Chapter

Laparoscopic Sleeve Gastrectomy: Outcomes, Safety and Complications

Wahiba Elhag and Walid El Ansari

Abstract

Worldwide, the numbers of laparoscopic sleeve gastrectomy (LSG) performed grown exponentially over the last decade, because of its simplicity, safety profile and excellent outcomes in terms of durable weight loss and improvement of obesity-associated comorbidities. This chapter will provide a comprehensive review on the outcomes of LSG as a metabolic surgery. It appraises LSG's short, mid and long term weight loss outcomes, and compares these outcomes with those of other types of bariatric surgery. Then, a wider range of LSG outcomes are discussed, including a variety of comorbidities, clinical, biochemical and inflammatory parameters, while appraising the positive metabolic effects of LSG. The chapter also outlines the issues pertaining to LSG among a range of special populations such as adolescents, the elderly, renal transplant patients and others. The chapter concludes with a review of the safety and most common complications that may be encountered in the short term and long term, including surgical and nutritional complications, as well as mortality.

Keywords: bariatric surgery, laparoscopic sleeve gastrectomy, technique, perioperative care

1. Introduction

Sleeve gastrectomy (SG) is a restrictive bariatric procedure that was first described as the initial step in biliopancreatic diversion (BPD). Its relative technical ease, effectiveness in weight loss (WL) as a stand-alone procedure, and durability in managing obesity and its comorbid conditions have rendered it the most common bariatric surgery (BS) globally. Below, we discuss the outcomes of LSG.

2. Outcomes

2.1 Anthropometric (weight loss)

WL outcomes after bariatric surgery can be expressed as percentage of excess WL (EWL%) or percentage of excess BMI loss (EBMIL%) [1]. Excess weight is 'ideal body weight subtracted from actual body weight' As for the reporting of the duration of follow up, short-term follow-up is defined as <3 years after intervention, medium-term is ≥3 and <5 years after intervention, and long-term is ≥5 years after intervention [1]. The percentage of excess weight loss (EWL%) varies with the follow-up duration. The average expected EWL% post LSG is 50–60% [2]. A study of 12,129 patients found that the mean EWL% was about 60% at 1 year after surgery, and 65% at 2 years [3]. Midterm (3 years) WL outcomes ranged from 46% to 84.5% [4, 5]. Long term (≥5 years) evidence suggests that although patients regain weight after LSG, they still accomplish a “durable” long-term weight. A review of 277 long-term studies that included 2713 patients revealed a mean 58.4%, 59.5%, 56.6%, 56.4%, and 62.5% EWL% at 5, 6, 7, 8, and 11 years, respectively [6].

When comparing WL outcomes of LSG with other restrictive procedure, LSG was a more effective procedure than laparoscopic adjustable gastric banding (LAGB), contributing to greater WL. For instance, in a review of 33 studies (4109 patients), LSG resulted in significantly higher EWL% compared with LAGB, where mean difference was −16.67% at 12 months, −19.63% at 24 months, and -19.28 at 36 months post surgery [7]. Two Large randomized control trails (RCT) assessed the long-term outcomes of LSG and Roux en Y gastric bypass (RYGB), the Swiss Multicenter Bypass or Sleeve Study (SM-BOSS) [8] and the SLEEVPASS [9]. Both studies reported similar EWL% at 5 years in LSG and RYGB (61.1% vs 68.3%) and (49% and 57%) respectively [8, 9].

2.2 Type 2 Diabetes Mellitus

The improvement in type 2 diabetes mellitus (T2DM) occurs soon after surgery and before considerable WL is achieved, which suggests the existence of weight-independent mechanisms. This is attributed to the changes in the gut hormones, mainly the increase in GLP-1 and the decrease in ghrelin hormone levels post LSG. In the long term, the significant weight loss with LSG leads to improvement in both hepatic and peripheral insulin sensitivity which contributes to T2DM resolution [10]. LSG is associated with significant T2DM improvement. Complete remission rates are 78.3% at 1 year, and 76.2% at 3 years follow up [11]. At 5 years, the remission rate ranged between 60.8% to 71.4% [11, 12].

A body of literature compared the T2DM outcomes of LSG vs conventional medical management [13, 14]. The 5 year outcomes from an RCT (STAMPEDE) that compared intensive medical therapy with BS (LSG or RYGB) found that among 134 individuals, diabetes remission was observed in 5% who received intensive medical therapy alone, compared with 23% who underwent LSG ($P = 0.07$) [14].

Compared with other restrictive procedures, LSG achieves better T2DM control than LAGB (odds ratio (OR): 0.22, 95% CI: 0.06–0.87, $P = 0.03$) [7]. LAGB does not cause changes in gut hormones and seem to depend exclusively on restriction for WL and diabetes improvement which might explain the better glycemic control seen after LSG [7]. On the other hand, studies comparing T2DM outcomes between LSG and RYGB reported similar remission rates [8, 9, 15]. A systematic review that included 857 diabetic patients, revealed that T2DM remission rate at 1 year was 63% (LSG) and 74% (RYGB) which were not statistically different [15]. The two RCTs cited previously also confirmed such finding [8, 9].

Several independent factors were identified as predictors of complete T2DM remission, including preoperative HbA1C, EWL%, insulin therapy, age, and oral hypoglycemic medications [11, 16].

2.3 Hypertension and cardiovascular disease

Hypertension has long been associated with obesity. LSG was found to improve hypertension both in the short and the long term [17, 18]. For some hypertensive patients, blood pressure returned to normal on the first day after LSG with a significant reduction observed within 10 days post LSG [17]. The improvement in the blood pressure observed before significant WL suggests other neural and hormonal mechanisms [17]. Over a period of 12 months, hypertension resolved in 87% and improved in 100% of patients [17]. The average number of antihypertensive agents per patient significantly declined from 1.5 to 0.6, and the number of patients requiring >2 antihypertensive agents also fell (baseline 49% vs at 12 months 22%) [17]. On the long-term, hypertension resolved in 62.17% of patients and improved in 35.7% at a mean period of 5.35 years [18]. Moreover, LSG resulted in lower incidence of hypertension on the long term (pre-operative 36.5% vs 14.79% at 5 years), potentially reducing the health system costs [18]. The improvement in hypertension also contributes to a significant 10 year reduction of cardiovascular risk including myocardial infarction and stroke post LSG [19].

2.4 Hyperlipidemia

Hyperlipidemia is a main comorbidity in severe obesity. LSG regulates lipid markers, with considerable reduction in triglyceride, total cholesterol, very low density lipoprotein (VLDL) cholesterol, and low-density lipoprotein (LDL) cholesterol levels, with increase in high-density lipoprotein (HDL) cholesterol level [20, 21]. At 1-year post LSG, remission of hypercholesterolemia and hypertriglyceridemia was attained in 45% and 86% of the patients respectively [20]. Moreover, the improvement observed led to the discontinuation of medication among 43.7% of the patients [20]. On the long term, LSG showed significant improvement in HDL cholesterol and triglyceride compared with preoperative levels [21]. The decreased LDL cholesterol was significant at 1 year and 3 years post surgery, but the effect at 5 years did not reach statistical significance [21]. Overall complete remission of hypercholesteremia at 1, 3 and 5 years was 40.0%, 45.6%, 26.1% respectively [21]. Hypertriglyceridemia remission rate was 72.2%, 66% and 72.2% at 1, 3 and 5 years respectively [21].

2.5 Non-alcoholic fatty liver disease (NAFLD)

NAFLD is liver steatosis in the absence of secondary causes of hepatic fat accumulation such as alcohol abuse. NAFLD can progress to nonalcoholic steatohepatitis (NASH), liver cirrhosis, liver failure, and hepatocellular carcinoma [22]. It is linked to obesity and frequently associated with metabolic syndrome [22]. WL and metabolic improvement post LSG result in a significant improvement in NAFLD. In one study, a liver biopsy was obtained in 134 LSG patients during surgery and 192 days after surgery [23]. There was significant improvement in liver histology following LSG, evident by the improvement in NALFD-Activity-Score (NAS) ($P<0.001$) [23]. NAS is a scoring system developed as a tool to measure changes in NAFLD during therapeutic trials [24]. In the previous study, the percentage of patients with NASH decreased from 18% to 3% [23]. The improvement was greater in severe cases of NAFLD including those with steatohepatitis, bridging fibrosis or cirrhosis. LSG does not only improve the histology and liver function of patients with NAFLD but also reduces the oxidative stress and inflammatory processes involve in the mechanism of NAFLD, where there was significant changes in plasma and liver markers of oxidative stress and inflammation (including chemokine C-C motif ligand 2, paraoxonase-1, galectin-3, and sonic hedgehog) [25]. These data suggest that LSG could be used as therapeutic option to improve NAFLD.

2.6 Obstructive sleep apnea (OSA)

Severe obesity is associated with a high prevalence of moderate-to-severe OSA. A metanalysis showed that at a mean of 24.7 months, LSG resulted in resolution and improvement of sleep apnea in 72% and 51% of patients respectively [26]. One study showed that the apnea hypopnea index significantly decreased from 45.8 to 11.3 events/hour ten months post LSG [27]. The rapid improvement of moderate-to-severe OSA observed post LSG is likely due to the reduced neck circumference. Interestingly, this does not correlate with EWL% which suggests that a weight-independent factors may play a role and hence warrant further research [27].

2.7 Asthma

Obesity is a risk factor for asthma. Many inflammatory markers (e.g. interleukins 5, 6, 13, 17) implicated in the pathogenesis and disease activity of asthma are increased with obesity [28]. WL post LSG results in significantly improved asthma symptoms. A prospective study of 78 subjects compared asthma patients undergoing BS with obese controls. In this study, BS including LSG, resulted in significantly improved small airway function, airway hyperresponsiveness, asthma control and quality of life (QoL) [29]. There was also a decrease in systemic inflammation and bronchial inflammation (mast cell counts) one year after BS [29]. Asthma medication usage was also reduced following LSG [30]. A retrospective analysis of 751 asthmatic patients, including 80 LSG patients, found that the number of prescribed asthma medications among all procedures significantly decreased by 27% at 30 days post-surgery, 37% at 6 months, 44% at 1 year, and 46% at 3 years [30].

2.8 Gastroesophageal reflux disease (GERD)

LSG may improve GERD symptoms as a result of the accelerated gastric emptying and WL. A study of GERD in 65 patients after LSG, including 24-hour pH probe data, suggested that the preexisting reflux improved, and that the de novo reflux rate was low (5.4%) [31]. Appraisal of LSG's effects of on GERD (median follow-up 56 months) using a quality-of-life questionnaire found that GERD-HRQL scores decreased from 7 to 3 [32]. In the same study, GERD-HRQL scores improved in 55 patients, worsened in 21, de novo GERD was observed in 10, and no change in 14 patients [32]. A systematic review (25 studies) reported clinical improvement in 1863 patients at an average of 20 ± 15 months post-LSG; however the review also reported worsening of symptoms in 5953 patients over a period of 29 ± 22 months [33]. However, most research used clinical evaluation, with few studies using endoscopy, 24-hour ambulatory pH, esophageal manometry or contrast studies [33].

2.9 Mental health

Due to the significant association of depression with obesity, it is a common disorder among individuals selected for BS. LSG results in significant improvement in various psychological dimensions. At one year post LSG, depressive symptoms, self-esteem, eating behavior and cognitive restraint showed improving trends [34]. Eating behavior also improves post LSG. In a prospective study of 75 individuals before and 48 months after LSG, the number of patients with binge eating disorder was lower at follow up (decreased from 13% to 2%) [35]. Similarly, the subscales of disinhibition and feelings of hunger both decreased post LSG ($p < 0.001$ for both) [35]. An important outcome post BS is the effect on psychiatric medications, specially depression and anxiety medication. A retrospective study of 50 patients found that at 3- to 6-months post LSG, anxiety symptoms improved in >50% of subjects and most patients were on the same or reduced dosage of medication (62% unchanged, 24% decreased) [36]. Depression symptoms improved in 67%, while 62% of them remained in the same regimen and 26% discontinued their medications

[36]. This suggests that LSG not only results in early improvement in symptoms of depression or anxiety, but also reduces the dosage of psychiatric medications [36].

2.10 Quality of life (QoL)

Morbid obesity together with obesity-related diseases have a negative impact on the QoL. BS, apart from decreasing mortality and morbidity, achieves long-lasting QoL improvement. Significant improvements in physical, psychosocial, and sexual QoL are reported post LSG [37]. QoL and status of general well-being significantly improved 1 to 2 years post LSG [38, 39]. This improvement was also sustained on the long term. For instance, a 10 year follow up study reported significant increase in total QoL before and 10 years after LSG [39]. The global physical health QoL increased from 45.6 ± 20.7 to 62.3 ± 23 at 10 years; the global mental health QoL increased from 49.5 ± 17.7 to 62.2 ± 17.8; and the global total QoL score pre-surgery that was 48.3 ± 20.6 increased to 65.1 ± 21.4 at 10 years [39].

2.11 Biochemical and inflammatory markers

Obesity, especially visceral obesity, is considered as a low-grade inflammatory disease. Serum concentrations of a number of inflammatory markers including C-reactive protein (CRP), tumor necrosis factor-α (TNF-α), and interleukin-6 (IL-6) are elevated in overweight and obese individuals [40]. LSG improves the course of chronic diseases and the state of inflammation associated with obesity. Evidence showed improvements in systemic and urinary inflammatory markers with a significant decrease in interleukin-6 (IL-6), CRP, ferritin, and TNF-α [41]. These changes were also demonstrated in patients with T2DM, where there was significant improvement in inflammatory biomarkers including CRP ($P = 0.003$) and IL-6 at ($P = 0.001$) 6 months post LSG [42]. The reduction in inflammatory factors suggests that LSG may play a role in reducing the risk of T2DM and cardiovascular disease.

2.12 Reproductive systems

2.12.1 Polycystic ovarian syndrome

Polycystic ovarian syndrome (PCOS) is a common endocrine disorder associated with obesity. Women with PCOS have hyperandrogenism and hyperinsulinemia with subsequent insulin resistance and infertility [43]. LSG is effective in treating PCOS, resulting not only in WL, but also significant improvement in the hormonal profile [43, 44]. Significant decrease is observed as early as 3 months post-surgery in luteinizing hormone (LH) levels (7.2 vs. 4.5 mIU/mL), with inversion of LH/FSH ratio ($P = 0.008$), as well as significant decrease in fasting insulin levels (24.4 mIU/mL vs. 9.0 mIU/mL) [44]. LSG also positively augments fertility rates [43, 45]. A cohort of 53 women had a progressive increase of serum anti-Mullerian hormone (marker of ovarian reserve) levels 6 months after LSG [45]. These hormonal changes were also associated with the regulation of the menstrual cycle and resolution of dysmenorrhea [45]. Moreover, 22% percent of PCOS patients became pregnant within 12 months, 69% of which were previously nulliparous [43].

2.12.2 Maternal and perinatal outcomes after LSG

Obese women have increased rates of adverse obstetric outcomes that include gestational diabetes mellitus, gestational hypertension, preeclampsia, cesarean section delivery, and adverse neonatal outcomes including congenital malformations, macrosomia, and stillbirths [46]. WL with LSG has better maternal and perinatal outcomes [47]. A retrospective study comparing women who had undergone LSG with matching controls found that the LSG group had lower rates of gestational DM (3.4% vs 17.6%, P = 0.001), large-for-gestational-age neonates (1.7% vs 19.3%, P = 0.001), and birth weight > 4000 grams (0.8% vs 7.6%, P = 0.02) [47]. Conversely, LSG was associated with higher proportions of small-for-gestational-age (SGA) neonates (14.3% vs 4.2%, P = 0.01) and low-birth-weight neonates (12.6% vs 4.2%, P = 0.03) [47]. Cesarean delivery rates were lower in the LSG group (10.1% vs 20.2%, P = 0.04) [47]. However, LSG patients also had higher risk of iron deficiency anemia requiring treatment with intravenous iron supplementation during pregnancy [47]. This suggests that although LSG improves pregnancy outcomes, however, pregnant women need close monitoring for nutritional deficiencies post LSG.

2.12.3 Male sex hormones

Severe obesity in male patients is accompanied with abnormal sex hormone levels and male hypogonadism. Evidence showed a negative impact of excessive BMI on testosterone levels, sexual function and sperm parameters [48]. LSG is associated with improvement in sexual and reproductive health, and may ameliorate the sex hormone unbalance seen with obesity [49]. The total testosterone levels were significantly increased at 1, 3, 6 months after BS (13.1 ± 7.0, 13.6 ± 5.7, 21.0 ± 19.3 nmol/L, respectively), and estradiol levels significantly decreased at 6 months after surgery (91.4 ± 44.9 pmol/L) [49]. WL with LSG also has favorable effects on semen parameters of patients with pre-existing azoospermia and oligospermia [50]. There was a significant increase in the sperm concentration in men with azoospermia and oligospermia 1 year post LSG (both P < 0.05) [50]. Interestingly, the changes in semen and hormones were not affected by the extent of WL experienced by the patients, suggesting an independent mechanism [50].

3. LSG in special populations

3.1 The elderly (>60 years)

Most elderly patients have multiple comorbidities, which are aggravated when severe obesity coexists. Obesity increases their risk of developing cancer, heart disease, diabetes, lower extremity arthritis, sleep apnea, and stroke, with higher mortality risks from cardiovascular disease [51]. LSG is effective for patients older than 65 years resulting in significant WL, comorbidities remission, and improved QoL [52, 53]. LSG for those older than 65 years (median BMI 43 kg/m^2) showed low complications, where only 3.7% had gastric leak with no reported mortality and a median hospital stay of 5 days [52], BMI decreased to 35, 32.9 and 30.7 kg/m^2 at 6, 12 and 24 months after LSG and the mean EWL was 76.3% at 2 years [52]. Moreover, T2DM, hypertension, dyslipidemia, OSA, and arthralgia showed significant remission at 1 and 2 years following LSG [52]. As for QoL, there was also significant improvement in the scales that represent physical health, mental health (social function), general health perception and vitality scores [52].

3.2 Adolescents

Severe obesity in adolescents is associated with multiple comorbidities such as T2DM, hypertension, sleep apnea, fatty liver disease, decreased QoL and cardiovascular mortality in adulthood [54]. LSG has become the most used operation among adolescents with severe obesity mainly because of comparable WL outcomes and morbidities resolution to RYGB [55]. Moreover, LSG carries lower risk of surgical and nutritional complications [55, 56]. Indications for BS in adolescents largely mirrors the recommendations for adults [54]. There are no data to suggest that a youth's puberty status or linear growth is adversely affected by BS. A study showed improved linear growth in children after LSG compared with matched controls [57]. LSG results is significant WL, with EWL% at one year ranging from 49% to 81% [56, 58], and with durable long term WL (78%) (5 years)[58]. In terms of comorbidities, surgical treatment of adolescents with severe obesity and T2DM resulted in superior glycemic control than medical treatment. Across two different studies, the Teen-Longitudinal Assessment of BS (Teen-LABS) and the Treatment Options of Type 2 Diabetes in Adolescents and Youth (TODAY) study, a comparison of the glycemic control data showed that at 2 years, the mean hemoglobin A1c concentration decreased from 6.8% to 5.5% in Teen-LABS and increased from 6.4% to 7.8 in the TODAY study [55]. At 5 years post LSG, the remission rate of insulin resistance and T2DM was 100% and 87% respectively [58]. LSG also has a favorable outcome in terms of improvement of nonalcoholic steatohepatitis (NASH) [59]. Among adolescents who underwent LSG, NASH reverted completely in all patients and hepatic fibrosis stage 2 disappeared in 90% of the patients [59]. Moreover, LSG resulted in marked and sustained improvements in HRQoL, weight-related QoL and body image satisfaction [55, 60].

3.3 Low BMI

BS promotes marked and durable resolution of the clinical manifestations of diabetes in morbidly obese patients with T2DM. However, among Asians, the risks associated with T2DM and cardiovascular disease occur at a lower BMI than in Whites [61]. Patients with BMI < 35 kg/m^2 who have uncontrolled and life-threatening comorbidities do not meet the traditional criteria for obesity surgery. A surgical approach may be appropriate as an alternative for inadequately controlled T2DM in suitable surgical candidates with mild to moderate obesity (BMI 30–35 kg/m^2) [62].

3.3.1 Class I obesity (< 30 BMI)

For patients with BMI < 30 kg/m^2, a meta-analysis (12 studies, including 697 Asians) found that at 12 months postoperatively, BMI and waist circumference were reduced by 2.88 kg/m^2 and 12.92 cm, respectively [61]. There was a significant improvement in glycemic control, lipid profiles, and β-cell function in the short and medium terms (6–24 months) [61]. A study of 25 Asians with T2DM and BMI of 23.23 to 29.97 kg/m^2 showed that the complete remission rates at 3, 6, and 12 months postoperatively for T2DM were 40%, 60%, 68% respectively, hypertension (22.2%, 50%, 75% respectively), hypertriglyceridemia (66.7%, 66.7%, 100% respectively), and hypercholesterolemia (41.7%, 60%, 100% respectively) [63].

3.3.2 Class II obesity (<35 BMI)

In a randomized controlled trial where 34% of the patients had BMI < 35 kg/m^2, WL and diabetes remission were greater post LSG than after conventional treatment, and were comparable to RYGB [64]. Midterm follow-up (3 years) of 252 patients with BMI < 35 showed %EWL of 75.8% [65]. Insulin resistance remitted in 89.4%, dyslipidemia in 52%, NAFLD in 84.6%, hypertension in 75% and GERD in 65% [65]. T2DM showed 60% complete remission and 40% improvement [65].

The morbidity rate was 2.4%, two patients required reoperations, and no leaks or mortality were reported [65]. This suggests that LSG in patients with BMI < 35 kg/m^2 is safe and effective, and BMI should not be the only indicator to consider BS. Further studies with longer follow-ups are required.

3.4 Renal transplant patients

Morbid obesity is a barrier to kidney transplantation due to inferior outcomes, higher rates of new-onset diabetes after transplantation, delayed graft function, and graft failure [66]. LSG improves renal transplant candidacy and post transplant outcomes in morbidly obese patients [67, 68]. Kidney recipients who underwent LSG were compared with similar BMI recipients who did not undergo LSG [67]. In this study, the BMI decreased from 41.5 to 32.3 kg/m^2, with no complications, readmissions, or mortality following LSG [67]. After transplantation, one patient experienced delayed graft function and no other patients had new-onset diabetes [67]. Moreover, allograft survival and patient survival at 1-year post transplantation were 100% [67]. Compared with non-LSG patients, post-LSG recipients had significantly lower delayed graft function rates and renal dysfunction-related readmissions [67]. Longer duration studies showed that LSG in patients with obesity and end-stage kidney disease was associated with lower all-cause mortality at 5 years compared with usual care (cumulative incidence 25.6% vs 39.8%; hazard ratio 0.69, 95% CI, 0.60–0.78), which is likely driven by the lower mortality from cardiovascular disease [68]. Moreover, LSG was associated with an increased rate of kidney transplant at 5 years (cumulative incidence 33.0% vs 20.4%; hazard ratio 1.82; 95% CI, 1.58–2.09) [68].

3.5 Inflammatory bowel disease (IBD)

Historically, IBD patients were unlikely to be overweight or obese due to the malabsorption and catabolic disease state; however, the increasing rates of obesity along with enhanced therapeutics have now resulted in higher incidence of obese patients. The prevalence of obesity and severe obesity among IBD patients is about 20–30% and 2–5%, respectively [69]. LSG is safer compared with RYGB for IBD patients as immunosuppressant drugs might place IBD patients at higher risk of surgical complications. The underlying nutritional deficiencies in IBD patients may also increase susceptibility to micronutrient deficiencies after BS. Moreover, IBD could increase the conversion rate of laparoscopic to open surgeries [70]. Despite these concerns, studies have found that LSG has favorable outcomes in patients with IBD. For example, one study showed that among patients with Crohn's disease (CD) or ulcerative colitis (UC) who underwent RYGB (n= 19) and LSG (n= 35), both operations led to significant WL at 1 year [71]. Additionally, a sizable proportion of patients experienced improvements in IBD after RYGB and LSG [71]. There were no significant differences in the proportion of patients with UC who had improved (27% vs 8%), unchanged (64% vs 92%), or worse (9% vs 0%) IBD medication requirements, respectively [71]. Similar analysis among patients with CD showed no significant differences in the proportion of patients who had improved (37.5% vs 44%) or unchanged (25% vs 52%) IBD-medication requirements after RYGB and LSG, respectively. However, there was a significant difference in the proportion of patients who had worsened CD after RYGB compared with LSG (37.5% vs 4%, p = 0.016) [71]. In terms of complications, a metanalysis (10 studies) favored LSG over RYGB for early (<30 days) complications (LSG 14.9% vs RYGB 28.9%) and late (>30 days) complications (LSG 15.0% vs RYGB 26.8%) [70].

4. Safety and complications

The rate of major complications after LSG is 0–6% [72, 73]. Early complications include leak, bleeding, symptomatic stenosis, deep vien thrombosis/pulmonary embolism (DVT/PE), risk of portomesenteric venous thrombosis, and dehydration. Late complications include stricture, weight regain, and malnutrition.

4.1 30-day morbidity and mortality

Mortality after LSG is currently low. A large study that included 134,142 patients where 69% of patients underwent LSG and 31% had RYGB found that the mortality and morbidity rates were significantly lower in LSG compared with RYGB (0.1% vs 0.2%; 5.8% vs 11.7%, respectively). The most important predictors of morbidity and mortality outcomes were BMI, albumin, and age [74].

4.2 Leak

Leak rates range from 0.5–7.0%, though most recent reported leak rate is about 1%, reflecting improvements with time and experience in the LSG technique [73, 75]. Gastric leak can result from mechanical forces that stress the staple line or ischemia. About 75–85% of LSG leaks occur at the proximal third of the greater curvature staple line, as opposed to the distal or antral staple line, and usually occur at postoperative day 5 or later [75]. Clinically, post-LSG leak presents with left upper quadrant pain, tachycardia, fever, or leukocytosis. Upper gastrointestinal contrast studies have low sensitivity (0–25%) but high specificity (90–95%) [72]. Due to its greater sensitivity, computerized tomography (CT) scan with oral and intravenous contrast is now used for diagnosis of a leak in clinically stable patients with suggestive signs or symptoms [72]. For acute postoperative leak, patients who are not stable enough for CT should be returned to the operating room for diagnostic laparoscopy. In acute leak, the objective is adequate drainage to prevent or mitigate abdominal sepsis. Treatment includes adequate drainage, nutritional support, and antibiotics. In most cases, resolution of the leak is a matter of time, sometimes taking several months [76]. Endoscopic treatments are increasingly utilized with variable success rates in an effort to avoid surgical interventions [77].

4.3 Stenosis

Stenosis can result from the surgical technique or ischemia with subsequent stricture development. Clinically, significant stenosis occurs in 0.5–3.5% of cases, most often in a short segment located at mid-body, near the incisura [78]. Diagnosis is made by upper gastrointestinal contrast studies. Initial management is endoscopic balloon dilatation, probably requiring 2–4 dilation sessions, with 95–100% long-term success rates [79]. However, there is a 2–5% risk of perforation associated with dilation [72]. For cases where endoscopic dilation fails, the options include endoscopic stenting or conversion to RYGB [80].

4.4 Hemorrhage

Postoperative hemorrhage is rare after LSG and less common than with RYGB. Bleeding usually occurs at the staple line and is extraluminal in about half of the cases. CT scan confirms the diagnosis, and emergency surgical intervention is required for clinically significant active hemorrhage. For intraluminal bleeding, endoscopic interventions, including epinephrine injection, heater probe, and clipping, are effective [72].

4.5 GERD

Significant GERD is considered a contraindication for LSG. Some studies show an increased prevalence of GERD in patients after LSG. This is likely due to hypotensive lower esophageal sphincter, disruption of the angle of His, reduced gastric compliance with higher intragastric pressure, and decreased gastric emptying. Late dilatation of the sleeve, and occurrence of hiatal hernia could also play a role in the worsening of GERD [81]. It is not recommended to empirically start antacid medication for prophylaxis after LSG [82]. However, for patients who develop reflux after LSG, treatment options are proton-pump inhibitors or conversion to RYGB [83].

4.6 Portomesenteric venous thrombosis

Portomesenteric venous thrombosis is a rare complication of LSG thought to be secondary to regional postsurgical inflammation, change in venous outflow, and dehydration predisposing to clot formation [72]. Patients may present 1–2 weeks after surgery with vague abdominal pain, severe nausea and vomiting, fever and diffuse abdominal tenderness. Diagnosis is confirmed with CT scan. Treatment consists of anticoagulation, fluid resuscitation, and bowel rest. Thrombolytics may be indicated depending on severity of symptoms. There are no established guidelines for the duration of anticoagulation therapy, but patients are usually treated for 3–6 months. Surgical treatment is reserved for patients with evidence of infarcted bowel [84].

4.7 Nutritional deficiencies

Although LSG is viewed as a restrictive procedure, some degree of malabsorption is also expected. After recovering from surgery, patients are at risk of macronutrient deficiencies in the long term due to reduced dietary intake, decreased gastric secretion of hydrochloric acid and intrinsic factor, and poor food choices. The most common micronutrient deficiencies are of vitamins B12 and D, iron, and calcium [85]. Other micronutrient deficiencies that can lead to severe complications include thiamine, folate, and fat-soluble vitamins [85]. Daily micronutrient supplements are necessary, including multivitamin concentrate (with iron, copper, and zinc), calcium citrate with vitamin D, vitamin B12, and elemental iron [82]. However, multivitamins or nutritional supplements are typically not initiated in the immediate postoperative period [82]. It is necessary to clinically monitor the bariatric patient during the first five years. Some evidence suggests that patients experienced fewer nutrient deficiencies after LSG than after RYGB [86].

4.8 Mortality

Mortality after LSG is currently low according to data from the American College of Surgeons - BS Center Network (includes 28616 patients in 25 hospitals in the USA), where the 30-day mortality was 0.11% and the 1 year mortality was 0.21% [87].

5. Conclusion

Since its evolution from the initial step of a staged procedure to a stand-alone procedure, LSG has emerged as the most commonly performed bariatric operation worldwide. This is due to its technical ease, coupled with decreased surgical complications in comparison with other more complex surgical procedures. It has proven to be safe and effective in achieving weight loss and addressing the metabolic derangements associated with obesity. In addition, long term outcomes have demonstrated that the durability of LSG is comparable with that of other bariatric procedures.

Conflict of interest

None.

Author details

Wahiba Elhag[1] and Walid El Ansari[2,3,4]*

1 Department of Bariatric Surgery/Bariatric Medicine, Hamad General Hospital, Doha, Qatar

2 Department of Surgery, Hamad General Hospital, Doha, Qatar

3 College of Medicine, Qatar University, Doha, Qatar

4 Schools of Health and Education, University of Skovde, Skövde, Sweden

*Address all correspondence to: welansari9@gmail.com

References

[1] Brethauer SA, Kim J, el Chaar M, et al. Standardized outcomes reporting in metabolic and bariatric surgery. Surg Obes Relat Dis. 2015;**11**:489-506

[2] Mechanick JI, Apovian C, Brethauer S, et al. Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures - 2019 update: cosponsored by American Association of Clinical Endocrinologists/ American College of Endocrinology, The Obesity Society, American Society for Metabolic & Bariatric Surgery, Obesity Medicine Association, and American Society of Anesthesiologists. Surg Obes Relat Dis. 2020;**16**:175-247

[3] Fischer L, Hildebrandt C, Bruckner T, et al. Excessive weight loss after sleeve gastrectomy: a systematic review. Obes Surg. 2012;**22**:721-731

[4] Lemanu DP, Singh PP, Rahman H, Hill AG, Babor R, MacCormick AD. Five-year results after laparoscopic sleeve gastrectomy: a prospective study. Surg Obes Relat Dis. 2015;**11**:518-524

[5] Boza C, Salinas J, Salgado N, Pérez G, Raddatz A, Funke R, et al. Laparoscopic sleeve gastrectomy as a stand-alone procedure for morbid obesity: report of 1,000 cases and 3-year follow-up. Obes Surg. 2012;**22**:866-871

[6] Juodeikis Ž, Brimas G. Long-term results after sleeve gastrectomy: A systematic review. Surg Obes Relat Dis. 2017;**13**:693-699

[7] Li L, Yu H, Liang J, Guo Y, Peng S, Luo Y, et al. Meta-analysis of the effectiveness of laparoscopic adjustable gastric banding versus laparoscopic sleeve gastrectomy for obesity. Medicine (Baltimore). 2019;**98**:e14735

[8] Peterli R, Wölnerhanssen BK, Peters T, et al. Effect of Laparoscopic Sleeve Gastrectomy vs Laparoscopic Roux-en-Y Gastric Bypass on Weight Loss in Patients With Morbid Obesity: The SM-BOSS Randomized Clinical Trial. JAMA. 2018;**319**:255-265

[9] Salminen P, Helmiö M, Ovaska J, et al. Effect of Laparoscopic Sleeve Gastrectomy vs Laparoscopic Roux-en-Y Gastric Bypass on Weight Loss at 5 Years Among Patients With Morbid Obesity. JAMA. 2018;**319**:241-254

[10] Jiménez A, Casamitjana R, Flores L, Delgado S, Lacy A, Vidal J. GLP-1 and the long-term outcome of type 2 diabetes mellitus after Roux-en-Y gastric bypass surgery in morbidly obese subjects. Ann Surg. 2013;**257**:894-899

[11] Viscido G, Gorodner V, Signorini FJ, et al. Obese Patients with Type 2 Diabetes: Outcomes After Laparoscopic Sleeve Gastrectomy. J Laparoendosc Adv Surg Tech A. 2019;**29**:655-662

[12] Switzer NJ, Prasad S, Debru E, Church N, Mitchell P, Gill RS. Sleeve Gastrectomy and Type 2 Diabetes Mellitus: a Systematic Review of Long-Term Outcomes. Obes Surg. 2016;**26**:1616-1621

[13] Gu J, Vergis A. Diabetes improvement and bariatric surgery—review of laparoscopic Roux-en-Y gastric bypass vs. laparoscopic vertical sleeve gastrectomy. Ann Transl Med [Internet]. 2020 [cited 2020 Aug 12];8.

[14] Schauer PR, Bhatt DL, Kirwan JP, et al. Bariatric Surgery versus Intensive Medical Therapy for Diabetes - 5-Year Outcomes. N Engl J Med. 2017;**376**:641-651

[15] Cho J-M, Kim HJ, Lo Menzo E, Park S, Szomstein S, Rosenthal RJ. Effect of sleeve gastrectomy on type 2

diabetes as an alternative treatment modality to Roux-en-Y gastric bypass: systemic review and meta-analysis. Surg Obes Relat Dis. 2015;**11**:1273-1280

[16] Elgenaied I, El Ansari W, Elsherif MA, Abdulrazzaq S, Qabbani AS, Elhag W. Factors associated with complete and partial remission, improvement, or unchanged diabetes status of obese adults 1 year after sleeve gastrectomy. Surg Obes Relat Dis. 2020; May 27:S1550-7289(20)30271-9. doi: 10.1016/j.soard.2020.05.013. Online ahead of print.

[17] Yin X, Qian J, Wang Y, et al. Short-term outcome and early effect on blood pressure of laparoscopic sleeve gastrectomy in morbidly obese patients. Clin Exp Hypertens. 2019;**41**:622-626

[18] Graham C, Switzer N, Reso A, et al. Sleeve gastrectomy and hypertension: a systematic review of long-term outcomes. Surg Endosc. 2019;**33**:3001-3007

[19] Blanco DG, Funes DR, Giambartolomei G, Lo Menzo E, Szomstein S, Rosenthal RJ. Laparoscopic sleeve gastrectomy versus Roux-en-Y gastric bypass in cardiovascular risk reduction: A match control study. Surg Obes Relat Dis. 2019;**15**:14-20

[20] Vigilante A, Signorini F, Marani M, et al. Impact on Dyslipidemia After Laparoscopic Sleeve Gastrectomy. Obes Surg. 2018;**28**:3111-3115

[21] Golomb I, Ben David M, Glass A, Kolitz T, Keidar A. Long-term Metabolic Effects of Laparoscopic Sleeve Gastrectomy. JAMA Surg. 2015;**150**:1051-1057

[22] Marchisello S, Di Pino A, Scicali R, et al. Pathophysiological, Molecular and Therapeutic Issues of Nonalcoholic Fatty Liver Disease: An Overview. Int J Mol Sci [Internet]. 2019 [cited 2020 Aug 13];20.

[23] von Schönfels W, Beckmann JH, Ahrens M, et al. Histologic improvement of NAFLD in patients with obesity after bariatric surgery based on standardized NAS (NAFLD activity score). Surg Obes Relat Dis. 2018;**14**:1607-1616

[24] Brunt EM, Kleiner DE, Wilson LA, Belt P, Neuschwander-Tetri BA. The NAS and The Histopathologic Diagnosis in NAFLD: Distinct Clinicopathologic Meanings. Hepatology. 2011;**53**:810-820

[25] Cabré N, Luciano-Mateo F, Fernández-Arroyo S, et al. Laparoscopic sleeve gastrectomy reverses non-alcoholic fatty liver disease modulating oxidative stress and inflammation. Metab Clin Exp. 2019;**99**:81-89

[26] Sarkhosh K, Switzer NJ, El-Hadi M, Birch DW, Shi X, Karmali S. The impact of bariatric surgery on obstructive sleep apnea: a systematic review. Obes Surg. 2013;**23**:414-423

[27] Timmerman M, Basille D, Basille-Fantinato A, et al. Short-Term Assessment of Obstructive Sleep Apnea Syndrome Remission Rate after Sleeve Gastrectomy: a Cohort Study. Obes Surg. 2019;**29**:3690-3697

[28] Mohan A, Grace J, Wang BR, Lugogo N. The Effects of Obesity in Asthma. Curr Allergy Asthma Rep. 2019;**19**:49

[29] van Huisstede A, Rudolphus A, Castro Cabezas M, et al. Effect of bariatric surgery on asthma control, lung function and bronchial and systemic inflammation in morbidly obese subjects with asthma. Thorax. 2015;**70**:659-667

[30] Guerron AD, Ortega CB, Lee H-J, Davalos G, Ingram J, Portenier D. Asthma medication usage is significantly reduced following bariatric surgery. Surg Endosc. 2019;**33**:1967-1975

[31] Rebecchi F, Allaix ME, Giaccone C, Ugliono E, Scozzari G, Morino M. Gastroesophageal reflux disease and laparoscopic sleeve gastrectomy: a physiopathologic evaluation. Ann Surg. 2014;**260**:909-914 discussion 914-915

[32] Balla A, Quaresima S, Palmieri L, et al. Effects of Laparoscopic Sleeve Gastrectomy on Quality of Life Related to Gastroesophageal Reflux Disease. J Laparoendosc Adv Surg Tech A. 2019;**29**:1532-1538

[33] Stenard F, Iannelli A. Laparoscopic sleeve gastrectomy and gastroesophageal reflux. World J Gastroenterol. 2015;**21**:10348-10357

[34] Çalışır S, Çalışır A, Arslan M, İnanlı İ, Çalışkan AM, Eren İ. Assessment of depressive symptoms, self-esteem, and eating psychopathology after laparoscopic sleeve gastrectomy: 1-year follow-up and comparison with healthy controls. Eat Weight Disord. 2019; 2019;10.1007/s40519-019-00785-7. doi:10.1007/s40519-019-00785-7. Online ahead of print.

[35] Mack I, Ölschläger S, Sauer H, et al. Does Laparoscopic Sleeve Gastrectomy Improve Depression, Stress and Eating Behaviour? A 4-Year Follow-up Study. Obes Surg. 2016;**26**:2967-2973

[36] Monte SV, Russo KM, Mustafa E, Caruana JA. Impact of Sleeve Gastrectomy on Psychiatric Medication Use and Symptoms. J Obes [Internet]. 2018 [cited 2020 Aug 1];2018.

[37] Brunault P, Frammery J, Couet C, et al. Predictors of changes in physical, psychosocial, sexual quality of life, and comfort with food after obesity surgery: a 12-month follow-up study. Qual Life Res. 2015;**24**:493-501

[38] Charalampakis V, Bertsias G, Lamprou V, de Bree E, Romanos J, Melissas J. Quality of life before and after laparoscopic sleeve gastrectomy. A prospective cohort study. Surg Obes Relat Dis. 2015;**11**:70-76

[39] Major P, Matłok M, Pędziwiatr M, et al. Quality of Life After Bariatric Surgery. Obes Surg. 2015;**25**:1703-1710

[40] Faam B, Zarkesh M, Daneshpour MS, Azizi F, Hedayati M. The association between inflammatory markers and obesity-related factors in Tehranian adults: Tehran lipid and glucose study. Iran J Basic Med Sci. 2014;**17**:577-582

[41] Gumbau V, Bruna M, Canelles E, et al. A prospective study on inflammatory parameters in obese patients after sleeve gastrectomy. Obes Surg. 2014;**24**:903-908

[42] Mallipedhi A, Prior SL, Barry JD, Caplin S, Baxter JN, Stephens JW. Changes in inflammatory markers after sleeve gastrectomy in patients with impaired glucose homeostasis and type 2 diabetes. Surg Obes Relat Dis. 2014;**10**:1123-1128

[43] Dilday J, Derickson M, Kuckelman J, et al. Sleeve Gastrectomy for Obesity in Polycystic Ovarian Syndrome: a Pilot Study Evaluating Weight Loss and Fertility Outcomes. Obes Surg. 2019;**29**:93-98

[44] Machado Júnior AS, Ribeiro CBL, Santa-Cruz F, et al. The Effect of Sleeve Gastrectomy on the Hormonal Profile of Patients with Polycystic Ovary Syndrome. Obes Surg. 2019;**29**:2415-2419

[45] Pilone V, Tramontano S, Renzulli M, et al. Evaluation of anti-Müller hormone AMH levels in obese women after sleeve gastrectomy. Gynecol Endocrinol. 2019;**35**:548-551

[46] Schummers L, Hutcheon JA, Bodnar LM, Lieberman E, Himes KP. Risk of adverse pregnancy outcomes by prepregnancy body mass index: a population-based study to inform

prepregnancy weight loss counseling. Obstet Gynecol. 2015;**125**:133-143

[47] Rottenstreich A, Elchalal U, Kleinstern G, Beglaibter N, Khalaileh A, Elazary R. Maternal and Perinatal Outcomes After Laparoscopic Sleeve Gastrectomy. Obstet Gynecol. 2018;**131**:451-456

[48] Mihalca R, Fica S. The impact of obesity on the male reproductive axis. J Med Life. 2014;**7**:296-300

[49] Zhu C, Zhang Y, Wang X, et al. Effect of laparoscopic sleeve gastrectomy on sex hormone in male severe obesity. Zhonghua Wei Chang Wai Ke Za Zhi. 2017;**20**:405-410

[50] El Bardisi H, Majzoub A, Arafa M, et al. Effect of bariatric surgery on semen parameters and sex hormone concentrations: a prospective study. Reprod Biomed Online. 2016;**33**:606-611

[51] Zamboni M, Mazzali G, Zoico E, et al. Health consequences of obesity in the elderly: a review of four unresolved questions. Int J Obes (Lond). 2005;**29**:1011-29.

[52] Lainas P, Dammaro C, Gaillard M, Donatelli G, Tranchart H, Dagher I. Safety and short-term outcomes of laparoscopic sleeve gastrectomy for patients over 65 years old with severe obesity. Surg Obes Relat Dis. 2018;**14**:952-959

[53] Dowgiałło-Wnukiewicz N, Janik MR, Lech P, et al. Outcomes of sleeve gastrectomy in patients older than 60 years: a multicenter matched case-control study. Wideochir Inne Tech Maloinwazyjne. 2020;**15**:123-128

[54] Pratt JSA, Browne A, Browne NT, et al. ASMBS pediatric metabolic and bariatric surgery guidelines, 2018. Surg Obes Relat Dis. 2018;**14**:882-901

[55] Inge TH, Courcoulas AP, Jenkins TM, et al. Weight Loss and Health Status 3 Years after Bariatric Surgery in Adolescents. N Engl J Med. 2016;**374**:113-123

[56] Elhag W, El Ansari W, Abdulrazzaq S, Abdullah A, Elsherif M, Elgenaied I. Evolution of 29 Anthropometric, Nutritional, and Cardiometabolic Parameters Among Morbidly Obese Adolescents 2 Years Post Sleeve Gastrectomy. Obes Surg. 2018;**28**:474-482

[57] Alqahtani A, Elahmedi M, Qahtani ARA. Laparoscopic Sleeve Gastrectomy in Children Younger Than 14 Years: Refuting the Concerns. Ann Surg. 2016;**263**:312-319

[58] Khidir N, El-Matbouly MA, Sargsyan D, Al-Kuwari M, Bashah M, Gagner M. Five-year Outcomes of Laparoscopic Sleeve Gastrectomy: a Comparison Between Adults and Adolescents. Obes Surg. 2018;**28**:2040-2045

[59] Manco M, Mosca A, De Peppo F, et al. The Benefit of Sleeve Gastrectomy in Obese Adolescents on Nonalcoholic Steatohepatitis and Hepatic Fibrosis. J Pediatr. 2017;**180**:31-37.e2.

[60] El-Matbouly MA, Khidir N, Touny HA, El Ansari W, Al-Kuwari M, Bashah M. A 5-Year Follow-Up Study of Laparoscopic Sleeve Gastrectomy Among Morbidly Obese Adolescents: Does It Improve Body Image and Prevent and Treat Diabetes? Obes Surg. 2018;**28**:513-519

[61] Ji G, Li P, Li W, et al. The Effect of Bariatric Surgery on Asian Patients with Type 2 Diabetes Mellitus and Body Mass Index < 30 kg/m2: a Systematic Review and Meta-analysis. Obes Surg. 2019;**29**:2492-2502

[62] Rubino F, Nathan DM, Eckel RH, et al. Metabolic Surgery in the Treatment Algorithm for Type 2 Diabetes: A Joint Statement by

International Diabetes Organizations. Diabetes Care. 2016;**39**:861-877

[63] Wang L, Wang J, Jiang T. Effect of Laparoscopic Sleeve Gastrectomy on Type 2 Diabetes Mellitus in Patients with Body Mass Index less than 30 kg/m2. Obes Surg. 2019;**29**:835-842

[64] Schauer PR, Kashyap SR, Wolski K, et al. Bariatric surgery versus intensive medical therapy in obese patients with diabetes. N Engl J Med. 2012;**366**:1567-1576

[65] Berry MA, Urrutia L, Lamoza P, et al. Sleeve Gastrectomy Outcomes in Patients with BMI Between 30 and 35-3 Years of Follow-Up. Obes Surg. 2018;**28**:649-655

[66] Sood A, Hakim DN, Hakim NS. Consequences of Recipient Obesity on Postoperative Outcomes in a Renal Transplant: A Systematic Review and Meta-Analysis. Exp Clin Transplant. 2016;**14**:121-128

[67] Kim Y, Jung AD, Dhar VK, et al. Laparoscopic sleeve gastrectomy improves renal transplant candidacy and posttransplant outcomes in morbidly obese patients. Am J Transplant. 2018;**18**:410-416

[68] Sheetz KH, Gerhardinger L, Dimick JB, Waits SA. Bariatric Surgery and Long-term Survival in Patients With Obesity and End-stage Kidney Disease. JAMA Surg. 2020;

[69] Steed H, Walsh S, Reynolds N. A brief report of the epidemiology of obesity in the inflammatory bowel disease population of Tayside. Scotland. Obes Facts. 2009;**2**:**370**-372

[70] Garg R, Mohan BP, Ponnada S, Singh A, Aminian A, Regueiro M, et al. Safety and Efficacy of Bariatric Surgery in Inflammatory Bowel Disease Patients: a Systematic Review and Meta-analysis. Obes Surg. 2020; 10.1007/s11695-020-04729-4. doi:10.1007/s11695-020-04729-4. Online ahead of print.

[71] Heshmati K, Lo T, Tavakkoli A, Sheu E. Short-Term Outcomes of Inflammatory Bowel Disease after Roux-en-Y Gastric Bypass vs Sleeve Gastrectomy. J Am Coll Surg. 2019;**228**:893-901.e1

[72] Chung AY, Thompson R, Overby DW, Duke MC, Farrell TM. Sleeve Gastrectomy: Surgical Tips. J Laparoendosc Adv Surg Tech A. 2018;**28**:930-937

[73] Stroh C, Köckerling F, Volker L, et al. Results of More Than 11,800 Sleeve Gastrectomies: Data Analysis of the German Bariatric Surgery Registry. Ann Surg. 2016;**263**:949-955

[74] Kumar SB, Hamilton BC, Wood SG, Rogers SJ, Carter JT, Lin MY. Is laparoscopic sleeve gastrectomy safer than laparoscopic gastric bypass? a comparison of 30-day complications using the MBSAQIP data registry. Surg Obes Relat Dis. 2018;**14**:264-269

[75] Kim J, Azagury D, Eisenberg D, DeMaria E, Campos GM. American Society for Metabolic and Bariatric Surgery Clinical Issues Committee. ASMBS position statement on prevention, detection, and treatment of gastrointestinal leak after gastric bypass and sleeve gastrectomy, including the roles of imaging, surgical exploration, and nonoperative management. Surg Obes Relat Dis. 2015;**11**:739-748

[76] Nimeri A, Ibrahim M, Maasher A, Al HM. Management Algorithm for Leaks Following Laparoscopic Sleeve Gastrectomy. Obes Surg. 2016;**26**:21-25

[77] Souto-Rodríguez R, Alvarez-Sánchez M-V. Endoluminal solutions to bariatric surgery complications: A review with a focus on technical

aspects and results. World J Gastrointest Endosc. 2017;**9**:**105**-126

[78] Parikh A, Alley JB, Peterson RM, et al. Management options for symptomatic stenosis after laparoscopic vertical sleeve gastrectomy in the morbidly obese. Surg Endosc. 2012;**26**:738-746

[79] Shnell M, Fishman S, Eldar S, Goitein D, Santo E. Balloon dilatation for symptomatic gastric sleeve stricture. Gastrointest Endosc. 2014;**79**:521-524

[80] Kalaiselvan R, Ammori BJ. Laparoscopic median gastrectomy for stenosis following sleeve gastrectomy. Surg Obes Relat Dis. 2015;**11**:474-477

[81] Oor JE, Roks DJ, Ünlü Ç, Hazebroek EJ. Laparoscopic sleeve gastrectomy and gastroesophageal reflux disease: a systematic review and meta-analysis. Am J Surg. 2016;**211**:250-267

[82] Telem DA, Gould J, Pesta C, et al. American Society for Metabolic and Bariatric Surgery: care pathway for laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2017;**13**:742-749

[83] Mandeville Y, Van Looveren R, Vancoillie P-J, et al. Moderating the Enthusiasm of Sleeve Gastrectomy: Up to Fifty Percent of Reflux Symptoms After Ten Years in a Consecutive Series of One Hundred Laparoscopic Sleeve Gastrectomies. Obes Surg. 2017;**27**:1797-1803

[84] Tan SBM, Greenslade J, Martin D, Talbot M, Loi K, Hopkins G. Portomesenteric vein thrombosis in sleeve gastrectomy: a 10-year review. Surg Obes Relat Dis. 2018;**14**:271-275

[85] Sarker A, Meek CL, Park A. Biochemical consequences of bariatric surgery for extreme clinical obesity. Ann Clin Biochem. 2016;**53**:21-31

[86] Gehrer S, Kern B, Peters T, Christoffel-Courtin C, Peterli R. Fewer nutrient deficiencies after laparoscopic sleeve gastrectomy (LSG) than after laparoscopic Roux-Y-gastric bypass (LRYGB)-a prospective study. Obes Surg. 2010;**20**:447-453

[87] Hutter MM, Schirmer BD, Jones DB, et al. First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass. Ann Surg. 2011;**254**:410-420 discussion 420-422