrum

the most reproducible and predictive of response to reflux therapy is total acid exposure time (AET) [14]. AET > 6% is diagnostic of pathologic reflux in accordance with the Lyon consensus. Where AET is borderline (4–6%), then other supporting factors may be association of reflux symptoms, reflux episodes > 80, low mean nocturnal baseline impedance, and low post reflux swallow-induced peristaltic wave index (cite). The DeMeester reflux score, a weighted score of six pH monitoring parameters, with a threshold of > 14.7 is also considered diagnostic of GERD [50].

It is recognized that the established parameters of these functional assessments are studied from patients without altered anatomy. The physiology of the post-LSG state may therefore require altered or even specific criteria to diagnose GERD. It has been proposed that the criteria for GERD diagnosis post-LSG is a Reflux symptom score of

11.5 (sensitivity 84.0%, specificity 68.2%) and supine acid exposure of 2.65% (sensitivity 67.1%, specificity 70.8%), though further multi-center evaluation of these thresholds is still required [13, 51].

Medical Therapy Options

The medical management of GERD following LSG is similar to those who have not undergone bariatric surgery. All patients should be educated in regards to lifestyle modifications including dietary changes, reduction in alcohol use and cessation of smoking [52]. Patients should be started on antisecretory medications, with PPIs being the mainstay of treatment. Regular use of PPIs allows for long-term inhibition of gastric acid secretion, without any dose-tolerance phenomena [53]. In the setting of intractable GERD, PPI therapy should be optimised to maximise the daily duration the intragastric pH is greater than 4 (pH4 time) [54].

The pharmacokinetic potency of each PPI varies with a different pH4 time (pantoprazole lowest, rabeprazole highest); however, twice-daily dosing of any PPI results in equivalent pH4 times. For example, dosing with pantoprazole 20 mg twice daily was equivalent to the pH4 time of the comparatively higher potency rabeprazole 40 mg twice daily [54]. Twice-daily dosing is superior to daily dosing, however there was no increase in benefit with three-times daily dosing [55]. Clinically, there is minimal difference between the various PPI choices when used at optimal doses in terms of symptom relief or improvement in endoscopically proven erosive esophagitis [55, 56]. More importantly, patients must be educated in regard to compliance and timing of medication. Any PPIs should be taken 30 to 60 min prior to meals for the optimal dose effect [15].

Whilst histamine H2-receptor antagonists (H2RAs) have been used to treat GERD in the general population, H2RAs demonstrate a tolerance phenomenon following repeated use after only two weeks, and hence are not ideal for use in the post-LSG patient population [53].

Endoscopic Therapies

When medical management does not resolve post-LSG GERD, patients may be considered for endoscopic therapy. It is important to note the long-term evidence for most endoscopic treatments following bariatric surgery is limited [57]. If there is an obvious mechanical cause such as incisura stenosis, balloon dilatation has been shown to be safe and effective as a first line therapy [58] with gastric myotomy another potential albeit superficially evaluated therapy [59]. Endoscopic stenting can be performed, but may have high rates of patient intolerance [23]. Other available endoscopic techniques are novel, and include mucosal resection, plication, use of inert biopolymers or radiofrequency ablation to induce scarring at the gastro-esophageal junction (GEJ) or LES [57]. The antireflux mucosectomy (ARMS) procedure, which involves endoscopic mucosal resection of 75% of the GEJ to induce scarring and retraction in the area has demonstrated safety and possible efficacy in case series [60, 61]. Endoscopic radiofrequency with the Stretta system involves delivery of thermal energy to the LES to remodel the musculature of the LES and cardia, resulting in increased LES tone and reduced transient inappropriate LES relaxation [62]. It has been shown to be safe and effective in the non-bariatric population, and reduces PPI requirements in post-LSG patients [63, 64]. However, it remains a novel therapy in the post-operative setting and long-term results in the bariatric surgery patients are unknown.

Operative Intervention

Long-term (> 10 year) follow-up demonstrates a 22.6% conversion rate of LSG, most commonly for failure of weight loss, or reflux [65]. The ideal revisional surgery post-LSG remains highly individualised, only being considered after failure of maximal medical therapy and appropriate preoperative investigations. The literature surrounding revision or conversion surgery post-LSG is heterogeneous in design and surgical technique and there is a paucity of objective assessment and prospective comparison and randomized trial data [66].

Conversion to Roux-en-Y gastric bypass (RYGB) has been shown to be effective in post-LSG reflux management. The approach was considered best practice in a recent 2023 expert's modified Delphi consensus [67]. A published systematic review and meta-analysis of GERD as an indication for revisional surgery included 48 studies, involving 915 patients [68]. Pooled estimation demonstrated GERD requiring revision surgery in 7% of patients post-LSG, and a 99% remission rate following revision surgery with conversion to RYGB was the most performed procedure (73.2%). In this meta-analysis the definition of "reflux revision" was not stated however and the results seem incongruous with prospective studies showing high ongoing PPI use and abnormal esophageal acidification after sleeve to bypass conversion [69, 70]. Revisional RYGB has higher associated morbidity (18.6% vs 8.6%) compared to primary RYGB [71]. RYGB is also associated with long-term complications such as internal herniation, stomal ulceration, nutritional deficiencies, and chronic abdominal pain [72].

Either simultaneous HHR with RYGB or as a standalone is the second most reported operative intervention in the literature [68]. In the post-LSG anatomy, this generally involves a combination of posterior and/or anterior cruroplasty with phreno-esophageal ligament reconstruction or gastropexy without the potential for any fundoplication. Figure 3 is an intraoperative image demonstrating this technique

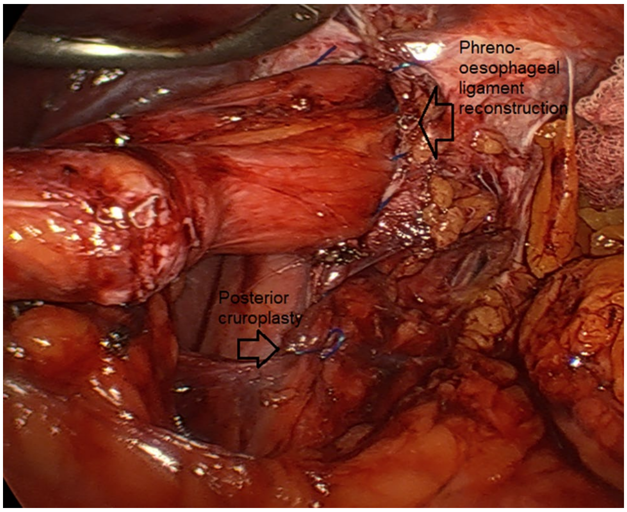

Fig. 3 Intraoperative image of the oesophageal hiatus following hiatal hernia repair post sleeve gastrectomy with arrows demonstrating posterior cruroplasty and reconstruction of the phreno-esophageal ligament using a non-absorbable barbed suture technique

using a non-absorbable barbed suture. Stand-alone hiatal hernia repair is controversial but has the potential to avoid gastric bypass. Three earlier studies with a combined 53 patients, reported resolution of symptoms with cessation of PPI therapy in 52.8% (n = 28) patients, with a follow-up ranging 6–12 months [73–75]. Promisingly, in a more recent case series of 99 revision patients (58 HHR alone), there was a 72.4% (n = 42) resolution of symptoms with HHR alone, compared to RYGB (82.1%, n = 24), and duodenal switch (100%, n = 12) [21]. Magnetic LES augmentation is another potential, non-bypass surgical therapy that shows promise, however overall experience with this is limited [76].

Overall, the comparison of other revision bypass surgeries against RYGB in the setting of post-LSG reflux is difficult. Comparative studies often focus on either failure or weight loss, or weight regain as the indication and tend to select patients for RYGB if GERD is present [77, 78]. This selection bias of treatment algorithms makes comparison problematic by design, however, in patients with who do not wish to undergo RYBP, targeting surgical therapy to a putative anatomic driver of reflux will be successful in many and will not rule out later RYBP if required.

Conclusion

Intractable GERD post-LSG requires a three-pronged assessment of clinical factors, anatomical evaluation and functional studies. Individualised patient management should consider endoscopic and revisional surgery options if symptoms persist despite maximal medical therapy.

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Declarations

Conflict of interest The authors (DLC, KLC, BEI, MLT) have no conflicts of interest to declare.

Research involving Human and Animal Rights and Informed Consent All patients have provided informed consent for the publication of all clinical and intraoperative images included in this manuscript and followed ethical standards. No other animal or human subjects were used in this manuscript by the authors.

References

1. Laffin M, Chau J, Gill RS, Birch DW, Karmali S. Sleeve gastrectomy and gastroesophageal reflux disease. J Obes. 2013;2013:741097.
2. Arterburn DE, Telem DA, Kushner RF, Courcoulas AP. Benefits and risks of bariatric surgery in adults: a review. JAMA. 2020;324(9):879–87.
3. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
4. 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(10):1778–86.
5. Felsenreich DM, Prager G, Kefurt R, Eilenberg M, Jedamzik J, Beckerhinn P, et al. Quality of life 10 years after sleeve gastrectomy: a multicenter study. Obes Facts. 2019;12(2):157–66.
6. Kowalewski PK, Olszewski R, Walędziak MS, Janik MR, Kwiatkowski A, Gałązka-Świderek N, et al. Long-term outcomes of laparoscopic sleeve gastrectomy—a single-center, retrospective study. Obes Surg. 2018;28(1):130–4.

7. Genco A, Soricelli E, Casella G, Maselli R, Castagneto-Gissey L, Di Lorenzo N, et al. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13(4):568–74.
8. Elkassem S. Gastroesophageal reflux disease, esophagitis, and barrett's esophagus 3 to 4 years post sleeve gastrectomy. Obes Surg. 2021;31(12):5148–55.
9. Wu WY, Chang SC, Hsu JT, Yeh TS, Liu KH. Gastroesophageal reflux disease symptoms after laparoscopic sleeve gastrectomy: a retrospective study. J Pers Med. 2022;12(11):1795.
10. Balla A, Palmieri L, Corallino D, Meoli F, Carlotta Sacchi M, Ribichini E, et al. Does sleeve gastrectomy worsen gastroesophageal reflux disease in obese patients? A Prospective Study Surg Innov. 2022;29(5):579–89.
11. Althuwaini S, Bamehriz F, Aldohayan A, Alshammari W, Alhaidar S, Alotaibi M, et al. Prevalence and predictors of gastroesophageal reflux disease after laparoscopic sleeve gastrectomy. Obes Surg. 2018;28(4):916–22.
12. Tomasicchio G, D'Abramo FS, Dibra R, Trigiante G, Picciariello A, Dezi A, et al. Gastroesophageal reflux after sleeve gastrectomy. Fact or fiction? Surgery. 2022;172(3):807–12.
13. Lim G, Johari Y, Ooi G, Playfair J, Laurie C, Hebbard G, et al. Diagnostic criteria for gastro-esophageal reflux following sleeve gastrectomy. Obes Surg. 2021;31(4):1464–74.
14. Gyawali CP, Kahrilas PJ, Savarino E, Zerbib F, Mion F, Smout A, et al. Modern diagnosis of GERD: the Lyon consensus. Gut. 2018;67(7):1351–62.
15. Naik RD, Meyers MH, Vaezi MF. Treatment of refractory gastroesophageal reflux disease. Gastroenterol Hepatol. 2020;16(4):196.
16. Nadaleto BF, Herbella FA, Patti MG. Gastroesophageal reflux disease in the obese: pathophysiology and treatment. Surgery. 2016;159(2):475–86.
17. Mocian F, Coroș M. Relationship between gastroesophageal reflux disease and laparoscopic sleeve gastrectomy: a narrative review. Wideochir Inne Tech Maloinwazyjne. 2021;16(4):648–55.
18. Küper M, Kramer K, Kischniak A, Zdichavsky M, Schneider J, Stüker D, et al. Dysfunction of the lower esophageal sphincter and dysmotility of the tubular esophagus in morbidly obese patients. Obes Surg. 2009;19(8):1143–9.
19. Che F, Nguyen B, Cohen A, Nguyen NT. Prevalence of hiatal hernia in the morbidly obese. Surg Obes Relat Dis. 2013;9(6):920–4.
20. Lazoura O, Zacharoulis D, Triantafyllidis G, Fanariotis M, Sioka E, Papamargaritis D, et al. Symptoms of gastroesophageal reflux following laparoscopic sleeve gastrectomy are related to the final shape of the sleeve as depicted by radiology. Obes Surg. 2011;21(3):295–9.
21. Indja B, Chan DL, Talbot ML. Hiatal reconstruction is safe and effective for control of reflux after laparoscopic sleeve gastrectomy. BMC Surg. 2022;22(1):1–8.
22. Johari Y, Lim G, Wickremasinghe A, Yue H, Seah J, Ooi G, et al. Pathophysiological mechanisms of gastro-esophageal reflux after sleeve gastrectomy. Ann Surg. 2022;276(5):e407–16.
23. Tian P, Fu J, Liu Y, Bian S, Li M, Zhang M, et al. Current status of gastroesophageal reflux disease after sleeve gastrectomy: Still a long way to go. Biosci Trends. 2021;15(5):305–12.
24. Braghetto I, Lanzarini E, Korn O, Valladares H, Molina JC, Henriquez A. Manometric changes of the lower esophageal sphincter after sleeve gastrectomy in obese patients. Obes Surg. 2010;20(3):357–62.
25. Yehoshua RT, Eidelman LA, Stein M, Fichman S, Mazor A, Chen J, et al. Laparoscopic sleeve gastrectomy—volume and pressure assessment. Obes Surg. 2008;18(9):1083–8.
26. Mion F, Tolone S, Garros A, Savarino E, Pelascini E, Robert M, et al. High-resolution impedance manometry after sleeve gastrectomy: increased intragastric pressure and reflux are frequent events. Obes Surg. 2016;26(10):2449–56.
27. Chern TY, Chan DL, Maani J, Ferguson JS, Talbot ML. High-resolution impedance manometry and 24-hour multichannel intraluminal impedance with pH testing before and after sleeve gastrectomy: de novo reflux in a prospective series. Surg Obes Relat Dis. 2021;17(2):329–37.
28. Daes J, Jimenez ME, Said N, Dennis R. Improvement of gastroesophageal reflux symptoms after standardized laparoscopic sleeve gastrectomy. Obes Surg. 2014;24(4):536–40.
29. Dent J, Vakil N, Jones R, Bytzer P, Schöning U, Halling K, et al. Accuracy of the diagnosis of GORD by questionnaire, physicians and a trial of proton pump inhibitor treatment: the Diamond Study. Gut. 2010;59(6):714–21.
30. Damiano A, Handley K, Adler E, Siddique R, Bhattacharyja A. Measuring symptom distress and health-related quality of life in clinical trials of gastroesophageal reflux disease treatment: further validation of the Gastroesophageal Reflux Disease Symptom Assessment Scale (GSAS). Dig Dis Sci. 2002;47(7):1530–7.
31. Carlsson R, Dent J, Bolling-Sternevald E, Johnsson F, Junghard O, Lauritsen K, et al. The usefulness of a structured questionnaire in the assessment of symptomatic gastroesophageal reflux disease. Scand J Gastroenterol. 1998;33(10):1023–9.
32. Yadlapati R, Gyawali CP, Pandolfino JE. AGA clinical practice update on the personalized approach to the evaluation and management of GERD: EXPERT REVIEW. Clin Gastroenterol Hepatol. 2022;20(5):984-94.e1.
33. Gasiorowska A, Fass R. The proton pump inhibitor (PPI) test in GERD: does it still have a role? J Clin Gastroenterol. 2008;42(8):867–74.
34. Sifrim D, Zerbib F. Diagnosis and management of patients with reflux symptoms refractory to proton pump inhibitors. Gut. 2012;61(9):1340–54.
35. Rengo M, Bellini D, Iorio O, De Cecco CN, Rizzello M, Cavallaro G, et al. Role of preoperative imaging with multidetector computed tomography in the management of patients with gastroesophageal reflux disease symptoms after laparoscopic sleeve gastrectomy. Obes Surg. 2013;23(12):1981–6.
36. Vilallonga R, Sanchez-Cordero S, Umpiérrez Mayor N, Molina A, Cirera de Tudela A, Ruiz-Úcar E, et al. GERD after bariatric surgery. Can we expect endoscopic findings? Medicina (Kaunas). 2021;57(5):506.
37. Dimbezel V, Nedelcu A, Danan M, Carandina S, Collet D, Gronnier C, et al. Endoscopic findings 5 years following sleeve gastrectomy. Obes Surg. 2020;30(10):3847–51.
38. Bhalla S, Yu JX, Varban OA, Schulman AR. Upper gastrointestinal series after sleeve gastrectomy is unnecessary to evaluate for gastric sleeve stenosis. Surg Endosc. 2021;35(2):631–5.
39. Li L, Gao H, Zhang C, Tu J, Geng X, Wang J, et al. Diagnostic value of X-ray, endoscopy, and high-resolution manometry for hiatal hernia: a systematic review and meta-analysis. J Gastroenterol Hepatol. 2020;35(1):13–8.
40. Chan DL, Wong SK, Lok HT, Iliopoulos J, Talbot ML, Hennessy A, et al. Accuracy of hiatal hernia diagnosis in bariatric patients: preoperative endoscopy versus intraoperative reference. JGH Open. 2020;4(6):1074–8.
41. Fisher OM, Chan DL, Talbot ML, Ramos A, Bashir A, Herrera MF, et al. Barrett's oesophagus and bariatric/metabolic surgery-IFSO 2020 position statement. Obes Surg. 2021;31(3):915–34.
42. Castagneto-Gissey L, Genco A, Del Corpo G, Badiali D, Pronio AM, Casella G. Sleeve gastrectomy and gastroesophageal reflux: a comprehensive endoscopic and pH-manometric prospective study. Surg Obes Relat Dis. 2020;16(11):1629–37.
43. Sharma A, Aggarwal S, Ahuja V, Bal C. Evaluation of gastroesophageal reflux before and after sleeve gastrectomy using

symptom scoring, scintigraphy, and endoscopy. Surg Obes Relat Dis. 2014;10(4):600–5.
44. Karila-Cohen P, Pelletier AL, Saker L, Laouénan C, Bachelet D, Khalil A, et al. Staple line intrathoracic migration after sleeve gastrectomy: correlation between symptoms, CT three-dimensional stomach analysis, and 24-h pH monitoring. Obes Surg. 2022;32(7):1–9.
45. Chan DL, Huang BW, Yip J, Chug M, Iliopoulos J, Hennessy A, et al. CT oesophageal hiatal surface area measurements: an objective and sensitive means of hiatal hernia detection. Surg Open Dig Adv. 2023;9: 100085.
46. Yadlapati R. High resolution manometry vs conventional line tracing for esophageal motility disorders. Gastroenterol Hepatol (N Y). 2017;13(3):176–8.
47. Balla A, Meoli F, Palmieri L, Corallino D, Sacchi MC, Ribichini E, et al. Manometric and pH-monitoring changes after laparoscopic sleeve gastrectomy: a systematic review. Langenbecks Arch Surg. 2021;406(8):2591–609.
48. Chan DL, Chern TY, Iliopoulos J, Hennessy A, Wong SKH, Ng EKW, et al. Accuracy of high-resolution manometry in hiatal hernia diagnosis in primary and revision bariatric surgery. Obes Surg. 2021;31(7):2906–12.
49. Rengarajan A, Bolkhir A, Gor P, Wang D, Munigala S, Gyawali CP. Esophagogastric junction and esophageal body contraction metrics on high-resolution manometry predict esophageal acid burden. Neurogastroenterol Motil. 2018;30(5): e13267.
50. Johnson LF, DeMeester TR. Development of the 24-hour intraesophageal pH monitoring composite scoring system. J Clin Gastroenterol. 1986;8(Suppl 1):52–8.
51. Anvari M, Allen C, Borm A. Laparoscopic Nissen fundoplication is a satisfactory alternative to long-term omeprazole therapy. Br J Surg. 1995;82(7):938–42.
52. Treitl D, Nieber D, Ben-David K. Operative treatments for reflux after bariatric surgery: current and emerging management options. J Gastrointest Surg. 2017;21(3):577–82.
53. Kinoshita Y, Ishimura N, Ishihara S. Advantages and disadvantages of long-term proton pump inhibitor use. J Neurogastroenterol Motil. 2018;24(2):182–96.
54. Patel A, Yadlapati R. Diagnosis and management of refractory gastroesophageal reflux disease. Gastroenterol Hepatol. 2021;17(7):305.
55. Graham DY, Tansel A. Interchangeable use of proton pump inhibitors based on relative potency. Clin Gastroenterol Hepatol. 2018;16(6):800-8.e7.
56. Gralnek IM, Dulai GS, Fennerty MB, Spiegel BM. Esomeprazole versus other proton pump inhibitors in erosive esophagitis: a meta-analysis of randomized clinical trials. Clin Gastroenterol Hepatol. 2006;4(12):1452–8.
57. King K, Sudan R, Bardaro S, Soriano I, Petrick AT, Daly SC, et al. Assessment and management of gastroesophageal reflux disease following bariatric surgery. Surg Obes Relat Dis. 2021;17(11):1919–25.
58. Agnihotri A, Barola S, Hill C, Neto MG, Campos J, Singh VK, et al. An algorithmic approach to the management of gastric stenosis following laparoscopic sleeve gastrectomy. Obes Surg. 2017;27(10):2628–36.
59. Zhang LY, Canto MI, Schweitzer MA, Khashab MA, Kumbhari V. Gastric per-oral endoscopic myotomy (G-POEM) for the treatment of gastric sleeve stenosis: a feasibility and safety study. Endoscopy. 2022;54(4):376–81.
60. Debourdeau A, Vitton V, Monino L, Barthet M, Gonzalez JM. Antireflux mucosectomy band (ARM-b) in treatment of refractory gastroesophageal reflux disease after bariatric surgery. Obes Surg. 2020;30(11):4654–8.
61. Hathorn KE, Jirapinyo P, Thompson CC. Endoscopic management of gastroesophageal reflux disease after sleeve gastrectomy by use of the antireflux mucosectomy procedure. VideoGIE. 2019;4(6):251–3.
62. Triadafilopoulos G, DiBaise JK, Nostrant TT, Stollman NH, Anderson PK, Wolfe MM, et al. The Stretta procedure for the treatment of GERD: 6 and 12 month follow-up of the US open label trial. Gastrointest Endosc. 2002;55(2):149–56.
63. 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(10):3125–30.
64. 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(12):4865–82.
65. Guan B, Chong TH, Peng J, Chen Y, Wang C, Yang J. Mid-long-term revisional surgery after sleeve gastrectomy: a systematic review and meta-analysis. Obes Surg. 2019;29(6):1965–75.
66. Matar R, Monzer N, Jaruvongvanich V, Abusaleh R, Vargas EJ, Maselli DB, et al. Indications and outcomes of conversion of sleeve gastrectomy to Roux-en-Y gastric bypass: a systematic review and a meta-analysis. Obes Surg. 2021;31(9):3936–46.
67. Kermansaravi M, Parmar C, Chiappetta S, Shikora S, Aminian A, Abbas SI, et al. Best practice approach for redo-surgeries after sleeve gastrectomy, an expert's modified Delphi consensus. Surg Endosc. 2023;37(3):1617–28.
68. Chiappetta S, Lainas P, Kassir R, Valizadeh R, Bosco A, Kermansaravi M. Gastroesophageal reflux disease as an indication of revisional bariatric surgery-indication and results-a systematic review and metanalysis. Obes Surg. 2022;32(9):3156–71.
69. Carandina S, Soprani A, Montana L, Murcia S, Valenti A, Danan M, et al. 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(6):732–7.
70. Felsenreich DM, Steinlechner K, Langer FB, Vock N, Eichelter J, Bichler C, et al. Outcome of sleeve gastrectomy converted to roux-en-Y gastric bypass and one-anastomosis gastric bypass. Obes Surg. 2022;32(3):643–51.
71. Pędziwiatr M, Małczak P, Wierdak M, Rubinkiewicz M, Pisarska M, Major P, et al. Revisional gastric bypass is inferior to primary gastric bypass in terms of short- and long-term outcomes-systematic review and meta-analysis. Obes Surg. 2018;28(7):2083–91.
72. Li JF, Lai DD, Lin ZH, Jiang TY, Zhang AM, Dai JF. Comparison of the long-term results of Roux-en-Y gastric bypass and sleeve gastrectomy for morbid obesity: a systematic review and meta-analysis of randomized and nonrandomized trials. Surg Laparosc Endosc Percutan Tech. 2014;24(1):1–11.
73. Gálvez-Valdovinos R, Cruz-Vigo JL, Marín-Santillán E, Funes-Rodríguez JF, López-Ambriz G, Domínguez-Carrillo LG. Cardiopexy with ligamentum teres in patients with hiatal hernia and previous sleeve gastrectomy: an alternative treatment for gastroesophageal reflux disease. Obes Surg. 2015;25(8):1539–43.
74. Hawasli A, Foster R, Lew D, Peck L. Laparoscopic Ligamentum Teres cardiopexy to the rescue; an old procedure with a new use in managing reflux after sleeve gastrectomy. Am J Surg. 2021;221(3):602–5.
75. Soong TC, Almalki OM, Lee WJ, Ser KH, Chen JC, Wu CC, et al. Revision of sleeve gastrectomy with hiatal repair with gastropexy for gastroesophageal reflux disease. Obes Surg. 2019;29(8):2381–6.
76. Khaitan L, Hill M, Michel M, Chiasson P, Woodworth P, Bell R, et al. Feasibility and efficacy of magnetic sphincter augmentation for the management of gastroesophageal reflux disease post-sleeve gastrectomy for obesity. Obes Surg. 2023;33(1):387–96.
77. Dijkhorst PJ, Boerboom AB, Janssen IMC, Swank DJ, Wiezer RMJ, Hazebroek EJ, et al. Failed sleeve gastrectomy: single anastomosis duodenoileal bypass or Roux-en-Y gastric bypass? A Multicenter Cohort Study Obes Surg. 2018;28(12):3834–42.

78. Hany M, Zidan A, Elmongui E, Torensma B. Revisional Roux-En-Y gastric bypass versus revisional one-anastomosis gastric bypass after failed sleeve gastrectomy: a randomized controlled trial. Obes Surg. 2022;32(11):3491–503.