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RESEARCH

Beyond the decade: unveiling long-term weight and co-morbidity outcomes up to 10 years post laparoscopic sleeve gastrectomy

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Abstract

Introduction Despite its effectiveness, long-term data on the safety and efficacy of laparoscopic sleeve gastrectomy (LSG) for morbid obesity are sparce.

Methods We collected data through phone interviews and hospital records for patients who had LSG, including those that then underwent revisional bariatric surgery, assessing their weight outcomes, associated health conditions, and complications.

Results 2982 patients (72% female) were included in the study, with a maximum follow-up reached of 13 years. The mean pre-operative age and body mass index (BMI) were 34.7 ± 11.3 years and 45.5 ± 7.7 kg/m2, respectively. The prevalence of obesity classes were as follows: Class I, 3.1%; Class II, 19.2%; and Class III, 75.9%. BMI at nadir was 32.35 Kg/m2 equating to a mean nadir excess weight loss (EWL) of 67.03%. Weight outcomes at 13 years post-LSG showed a mean BMI of 31.83 kg/m^2 and total weight loss (TWL) percentage of 31.43%. Weight loss outcomes varied according to pre-operative obesity class, with class I achieving the highest percentage EWL and class III observing the highest TWL at the end of one year. Weight regain occurred in 1.3% of the patient population, with class III experiencing the highest weight regain at 13 years. Significant reductions in comorbidities were observed, while complication rates were low, with 0.4% bleed, 0.5% leak, and 7.9% GERD.

Conclusion LSG demonstrates sustained weight loss and resolution of comorbidities with low complication rates. The influence of initial obesity class on weight loss was found to be significant in the first 18 months post-LSG.

Keywords Bariatric · Metabolic surgery · LSG · Sleeve gastrectomy · Long-term · Obesity class

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Introduction

The long-term management of the obesity crisis has become one of the most important items on the health budgets of countries around the world [1–3] given the chronic nature of the disease and the comorbidities associated with it. Bariatric surgery is the most effective treatment for managing morbid obesity, leading to satisfactory long-term weight loss and a significant reduction in related comorbidities [4].

Laparoscopic sleeve gastrectomy (LSG) was initially described either as a first step procedure for the biliopancreatic diversion duodenal switch (BPD/DS) [5] or as a primary intervention for high-risk bariatric patients scheduled to undergo laparoscopic Roux-en-Y gastric bypass (LRYGB) [6]. Over time, LSG has become the most frequently performed bariatric/metabolic procedure worldwide, largely due to its straightforward operative technique, absence of gastrointestinal anastomoses and foreign material, minimal alteration of patient anatomy, successful short- and mid-term weight loss outcomes, low morbidity rates, and its ability to be easily converted to another bariatric procedure [7–10]. However, despite its increasing popularity, a paucity of studies looking at long-term outcomes exist, restricting the assessment of the LSGs' sustained effectiveness and safety [11], while the ones that do exist exhibit high incidences of weight regain [12, 13] and de-novo reflux or worsening of pre-existing gastroesophageal reflux disease [14, 15].

We herein present our long-term primary LSG results in terms of weight loss, remission of comorbidities, and complication and reoperations rates at a single institution with a maximum follow-up time of 13 years.

Methods

Patient follow-up

We conducted follow-up assessments using phone interviews to gather information on long-term outcomes of LSG, which were further corroborated with data from hospital records. Our analysis includes data on patients who underwent revisional procedures after their initial LSG, and we report their outcomes separately. The study included patients who had their initial LSG procedure at our facility. All participants met the standard criteria for bariatric surgery, which include having a body mass index (BMI) of 40 or higher, or a BMI of 35 or higher accompanied by obesity-related health conditions [16].

We conducted telephone interviews that included comprehensive questions about weight changes, obesity-related health issues such as hypertension, type 2 diabetes mellitus (T2DM), and obstructive sleep apnea, as well as post-surgical complications like bleeding, leaks, and gastroesophageal reflux disease (GERD). The interviews also addressed whether patients required abdominoplasty after LSG or any subsequent bariatric surgery.

Pre-operative evaluation

Comprehensive pre-operative evaluation was performed on all patients as indicated by our previously performed studies [17].

LSG procedure technique

The LSG procedure involved the use of five laparoscopic ports while the patient was in the standard split-leg French position. The greater curvature of the stomach was devascularized starting 4 to 6 cm from the pylorus and extending to the angle of His. A 36-Fr calibrating bougie was then inserted from the stomach to the duodenum to guide the sleeve creation. Using a linear laparoscopic stapler, the stomach was divided along the bougie, ensuring the staple lines were placed 0.5 to 2 cm lateral to the esophagus. The bougie was subsequently removed, and a leak test was performed by injecting 100 ml of methylene blue. No intra-abdominal drains were used. If a hiatal hernia was detected during the operation, it was repaired concurrently with the sleeve gastrectomy.

To prevent venous thromboembolism, prophylactic measures were started within 12 h post-surgery and continued for two weeks [18]. A bariatric dietitian provided detailed dietary instructions for recovery [19] and patients were advised to attend regular follow-up appointments with their multidisciplinary bariatric team.

Definition of co-morbidities – diabetes

Diabetes was defined as either the Impaired glycaemia or impaired glucose tolerance and/or the need for insulin treatment and/or the need for oral antidiabetics (OAD) & insulin treatment and/or the need for oral hypoglycemics.

Definition of co-morbidities – GERD

Gastro-esophageal reflux disease (GERD) was defined for patients based on their use of medication or symptoms: (1) Daily use of H2 receptor antagonists (H2RA) or proton pump inhibitors (PPI); (2) Intermittent use of medication; or (3) Intermittent symptoms without the need for medication. All patients scheduled for sleeve gastrectomy at our institution were pre-operatively evaluated for reflux. For patients with Grade A or lower reflux, the sleeve gastrectomy proceeded, as obesity was considered the primary

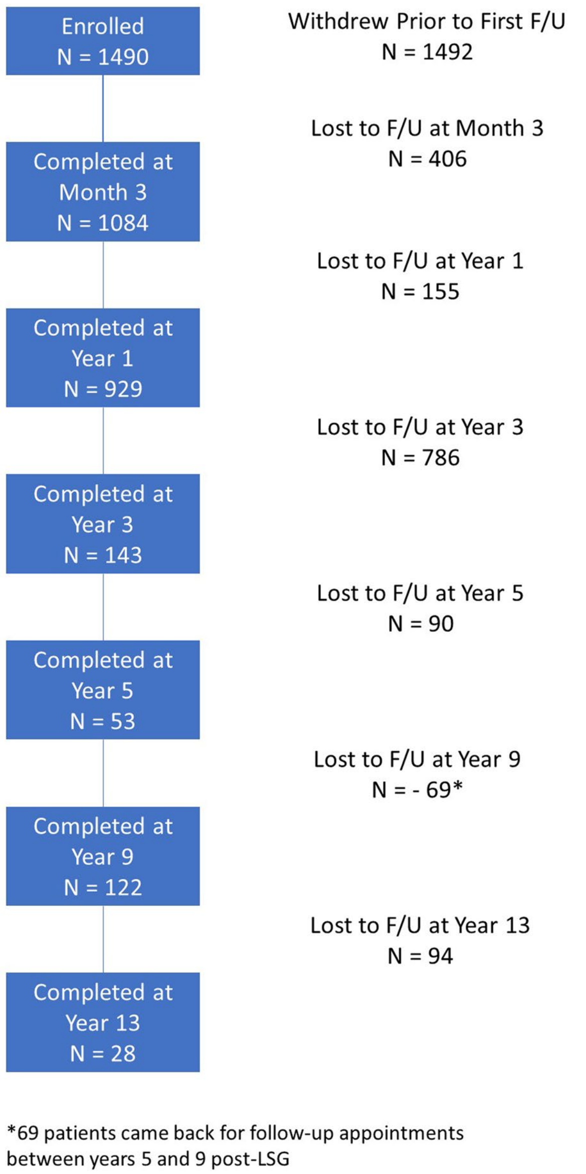

Fig. 1 Loss to Follow-Up (F/U) diagram over time

Table 1 Patient demographics pre-operatively

Demographics	Overall	Obesity Class I	Obesity Class II	Obesity Class III
Number of Patients	2982	93 (3.12%)	573 (19.2%)	2264 (75.9%)
Age at Surgery (Years)	34.69 (11.25)	37.62 (11.50)	36.09 (10.40)	34.20 (11.38)
Gender				
Male	835 (28%)			
Female	2147 (72%)			
Weight (Kg)	122.66 (24.60)	94.57 (10.15)	103.30 (11.22)	128.99 (23.84)
BMI (Kg/m^2)	45.50 (7.73)	33.53 (1.18)	37.94 (1.39)	48.00 (7.08)

cause. For those with Grade B reflux, further evaluation was conducted, and patients were placed on a PPI regimen as described previously [20]. If the reflux resolved, the sleeve gastrectomy was performed. Persistent reflux led to the recommendation of a Roux-en-Y gastric bypass instead.

Definition of co-morbidities – Hypertension (HTN)

Hypertension was categorized as either: (1) Treated hypertension; or (2) Untreated hypertension.

Definition of co-morbidities – Obstructive sleep apnea (OSA)

If the reflux resolved, the sleeve gastrectomy was performed. Persistent reflux led to the recommendation of a Roux-en-Y gastric bypass instead [21]. Apneas were identified by a ≥ 90% reduction in airflow for at least two breaths. Obstructive apneas were characterized by the presence of respiratory effort throughout the apnea event.

Postoperative evaluation

Follow-up assessments were scheduled at 1, 3, 6, and 12 months post-surgery, and annually thereafter for up to 13 years post-LSG. Weight loss was measured in terms of BMI changes, percentage of excess weight loss (%EWL), and percentage of total weight loss (%TWL). The patient follow-up attrition is illustrated in Fig. 1.

Statistical analysis

SPSS software version 22 was used to carry out statistical analysis of the data. A two-tailed unpaired Student's t-test was used to evaluate the significance of the difference between two values. For all data comparisons, statistical significance was defined as $p < 0.05$. %EWL was calculated using an ideal body weight equivalent to a BMI of 25 kg/m2.

Results

Baseline characteristics

Our study analyzed data from 2982 patients who had laparoscopic sleeve gastrectomy as a initial procedure, with 2147 (72%) being female. At the time of surgery, the average age was 34.69 years old (±11.25), the average pre-operative weight was 122.66 Kg (±24.60), resulting in an average BMI of 45.50 Kg/m^2 (±7.73) (Table 1). Of those patients, 93 (3.1%) were classified in the Class 1 obesity group

(BMI = 30–35 Kg/m^2), 573 patients (19.2%) in the Class 2 group (BMI = 35–40 Kg/m^2), and 2264 patients (75.9%) in the Class 3 group (BMI > 40 Kg/m^2). There were no significant differences in baseline characteristics across the different obesity classes.

The most prevalent pre-operative weight-related medical illness observed was diabetes (n = 309), followed by hypertension (n = 298) and obstructive sleep apnea (n = 127). The mean follow-up period was 8.60 (± 3.05) years.

Weight outcomes

Mean weight at 13 years was 84.57 Kg (Fig. 2), corresponding to a mean BMI of 31.83 Kg/m^2 (Fig. 3), an EWL% of 69.6% (Fig. 4) and TWL% of 31.43% (Fig. 5). The highest excess weight loss was achieved at 4 years post-op (EWL = 74.35%), while the highest total weight loss percentage was achieved at 18 months post-op (TWL = 32.96%) (Fig. 6). This corresponded to a %EWL of 101.72% in patients that were classified in the Class I obesity group pre-operatively, 78.34% in Class 2, and 71.73% in Class 3, respectively; and a %TWL of 34.12% in Class 1, 30.87% in Class 2, and 33.54% in Class 3, respectively.

Mean nadir weight achieved, measured 10 months onwards post-LSG, was 86.86 Kg (± 19.53), corresponding to a nadir BMI of 32.35 Kg/m^2 (± 6.91). This weight loss equated to a mean nadir excess weight loss (EWL) of 67.03% (± 27.65). Overall, 31 patients (17.8% of patients with data at 18 months; 1.04% of total patient population) attained insufficient weight loss, defined as an excess weight loss percentage of < 50% 18 months post-LSG [22], while a total of 40 patients (1.3% of total patient population) experienced weight regain, defined as progressive weight regain that occurred after achieving an initial successful weight loss (defined as an EWL > 50%) [22] (Figs. 2–6).

Baseline characteristics of patients that did not experience weight regain (WR) vs. patients that experienced weight regain (WR) did not show statistical differences (p > 0.005): age at LSG 36.78 years old (± 11.34) vs. 26.00 years old (± 1.41), respectively; pre-operative weight 125.67 Kg (± 23.67) vs. 143.00 Kg (± 19.80), respectively; pre-operative BMI 45.33 Kg/m^2 (± 7.47) vs. 42.70 Kg/m^2 (± 0.10), respectively.

There was a significant difference between starting obesity class and TWL at 2w (p = 0.001; obesity class 1 with the highest TWL) and 1y (p = 0.000; obesity class 3 with the highest, followed by class 2, and class 1). There was also a significant difference between starting obesity class and weight regain at 13 years (p = 0.011; obesity class 3 with the highest weight regain, followed by obesity class 1, then class 2).

Interestingly, we noted a significant difference between starting obesity class and weight (p = 0.000) at 2w, 3 m, 6 m, 1y and 18 m.

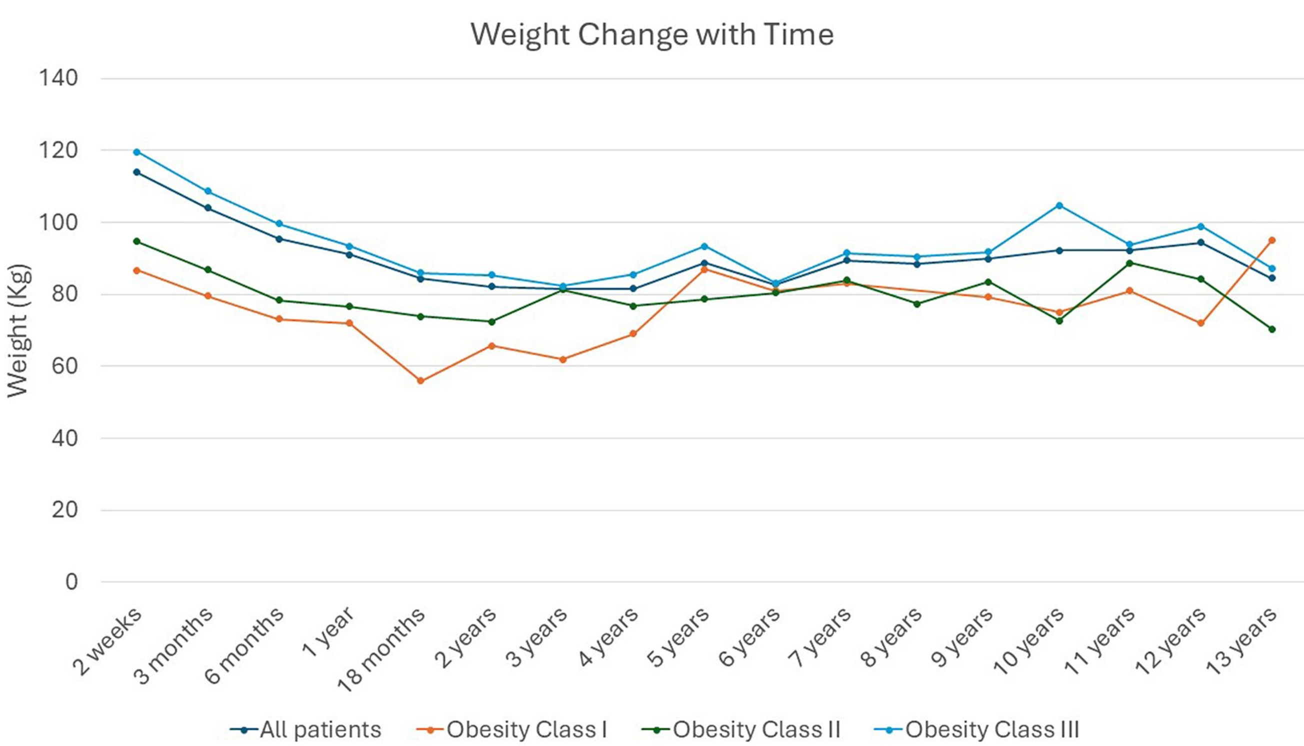

Fig. 2 Weight Change with time post-operatively; divided between the three obesity classes

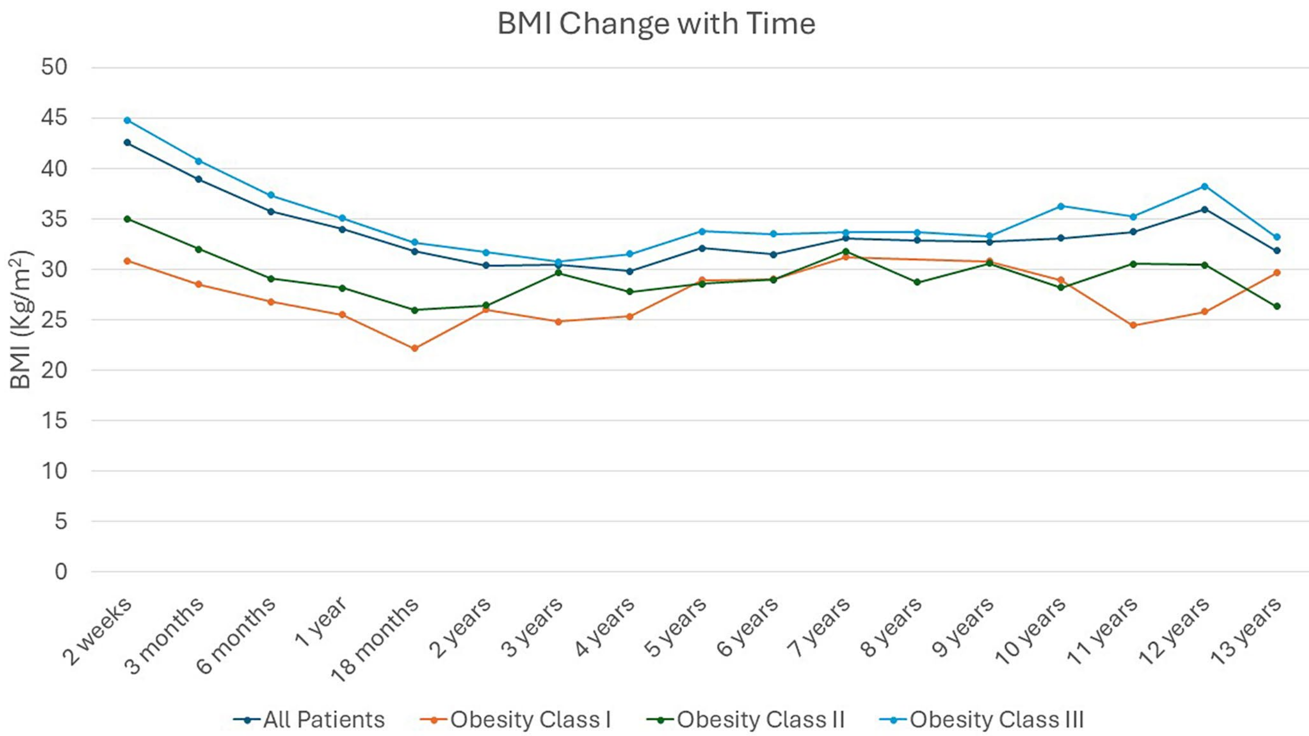

Fig. 3 BMI Change with time post-operatively; divided between the three obesity classes

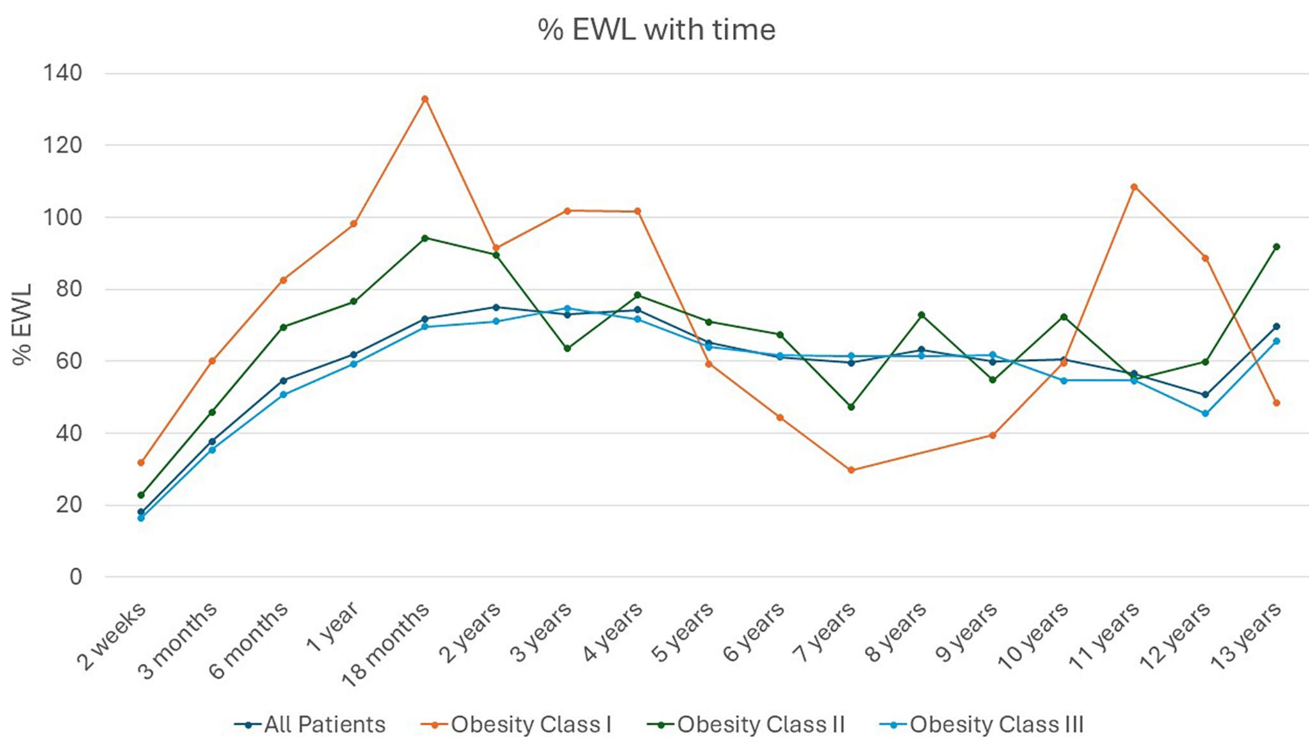

Fig. 4 Percent EWL with time post-operatively; divided between the three obesity classes

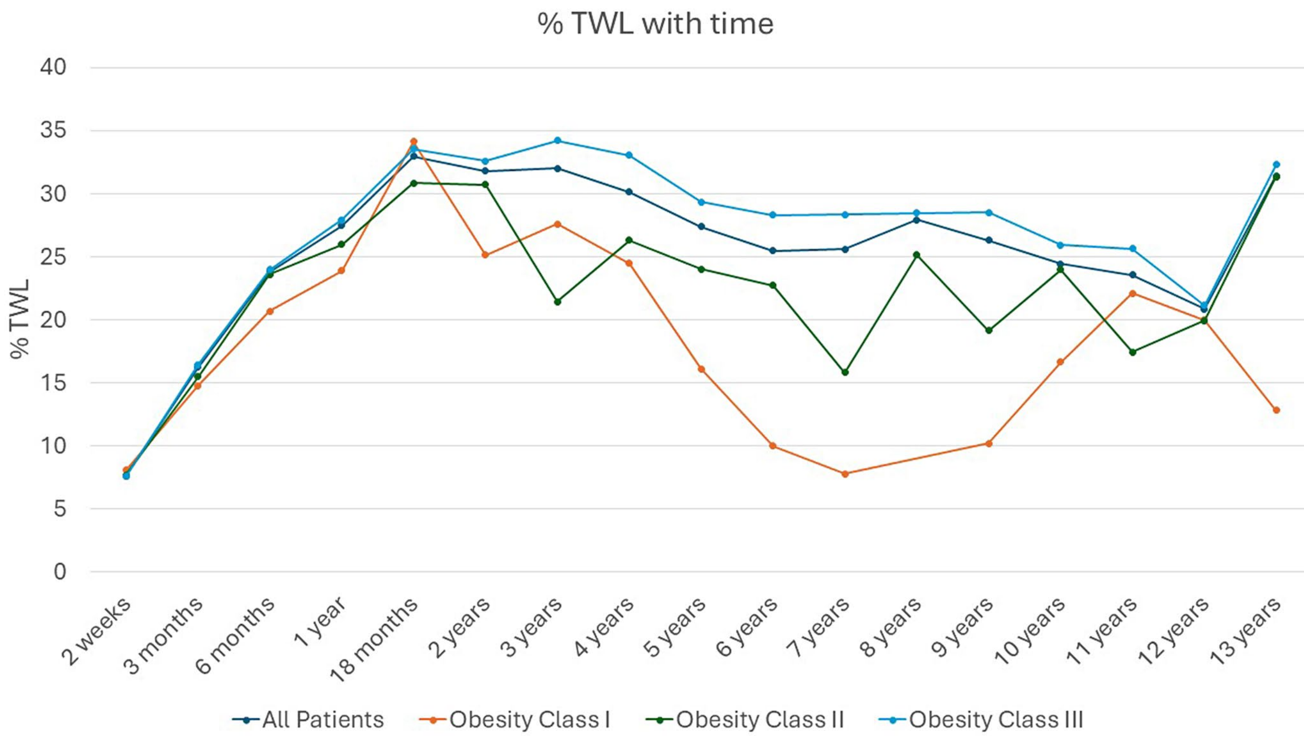

Fig. 5 Percent TWL with time post-operatively; divided between the three obesity classes

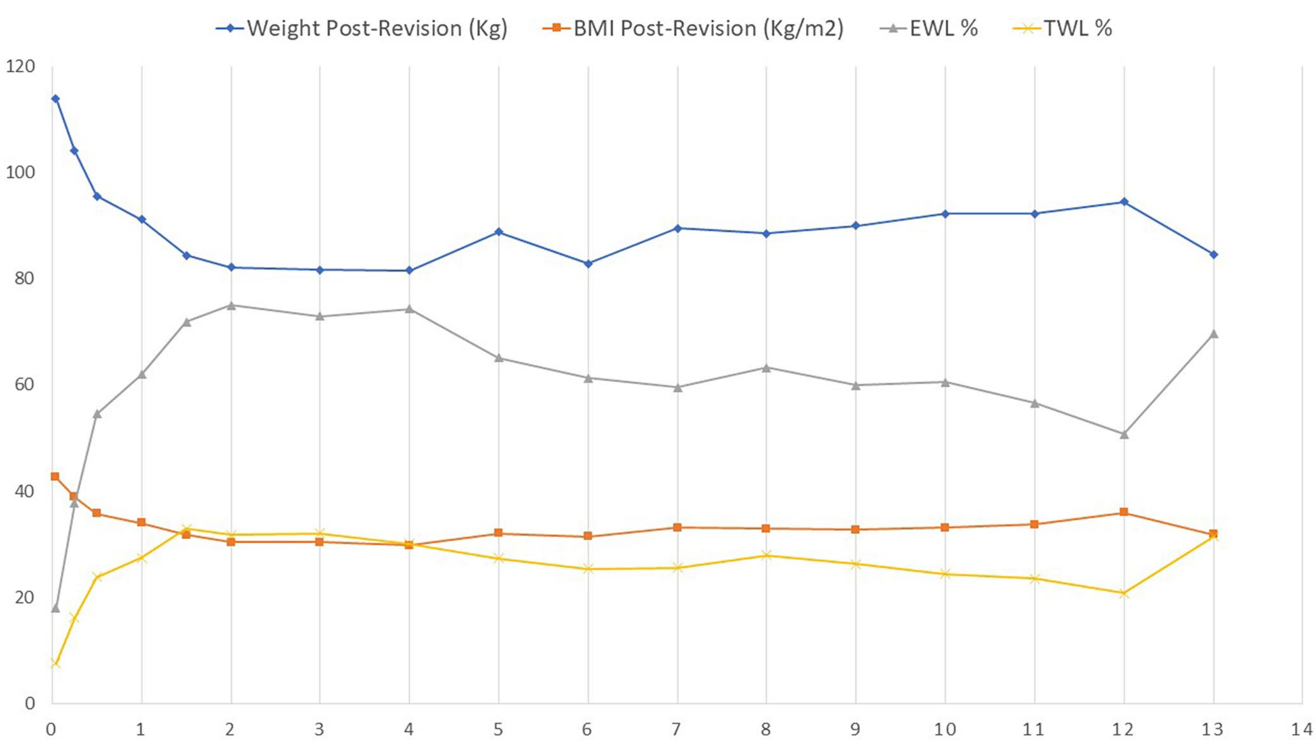

Fig. 6 Weight loss, Change in BMI, % Excess Weight loss and % Total Weight loss over 13 years

Table 2 Morbidity and co-morbidity resolution

Comorbidity	Pre-op (% of total patient population)	Resolved (% from pre-op)	*p*-value
OSA	127 (4.7%)	93 (73.2%)	**0.000**
Obesity Class I	2 (2.2%)	2 (100%)	
Obesity Class II	26 (4.5%)	21 (80.8%)	
Obesity Class III	91 (4.0%)	63 (69.2%)	
HTN	298 (10.0%)	80 (26.8%)	**0.000**
Obesity Class I	9 (9.7%)	3 (33.3%)	
Obesity Class II	58 (10.1%)	14 (24.1%)	
Obesity Class III	220 (9.7%)	59 (26.8%)	
DM	309 (10.4%)	119 (38.5%)	**0.000**
Type 1	31 (1.0%)	4 (12.9%)	
Obesity Class I	15 (16.1%)	7 (46.7%)	
Obesity Class II	66 (11.5%)	28 (42.4%)	
Obesity Class III	221 (9.8%)	83 (37.6%)	

Comorbidity outcomes and complications

Patients suffering from hypertension, obstructive sleep apnea and diabetes mellitus (DM) demonstrated significant reductions of these comorbidities from baseline ($p<0.001$ for all parameters) (Table 2). Of the patients that were diagnosed with type 1 DM pre-operatively, 4 patients experienced remission post-LSG (12.9%), defined as a decrease in insulin requirements.

Complications encountered post-LSG included bleed in 13 patients (0.4%), and leak in 16 patients (0.5%). Gastroesophageal reflux disease (GERD) was encountered in 237 (7.9%) of patients post-LSG, with the majority classified as Grade 1 GERD (235; 7.7%) (Table 3).

Results from patients that underwent revisional procedures

Revisional bariatric procedures were undertaken by 34 patients post-LSG (1.1%) after an average of 5.3 years, with the majority undergoing a revisional Roux-en-Y gastric bypass ($n=20$; 0.7%). Of the patients that underwent revisional procedures, 85.3% were female ($n=29$); with an average age of 36.88 (±10.4) prior to the primary procedure. 6% of the patients belonged to obesity class I, 20.6% to obesity class II and 73.5% to obesity class III. Pre-op weight was 116.6 kg (±15.8) corresponding to a pre-op BMI of 44.4 (±6.08).

The reasons behind the need for revisional surgery were weight regain ($n=22$; 64.7%), development of GERD ($n=8$; 23.5%), insufficient weight loss ($n=2$; 5.9%) and the development of hypoglycemic episodes ($n=2$; 5.9%).

The revision from LSG to RYGB in patients experiencing hypoglycemic episodes is warranted due to the physiological mechanisms underlying postprandial hyperinsulinemic hypoglycemia after LSG. Rapid gastric emptying and hormonal dysregulation, particularly exaggerated GLP-1 and insulin responses, often lead to severe, recurrent hypoglycemia that impairs quality of life and may cause dangerous complications [23, 24]. RYGB addresses these issues by slowing nutrient absorption, reducing rapid glucose spikes, and modulating gut hormones to prevent excessive insulin release [25, 26]. Studies have shown that revision to RYGB significantly improves or resolves hypoglycemia in most patients, making it a clinically justified option when conservative measures (e.g., dietary changes, medications) fail [27, 28]. Although revision surgery carries higher risks, the benefits of resolving hypoglycemia and improving metabolic control often outweigh these risks in carefully selected patients [29].

One patient (2.9%) experienced a bleed post primary LSG, 3 patients (8.8%) experienced a leak, and 10 patients (29.4%) experienced GERD.

Discussion

When the use of sleeve gastrectomy's began to rise in 2014, overtaking all other bariatric surgeries being performed at the time, no long-term data had existed on it's weight loss outcomes, making quantification of success difficult to predict when recommending this procedure. Our study aimed to report the long-term weight loss and comorbidity outcomes of patients who underwent laparoscopic sleeve gastrectomy as a primary bariatric procedure. The main findings of our

Table 3 Occurrence of post-op complications

	Bleed	Leak	GERD			Revisional Procedure Undertaken				Reason for Revision	
			Grade 1	Grade 2	Grade 3	Resleeve	Bypass	OAGB	Time until Revision (years)	Insufficient Weight Loss	Weight Regain
Overall	13 (0.4%)	16 (0.5%)	235 (7.7%)	1 (0.1%)	1 (0.1%)	9 (0.3%)	20 (0.7%)	5 (0.2%)	5.27 (2.64)	31 (1.04%)	40 (1.3%)
Obesity Class I	1 (1.1%)	-	8 (8.6%)	-	-	-	2 (10%)	-	7.45 (4.04)	-	2 (2.1%)
Obesity Class II	3 (0.5%)	2 (0.3%)	60 (10.5%)	-	-	2 (22.2%)	5 (25%)	-	7.18 (4.01)	2 (6.5%)	8 (1.4%)
Obesity Class III	9 (0.4%)	14 (0.6%)	158 (6.9%)	1 (0.1%)	1 (0.1%)	7 (77.8%)	13 (65%)	5 (100%)	7.47 (5.42)	29 (93.5%)	29 (1.3%)

study were to provide an insight on the successful long-term weight loss achieved after LSG, as well as the control of comorbidities associated with untreated obesity.

Primary LSG resulted in a sustained excess weight loss (EWL) of over 50% throughout the 13 year follow-up period, which is consistent with other studies examining long-term outcomes after LSG [30–32]. However, until recently, finding studies reporting on >7 year outcomes were rare, with the majority being published between the years of 2018–2021 [32–40]. A meta-analysis conducted by Clapp et al. [11] in 2018 was able to demonstrate successful weight loss achieved by patients at 7 + years post LSG, with 72.2% achieving a %EWL of >50%, while a systematic review conducted by Juodeikis et al. [41] was able to report a mean %EWL of 54.8% at 8 years post operatively. This has been emulated by our current study, with EWL standing in the range of 50.76–69.60 at 7 + years post-LSG.

Weight regain was defined as progressive weight regain occurring after an initial successful weight loss (EWL > 50%), while insufficient weight loss was defined as an excess weight loss percentage of < 50% at 18 months post-LSG [22], however, it is important to note that there is yet to be a standardized definition for these factors [42–45], making reporting outcome comparison complicated. Nonetheless, by the definition we use at our institute, the rates of weight regain and insufficient weight loss was 1.3% and 1.04%, respectively. These numbers were significantly lower than those encountered by previous studies such as that of Clapp et al., with a pooled weighted mean proportion of weight regain demonstrated to be 27.8% (range = 14–37%) [11]. However, it should be taken into consideration that our follow up percentage declined with time, with results obtained from 50% of patients at 2 weeks post-op, 31% of patients at 1 year post-op, and from 4% of patients at 9 years post-LSG, which could have affected follow-up results collected. A study conducted by Capoccia et al. [34] defined weight regain of ≥15 - <30% of maximum weight lost as mild, while a weight regain of >30% was defined as severe. According to this definition, 61 of our patients (2%) experienced mild weight regain and 79 patients (2.6%) experienced severe weight regain post operatively. When using the definition created by Sakran et al. [46], patients that regained < 25% of maximum weight lost were classified as having experienced mild weight regain, while those that regained ≥ 25% were classified as having experienced significant weight regain. According to this definition, 650 of our patients (22%) experienced mild weight regain, while 98 patients (3.3%) experienced significant weight regain. Further, our current study's cohort had a mean percentage weight regain of maximum weight loss of 32.89%, slightly lower than that reported by Sakran et al. (33.4%), while being slightly higher than that reported by Capoccia et al. (31.5%) [34].

Although the success of laparoscopic sleeve gastrectomy is no longer disputed, complications and failures following this procedures still exist, with weight regain and the recurrence of obesity being one of the major worries for patients and surgeons alike. This is where revisional/secondary bariatric procedures come into play. Revisional bariatric surgery post primary LSG have increased as of recent years, making it a focal research topic [47, 48]. However, the results of our long-term analysis was able to demonstrate a need for a revisional procedure in only 1.1% of our cohort, with the majority needing to be converted to a Roux-en-Y gastric bypass. This is quite small a number when compared to previous studies looking at long-term outcomes. For example, the study conducted by Felsenreich et al. [35] followed their patients for greater than 15 years, demonstrating a %EWL of 61% at the end of the study period, however, this was encountered with a high revision rate of 49.1%. Arman et al. reported a reoperation rate of 31.7% [49] and Kowalewski et al. demonstrated a revision rate of 16% after an 8 year follow-up period [50].

When it came to looking at resolution of comorbidities associated with obesity, we were able to demonstrate positive results, with a 73.2% resolution rate of patients with obstructive sleep apnea, a 26.8% resolution rate of hypertension, and a 38.5% resolution rate of type 2 diabetes mellitus. These numbers are lower than those seen by the study conducted by Kraljevic et al., with 60.5% resolution rates of hypertension and 61% resolution rates of DM [51]; as well as those encountered by Sakran et al. [46], with 51.7% resolution of hypertension, and a 72.2% resolution rate of DM encountered. On the other hand, complications encountered following the sleeve procedure were small in number with bleed encountered in 0.4% of patients post-op and a leak diagnosed in 0.5% of the patient population. This is comparable to other studies with post-operative leak rate for LSG varying between 1 and 3% for a primary procedure [52, 53], while incidence of bleeding following LSG's has been reported to range between 1.16 and 4.94% [41].

Gastroesophageal reflux disease has recently become a major concern following the performance of sleeve gastrectomy due to the association that has linked the two together. There have been multiple mechanisms proposed to explain this phenomena, and those include the large compliant stomach being transformed into a long and narrow tube. This implies a lack of gastric compliance, with an increased intraluminal pressure that correlates inversely with the diameter of the gastric tube and is increased when the pylorus is closed. Other factors are related to dismantling of the anatomical anti-reflux mechanisms, including disruption to the Hiss angle and resection of the sling fibers in the distal part of the lower sphincter, which results in low esophageal-sphincter pressure. The final shape of the sleeve also plays a role as it may favor GERD and regurgitation when it is funnel-shaped. The role of the gastric antrum has not been fully clarified but it is thought that extensive resection of the antrum may impair gastric emptying and favor GERD [54]. However, previous studies have been inconsistent with the effect that sleeves have on GERD. A national analysis conducted by DuPree et al. was able to show that 84.1% of patients that had pre-existing GERD continued to have GERD symptoms post LSG, while 8.6% developed GERD postoperatively [55]. The mechanisms in which GERD may improve after undergoing LSG include the decrease in intra-abdominal pressure due to weight loss, reduced acid production related to resection of the acid-producing gastric fundus, accelerated gastric emptying, and reduced gastric volume [14, 56]. Our study was able to demonstrate low de novo GERD rates, with only 7.9% of patients developing GERD, 99% of which classified as Grade 1. This is significantly lower than the number demonstrated by Kowalewski et al. (44% de novo GERD), Kraljevic et al. (32.4%) and Hauters et al. (43%) [38, 51], but closer to the percentage seen in Juodeikis et al.'s study (10%) [41], as well as Garg et al. [57] and Melissas et al. [58].

Study limitations

Despite the valuable insights provided by this study on long-term outcomes following laparoscopic sleeve gastrectomy (LSG), several limitations must be acknowledged.

One major limitation is the reliance on self-reported data collected via phone surveys for long-term follow-up. While we made efforts to cross-reference patient-reported outcomes with hospital records whenever possible, there is an inherent risk of recall bias and social desirability bias. Patients may have unintentionally misreported their weight, comorbidities, or complications due to memory limitations or personal perceptions of success. Furthermore, self-reported outcomes lack the objectivity of direct clinical assessments, such as in-person weight measurements, laboratory values, and imaging studies, which could provide a more accurate representation of metabolic outcomes and comorbidity resolution.

Another key limitation is the high attrition rate over time, with a substantial proportion of patients lost to follow-up beyond 10 years. At 2 weeks postoperatively, follow-up retention was 50%, which declined to 31% at 1 year and further decreased to approximately 4% by 9 years. By 13 years postoperatively, only 28 patients (less than 1% of the original cohort) remained available for analysis. This attrition introduces a potential selection bias, as patients who maintained long-term follow-up may not be representative of the entire cohort. Those who experienced weight regain, complications, or required additional medical intervention may have been more likely to seek alternative care or disengage from follow-up altogether. Conversely, patients who maintained successful weight loss and positive health outcomes may have been more motivated to remain in the study. As a result, the long-term findings reported here should be interpreted with caution, as they may overestimate the durability of LSG outcomes.

To mitigate these limitations in future studies, strategies such as standardized electronic health record integration, remote monitoring tools, and routine follow-up reminders could enhance long-term data collection. Additionally, a prospective study design with predefined follow-up intervals and objective metabolic assessments would provide a more comprehensive evaluation of LSG's long-term effectiveness.

Conclusion

Our results indicate that LSG is an effective bariatric procedure for weight loss, with a sustained %EWL up to 13 years post-operatively. Further, insufficient weight loss and weight regain were minimal within our cohort. Resolution of comorbidities was also seen to be satisfactory, and low complication rates were encountered within our cohort. Starting obesity class only significantly affected weight loss in the first 18 months post-operatively. However, loss to follow-up was a major limitation, and therefore, increased patient engagement in follow-up routines is crucial for collecting long-term data following bariatric procedures.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate Ethical approval to conduct the study was obtained from the Ministry of Health and Kuwait Institute for Medical Specialization Ethical Approval Board. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent for study participation was obtained from all subjects (if subjects are under 16, from a parent and/or legal guardian).

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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References

1. Stevens GA, Singh GM, Lu Y, Danaei G, Lin JK, Finucane MM et al (2012) National, regional, and global trends in adult overweight and obesity prevalences. Popul Health Metr 10(1):22 Epub 20121120. https://doi.org/10.1186/1478-7954-10-22
2. Bult MJ, van Dalen T, Muller AF (2008) Surgical treatment of obesity. Eur J Endocrinol 158(2):135–145. https://doi.org/10.1530/eje-07-0145PubMed PMID: 18230819
3. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J et al (2016) IFSO Worldwide Survey.: Primary, Endoluminal, and Revisional Procedures. Obes Surg. 2018;28(12):3783-94. https://doi.org/10.1007/s11695-018-3450-2. PubMed PMID: 30121858
4. Schauer PR, Bhatt DL, Kirwan JP, Wolski K, Aminian A, Brethauer SA et al (2017) Bariatric surgery versus intensive medical therapy for Diabetes — 5-Year outcomes. N Engl J Med 376(7):641–651 doi: 10.1056/NEJMoa1600869. PubMed PMID: 28199805
5. Gagner MIW, Pomp A (2005) Laparoscopic sleeve gastrectomy with second stage biliopancreatic diversion and duodenal switch in the superobese. In: Inabnet WDE, Ikramuddin S (eds) Laparoscopic bariatric surgery. Lippincott Williams & Wilkins, Philadelphia, pp 143–150
6. Felberbauer FX, Langer F, Shakeri-Manesch S, Schmaldienst E, Kees M, Kriwanek S et al (2008) Laparoscopic sleeve gastrectomy as an isolated bariatric procedure: Intermediate-Term results from a large series in three Austrian centers. Obes Surg 18(7):814–818. https://doi.org/10.1007/s11695-008-9483-1
7. Angrisani L, Santonicola A, Iovino P, Ramos A, Shikora S, Kow L (2021) Bariatric surgery survey 2018: similarities and disparities among the 5 IFSO chapters. Obes Surg 31:1937–1948
8. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J et al (2018) IFSO worldwide survey 2016: primary, endoluminal, and revisional procedures. Obes Surg 28:3783–3794
9. English WJ, DeMaria EJ, Brethauer SA, Mattar SG, Rosenthal RJ, Morton JM (2018) American society for metabolic and bariatric surgery Estimation of metabolic and bariatric procedures performed in the united States in 2016. Surg Obes Relat Dis 14(3):259–263
10. Lo Menzo E, Szomstein S, Rosenthal R (2015) Changing trends in bariatric surgery. Scand J Surg 104(1):18–23
11. Clapp B, Wynn M, Martyn C, Foster C, O'Dell M, Tyroch A (2018) Long term (7 or more years) outcomes of the sleeve gastrectomy: a meta-analysis. Surg Obes Relat Dis 14(6):741–747
12. Felsenreich DM, Langer FB, Kefurt R, Panhofer P, Schermann M, Beckerhinn P et al (2016) Weight loss, weight regain, and conversions to Roux-en-Y gastric bypass: 10-year results of laparoscopic sleeve gastrectomy. Surg Obes Relat Dis 12(9):1655–1662. https://doi.org/10.1016/j.soard.2016.02.021
13. Felsenreich DM, Ladinig LM, Beckerhinn P, Sperker C, Schwameis K, Krebs M et al (2018) Update: 10 years of sleeve Gastrectomy—the first 103 patients. Obes Surg 28(11):3586–3594. https://doi.org/10.1007/s11695-018-3399-1
14. Stenard F, Iannelli A (2015) Laparoscopic sleeve gastrectomy and gastroesophageal reflux. World J Gastroenterol 21(36):10348–10357. https://doi.org/10.3748/wjg.v21.i36.10348PubMed PMID: 26420961; PubMed Central PMCID: PMCPMC4579881
15. Felsenreich DM, Kefurt R, Schermann M, Beckerhinn P, Kristo I, Krebs M et al (2017) Reflux, sleeve dilation, and Barrett's esophagus after laparoscopic sleeve gastrectomy: Long-Term Follow-Up. Obes Surg 27(12):3092–3101. https://doi.org/10.1007/s11695-017-2748-9PubMed PMID: 28593484
16. Panel CDC (1991) Gastrointestinal surgery for severe obesity. Ann Intern Med 115(12):956–961
17. Shah SA, Khan NA, Qureshi FG (2024) Metabolic and bariatric surgery in children: current practices and outcomes. Curr Obes Rep 13(1):77–86
18. Telem DA, Gould J, Pesta C, Powers K, Majid S, Greenberg JA et al (2017) American society for metabolic and bariatric surgery: care pathway for laparoscopic sleeve gastrectomy. Surg Obes Relat Dis 13(5):742–749
19. Sherf Dagan S, Goldenshluger A, Globus I, Schweiger C, Kessler Y, Kowen Sandbank G et al (2017) Nutritional recommendations for adult bariatric surgery patients: clinical practice. Adv Nutr 8(2):382–394
20. Hanson MN, Dennis S, Altieri MS, Andalib A (2022) Reflux and bariatric surgery: a review of pre-operative assessment and post-operative approach. Mini-invasive Surg 6:9. https://doi.org/10.20517/2574-1225.2021.144
21. Richard B, Berry MRB, MEd RST, Charlene RPSGT, Gamaldo E, Susan MD, Harding M, Robin MD, Lloyd M, Carole MD, Marcus L (2015) MBBCh; and Bradley V. Vaughn, MD the AASM manual for the scoring of sleep and associated events rules, terminology and technical specifications. In: Med AAoS, editor. 13(5):665–6.
22. Rogula TG (2015) Weight regain after bariatric surgery—how should it be defined? Population. 25(10):1901–1908
23. Goldfine AB, Mun EC, Devine E, Bernier R, Baz-Hecht M, Jones DB et al (2007) Patients with neuroglycopenia after gastric bypass surgery have exaggerated incretin and insulin secretory responses to a mixed meal. J Clin Endocrinol Metab 92(12):4678–4685 Epub 20070925. https://doi.org/10.1210/jc.2007-0918
24. Service GJ, Thompson GB, Service FJ, Andrews JC, Collazo-Clavell ML, Lloyd RV (2005) Hyperinsulinemic hypoglycemia with nesidioblastosis after gastric-bypass surgery. N Engl J Med 353(3):249–254 doi: 10.1056/NEJMoa043690. PubMed PMID: 16034010
25. Peterli R, Wölnerhanssen BK, Peters T, Vetter D, Kröll D, Borbély Y et al (2018) 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 319(3):255–265 PubMed PMID: 29340679; PubMed Central PMCID: PMCPMC5833546
26. Capristo E, Panunzi S, De Gaetano A, Spuntarelli V, Bellantone R, Giustacchini P et al (2018) Incidence of hypoglycemia after

gastric bypass vs sleeve gastrectomy: A randomized trial. J Clin Endocrinol Metab 103(6):2136–2146. https://doi.org/10.1210/jc.2017-01695PubMed PMID: 29590421
27. Moreira RO, Moreira RB, Machado NA, Gonçalves TB, Coutinho WF (2008) Post-prandial hypoglycemia after bariatric surgery: Pharmacological treatment with verapamil and acarbose. Obes Surg 18(12):1618–1621 Epub 20080620. https://doi.org/10.1007/s11695-008-9569-9
28. Z'Graggen K, Guweidhi A, Steffen R, Potoczna N, Biral R, Walther F et al (2008) Severe recurrent hypoglycemia after gastric bypass surgery. Obes Surg 18(8):981–988 Epub 20080426. https://doi.org/10.1007/s11695-008-9480-4
29. Shoar S, Mahmoudzadeh H, Naderan M, Bagheri-Hariri S, Wong C, Parizi AS et al (2017) Long-Term Outcome of Bariatric Surgery in Morbidly Obese Adolescents: a Systematic Review and Meta-Analysis of 950 Patients with a Minimum of 3 years Follow-Up. Obes Surg.;27(12):3110-7. https://doi.org/10.1007/s11695-017-2738-y. PubMed PMID: 28573535
30. Felsenreich DM, Langer FB, Prager G (2019) Weight loss and resolution of comorbidities after sleeve gastrectomy: A review of Long-Term results. Scand J Surg 108(1):3–9 Epub 20180906. doi: 10.1177/1457496918798192. PubMed PMID: 30187823
31. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G (2016) Long-term (11+years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis 12(10):1778–1786 Epub 20160119. https://doi.org/10.1016/j.soard.2016.01.013
32. Kraljević M, Cordasco V, Schneider R, Peters T, Slawik M, Wölnerhanssen B et al (2021) Long-term effects of laparoscopic sleeve gastrectomy: what are the results beyond 10 years? Obes Surg 31:3427–3433
33. Ben-Porat T, Mashin L, Kaluti D, Goldenshluger A, Shufanieh J, Khalaileh A et al (2021) Weight loss outcomes and lifestyle patterns following sleeve gastrectomy: an 8-year retrospective study of 212 patients. Obes Surg 31(11):4836–4845
34. Capoccia D, Coccia F, Guarisco G, Testa M, Rendina R, Abbatini F et al (2018) Long-term metabolic effects of laparoscopic sleeve gastrectomy. Obes Surg 28:2289–2296
35. Felsenreich DM, Artemiou E, Steinlechner K, Vock N, Jedamzik J, Eichelter J et al (2021) Fifteen years after sleeve gastrectomy: weight loss, remission of associated medical problems, quality of life, and conversions to Roux-en-Y gastric bypass—long-term follow-up in a multicenter study. Obes Surg 31(8):3453–3461
36. Fiorani C, Coles SR, Kulendran M, McGlone ER, Reddy M, Khan OA (2021) Long-term quality of life outcomes after laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass—a comparative study. Obes Surg 31:1376–1380
37. Grönroos S, Helmiö M, Juuti A, Tiusanen R, Hurme S, Löyttyniemi E et al (2021) Effect of laparoscopic sleeve gastrectomy vs Roux-en-Y gastric bypass on weight loss and quality of life at 7 years in patients with morbid obesity: the SLEEVEPASS randomized clinical trial. JAMA Surg 156(2):137–146
38. Hauters P, Dubart J-W, Desmet J, Degolla R, Roumain M, Malvaux P (2021) Ten-year outcomes after primary vertical sleeve gastrectomy for morbid obesity: a monocentric cohort study. Surg Endosc 35:6466–6471
39. Ismail M, Nagaraj D, Rajagopal M, Ansari H, Nair M, Hegde A et al (2019) Seven-year outcomes of laproscopic sleeve gastectomy in Indian patients with different classes of obesity. Obes Surg 29:191–196
40. Major P, Stefura T, Dziurowicz B, Radwan J, Wysocki M, Małczak P et al (2020) Quality of life 10 years after bariatric surgery. Obes Surg 30:3675–3684
41. Juodeikis Ž, Brimas G (2017) Long-term results after sleeve gastrectomy: a systematic review. Surg Obes Relat Dis 13(4):693–699
42. Baig SJ, Priya P, Mahawar KK, Shah S, Group IBSOR (2019) Weight regain after bariatric surgery—a multicentre study of 9617 patients from Indian bariatric surgery outcome reporting group. Obes Surg 29:1583–1592
43. Brethauer SA, Kim J, El Chaar M, Papasavas P, Eisenberg D, Rogers A et al (2015) Standardized outcomes reporting in metabolic and bariatric surgery. Obes Surg 25:587–606
44. King WC, Hinerman AS, Belle SH, Wahed AS, Courcoulas AP (2018) Comparison of the performance of common measures of weight regain after bariatric surgery for association with clinical outcomes. JAMA 320(15):1560–1569
45. Voorwinde V, Steenhuis IH, Janssen IM, Monpellier VM, van Stralen MM (2020) Definitions of long-term weight regain and their associations with clinical outcomes. Obes Surg 30:527–536
46. Sakran N, Soifer K, Hod K, Sherf-Dagan S, Soued S, Kessler Y et al (2023) Long-term reported outcomes following primary laparoscopic sleeve gastrectomy. Obes Surg 33(1):117–128. https://doi.org/10.1007/s11695-022-06365-6
47. Silecchia G, De Angelis F, Rizzello M, Albanese A, Longo F, Foletto M (2015) Residual fundus or Neofundus after laparoscopic sleeve gastrectomy: is fundectomy safe and effective as revision surgery? Surg Endosc 29(10):2899–2903 Epub 20141206. https://doi.org/10.1007/s00464-014-4017-5
48. Homan J, Betzel B, Aarts EO, van Laarhoven KJ, Janssen IM, Berends FJ (2015) Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch. Surg Obes Relat Dis 11(4):771–777 Epub 20141014. https://doi.org/10.1016/j.soard.2014.09.029
49. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G (2016) Long-term (11+years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis 12(10):1778–1786
50. Kowalewski PK, Olszewski R, Walędziak MS, Janik MR, Kwiatkowski A, Gałązka-Świderek N et al (2018) Long-Term outcomes of laparoscopic sleeve Gastrectomy—a Single-Center, retrospective study. Obes Surg 28(1):130–134. https://doi.org/10.1007/s11695-017-2795-2
51. Kraljevic M, Cordasco V, Schneider R, Peters T, Slawik M, Wolnerhanssen B et al (2021) Long-Term effects of laparoscopic sleeve gastrectomy: what are the results beyond 10 Years?(Apr, 10.1007/s11695-021-05437-3, 2021). Obes Surg 31(8):3434–3435
52. Committee ACI (2012) Updated position statement on sleeve gastrectomy as a bariatric procedure. surgery for obesity and related diseases: official journal of the American society for bariatric surgery. 8(3):e21–e6
53. Abou Rached A, Basile M, El Masri H (2014) Gastric leaks post sleeve gastrectomy: review of its prevention and management. World J Gastroenterology: WJG 20(38):13904
54. Gálvez-Valdovinos R, Cruz-Vigo JL, Marín-Santillán E, Funes-Rodríguez JF, López-Ambriz G, Domínguez-Carrillo LG (2015) Cardiopexy with ligamentum Teres in patients with hiatal hernia and previous sleeve gastrectomy: an alternative treatment for gastroesophageal reflux disease. Obes Surg 25(8):1539–1543. https://doi.org/10.1007/s11695-015-1740-5PubMed PMID: 25990381
55. DuPree CE, Blair K, Steele SR, Martin MJ (2014) Laparoscopic sleeve gastrectomy in patients with preexisting gastroesophageal reflux disease: a National analysis. JAMA Surg 149(4):328–334. https://doi.org/10.1001/jamasurg.2013.4323PubMed PMID: 24500799
56. Sharma A, Aggarwal S, Ahuja V, Bal C (2014) Evaluation of gastroesophageal reflux before and after sleeve gastrectomy using symptom scoring, scintigraphy, and endoscopy. Surg Obes Relat Dis 10(4):600–605 Epub 20140128. https://doi.org/10.1016/j.soard.2014.01.017

57. Garg H, Aggarwal S, Misra MC, Priyadarshini P, Swami A, Kashyap L et al (2017) Mid to long term outcomes of laparoscopic sleeve gastrectomy in Indian population: 3–7 year results–A retrospective cohort study. Int J Surg 48:201–209
58. Melissas J, Braghetto I, Molina JC, Silecchia G, Iossa A, Iannelli A et al (2015) Gastroesophageal reflux disease and sleeve gastrectomy. Obes Surg 25:2430–2435

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