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ORIGINAL CONTRIBUTIONS

Trending Weight Loss Patterns in Obese and Super Obese Adolescents: Does Laparoscopic Sleeve Gastrectomy Provide Equivalent Outcomes in both Groups?

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Abstract

Background Many factors, including preoperative weight, may determine final weight loss after bariatric surgery; however, their proportional contribution is unclear. To such end, we evaluated weight loss patterns among obese adolescents.

Methods We evaluated 57 adolescents who underwent laparoscopic sleeve gastrectomy from 2011 to 2017. Data collection included demographics, anthropometrics, and comorbidities and was done over a 3-year follow-up period. Statistical analysis was performed using Student's *t* test and repeated measures ANOVA.

Results In the morbidly obese (MO) group, 82% were female, while 52% were male in the super obese (SMO) group ($P < 0.0059$). While 13/34 patients in the obese group achieved > 60% percent excess body weight loss (%EBWL), only 3/23 super obese patients achieved > 60% EBWL ($P = 0.0695$). %EBWL at 1-year follow-up significantly differed between the obese and super obese groups, 61.7 ± 14.6% and 47.7 ± 14.9% respectively ($P = 0.035$). The average BMI in the obese group was 29.8 at 1 year and 41.3 in the super obese group. There was a significant difference in the rate of excess weight loss (%EBWL/month) between the two groups ($P < 0.01$). There was good comorbidity resolution (about 70%) in both groups after surgery.

Conclusion Comorbidity resolution after sleeve gastrectomy is excellent in the adolescent population irrespective of initial BMI. Consideration should be given to earlier bariatric intervention in SMO adolescents to facilitate return to near normal BMI. Focus on education of referral sources, such as community pediatricians and family practitioners to facilitate early bariatric evaluation should be considered. Weight loss in postsurgical SMO patients should be carefully monitored and adjunctive interventions should be considered.

Keywords Adolescent obesity · Sleeve gastrectomy · Gastric bypass · Weight loss · Morbid obesity · Laparoscopic sleeve gastrectomy · Adolescence · Bariatric surgery

Introduction

The public health burden of adolescent obesity has been increasing for the past three decades [1]. The 2015–2016 National Health and Nutrition Examination Survey reported a 20.6% prevalence of obesity in the adolescent population (12–19) [1]. Obese adolescents face multisystem comorbidities warranting aggressive therapies. Diet alone, although the cornerstone of obesity therapy, results only in transient weight loss. Even when diet is combined with behavioral and pharmacotherapy, there is minimal longitudinal efficiency in terms of weight loss [2]. Bariatric surgery has been shown to be an effective intervention with sustainable long-term weight loss and comorbidity risk reduction [3, 4]. The final weight loss differs among patients, and it is unclear if the difference is secondary to dietary compliance, preoperative weight, metabolic differences, exercise habits, hormonal variations, or other unknown causes. Currently, sleeve gastrectomy is being offered to over 70% of adolescents undergoing weight loss surgery in the USA [5]. Recent studies suggested that

Level of Evidence: Level III

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preoperative BMI may affect nadir BMI following bariatric surgery [6].

It is still unclear if patients with high-preoperative BMI (BMI > 50 kg/m^2) would experience satisfactory weight loss following a solely restrictive procedure such as laparoscopic sleeve gastrectomy. Understanding the trajectory of weight loss and whether it is affected by preoperative BMI might elucidate better risk and outcome assessments in this population. To such end, we evaluated the pattern of weight loss and the relationship between preoperative BMI and the rate of weight loss in the adolescent population.

Materials & Methods

This is a single-center retrospective study of adolescent patients (16–21 years) who underwent sleeve gastrectomy from 2011 to 2017 at the Montefiore Medical Center, a bariatric center of excellence located in Bronx, NY. While the WHO age definition for adolescence is 12–19 years, recent research has expanded the timeframe to include young adulthood up to the age of 24 [7, 8]. In our practice and in this study, age 21 was used as a cut-off for adolescent obesity surgery.

All of the patients in the study were preoperatively evaluated at our medical center and were enrolled in an extensive multidisciplinary metabolic surgery program. All patients had a BMI that was greater than 120% of the 99th percentile for age and sex.

All patients underwent laparoscopic sleeve gastrectomy under general anesthesia. All sleeve gastrectomies were performed with calibration by a 40-French bougie and the technique is described elsewhere [9].

Patients were advanced along a standard bariatric dietary pathway that progressed from bariatric clear liquids supplemented by 78 g of liquid protein shakes to pureed foods, and then finally to solid foods over a period of 6 weeks. All patients were encouraged to develop fitness routines to promote weight loss. Chewable multivitamins and proton pump inhibitors were also started in this first phase. Additionally, they were to remain on supplementary vitamins, calcium, and iron for long-term nutritional support.

Outpatient clinic follow-up occurred at the following postoperative time points: 2 weeks, 4 weeks, 1 month, 6 weeks, 3 months, 6 months, 12 months, 24 months, 36 months, and yearly thereafter. Anthropometric measures (height, weight, and BMI) and comorbidity status were evaluated preoperatively and during these visits. During data analysis, patients were contacted via telephone for follow-up of comorbidities.

Patient information was initially extracted from the Montefiore's NSQIP database; then, the electronic medical record was used as a supplement. The time points included in our study were 1 month, 3 months, 6 months, 12 months, and 36 months. We included the closest data point when any of the time points were unavailable. If the 1-month data points were not available, we included data within 2–6 weeks following the surgery. If the 3-month and 6-month data points were not available, data points within 1 month were included. The 12-month and 36-month data points were approximated to the nearest 6 months.

The comorbidities we evaluated for resolution were hypertension (HTN), diabetes, and obstructive sleep apnea (OSA). HTN resolution was defined as medication independence, as per physician recommendation. Diabetes resolution was defined as normalization of HbA1c, in the setting of no current medical regimen. OSA resolution was defined as BiPAP independence.

Weight was recorded in lbs., and BMI in kg/m2. Both measures were evaluated during our 3-year follow-up period. Percent excess body weight was calculated in reference to an ideal body weight, which was calculated based on a BMI of 25. The velocity was evaluated by looking at the percent excess body weight loss (%EBWL) during the following time intervals, the first month, 1–3 months, 3–6 months, 6–12 months, and 12–36 months. The %EBWL occurring during these time periods were divided by the number of months within that period. The resulting measure for velocity of weight-loss is %EBWL per month. We did not use BMI *z*-scores to follow weight loss as recent studies have indicated that *z*-scores are not accurate in tracking changes in weight and may actually decrease with an increase in BMI > 5 units [10].

Once data extraction and values were conjured, the cohort was stratified into two groups, morbidly obese (BMI 35–49) and super obese (BMI ≧ 50) for subsequent analysis. Obesity is defined as BMI ≥ 30 kg/m^2 and is categorized into BMI-based classes: Class 1: BMI 30–34.9 kg/m^2, Class 2: BMI 35.0–39.9 kg/m^2, Class 3: BMI ≥ 40 kg/m^2, Class 4: BMI ≥ 50 kg/m^2, and Class 5: BMI ≥ 60 kg/m^2 [11]. All patients classified as obese are at or upwards of the 99th percentile for weight for their respective age group [12]. BMI of 35 was generally the lower limit for consideration for bariatric surgery in this study. Additionally, in the surgical literature, patients with BMI greater than 50 are referred to as super obese [13]. As such, we thought to compare patients at both ends of the bariatric surgery protocol spectrum (Class 2/3 Vs Class 4/5).

Primary and Secondary Outcomes

Our primary outcomes were %EBWL and BMI at defined time intervals (1 month, 3 months, 6 months, 1 year, 3 years); Rate of %EBWL over different time periods (1st month, months 1–3, months 3–6, months 6–12, years 1–3); and proportion of patients achieving %EBWL of ≥ 60%. Our secondary outcomes included resolution of the following comorbidities: diabetes, hypertension, and OSA.

Statistical Analyses

Statistical analysis for the differences in patient characteristics was done using Student's *t* test. For repeated measures, ANOVA was used to initially compare difference between groups. Hierarchical linear modeling (HLM) was used to evaluate %EBWL and the rate of %EBWL. The %EBWL and the rate of %EBWL, at each time point of follow-up for each patient, remained nested with that patient for purpose of hierarchical analysis and modeling.

Results

Follow-up

The follow-up rates for our study were 100% (57) at 3 months, 71.6% (41) at 6 months, 68.3% (39) at 12 months, and 60% (34) at 36 months. Patients with comorbidities at the time of initial evaluation were contacted individually by telephone to determine resolution or persistence. Nineteen patients were contacted, and 5 were not reachable by the telephone and were included in our intention-to-treat analysis.

Baseline Characteristics (Table 1)

The 57 patients included in the study cohort underwent laparoscopic sleeve gastrectomy between 2011 and 2017 and had a mean preoperative age of 19.2 ± 1.4 (range, 16–21). Eighty-two percent (28) of the adolescents in the MO group were female, compared with 48% (11) in the SMO group ($P < 0.0059$). The two preoperative groups were similar in terms of age and comorbidity status with the exception of sleep apnea, which was more among SMO patients ($P = .01$).

Outcomes

Weight Loss Outcomes and Trajectory (Figs. 1 and 2, Tables 2, 3 and 5)

The mean starting weight for the obese and super obese patients were 260.12 lbs (118.25 kg) and 347.85 lbs (158 kg), respectively (Table 2, Fig. 1a). In terms of BMI, the mean starting preoperative BMI for the obese and super obese patients were 43.10 and 57.58, respectively ($P < .001$) (Table 3, Fig. 1b). Both MO and SMO patients had comparable absolute weight loss measured in pounds at 1-month, 3-month, 6-month, 12-month, and 36-month follow-up (Table 5). Nadir weight loss was reached at 12 months and did not differ between the groups. The MO group reached a nadir of 84.7 lbs (38.5 kg) weight loss as compared with 92.5 lbs (42 kg) in the SMO group (Table 5). The two preoperative groups did not differ in terms of percent BMI change from baseline with obese and super obese patients reaching a plateau of 31% and 28%, respectively. The trajectory of both BMI and weight loss were similar and the initial weight difference between the groups persisted at each of the subsequent time point.

Table 1 Patients characteristics

	Overall	Obese	Super obese	*P* value
n	57	34	23	
Female	39	28	11	0.0059
Starting BMI	48.9 ± 8.8	43.1 ± 3.4 Range: 34.6–49.8 Median: 43.5	57.6 ± 6.9 Range: 50.29–79.53 Median: 55.82	0.0000
Age at surgery	19.2 ± 1.4	19.3 ± 1.4 Range:(16–21) Median: 19	18.9 ± 1.4 Range: (16–21) Median: 19	0.3464
NASH	25 (43.86%)	13	12	0.2981
Asthma	16 (28.07%)	9	7	0.7438
Sleep apnea	11 (19.3%)	3	8	0.0148
Vitamin deficiency	9 (15.79%)	5	4	0.7850
GERD	5 (8.77%)	2	3	0.3480
Thyroid disorders	5 (8.77%)	3	2	0.9866
Diabetes	4 (7.02%)	3	1	0.5163
Musculoskeletal (MSK) Disorders	4 (7.02%)	1	3	0.1430
HTN requiring medications	3 (5.26%)	1	2	0.3398
Smoker	2 (3.51%)	2	0	0.6833
Hyperlipidemia	2 (3.51%)	1	1	0.7771
Pseudo tumor cerebri	1 (1.75%)	0	1	0.2200

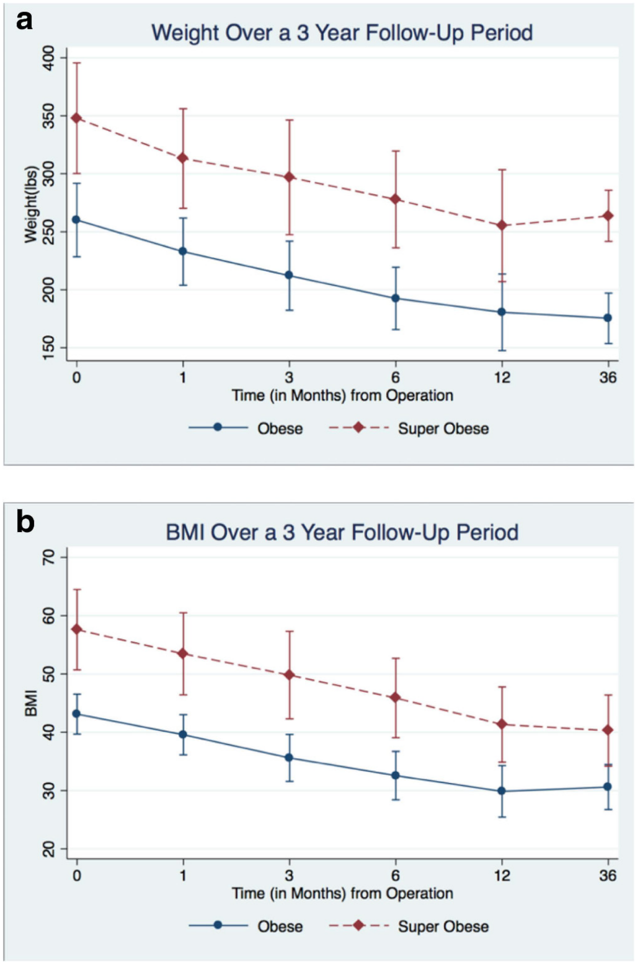

Fig. 1 **a** Trend of weight over a 3-year follow-up period. **b** Trend of BMI over a 3-year follow-up period

Reaching Target Weight Loss

In the study cohort, 13/34 (38%) MO patients achieved ≥ 60 %EBWL compared with only 3/23 SMO patients (P = 0.0695). One year or later following the operation, the proportion of the patients with an %EBWL of ≥ 60% were 10/18 (56%) MO patients, compared with 3/10 (33%) SMO patients (P = 0.194). We also observed no difference between the mean %EBWL at 12 months when comparing males (58.2 %EBWL) and females (56 %EBWL) (P = 0.742).

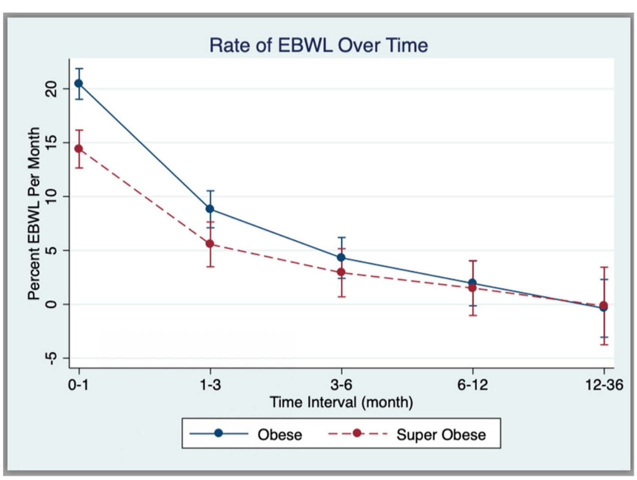

Fig. 2 Hierarchical linear modeling showing significant difference at the first time period but no difference in rate of %EBWL at other time points

Table 2 Weight during postoperative follow-up visits

	Mean weight O (lbs.)	Std.	Mean weight SO (lbs.)	Std.
Starting	260.12	31.65	347.9	47.7
1 month	232.88	28.97	313.1	42.9
3 months	212.14	29.77	296.9	49.4
6 months	192.52	26.83	277.9	41.7
12 months	180.61	33.03	255.3	48.2
36 months	175.44	21.70	263.7	22.0

The Pattern of Velocity of Weight Loss

Reporting weight loss outcomes as %EBWL revealed a difference in the nature of weight loss between the two groups. Compared with their super obese counterparts, MO adolescents lost a higher percentage of their excess body weight at each time point; the difference was significant at 3 months (P = 0.002) and 12 months (P = 0.028), with the 12 months %EBWL being 61.7 ± 14.6% and 47.7 ± 14.9% for MO and SMO adolescents, respectively (Tables 4 and 5). The greatest %EBWL occurred in the early postoperative period with 20.4 ± 5.7% and 14.4 ± 5.9% EBWL at 1-month follow-up in the obese and super obese groups, respectively. This maximum velocity of weight loss coincided with the time of the most severe dietary restrictions in our feeding protocol.

The rate of weight loss as evaluated by %EBWL/month revealed that in both adolescent groups nearly a 1/5 of the %EBWL occurs in the initial month following the operation, with 20.4 ± 5.7%/month and 14.4 ± 5.9%/month for the obese and the super obese, respectively. We found the rate of excess weight loss (%EBWL/month) between the two groups to be different (P < 0.01) at the first month (Fig. 2). In the nine subsequent points, there was no difference in the rate of

Table 3 BMI during postoperative follow-up visits

	Mean BMI obese (kg/m^2)	SD	Mean BMI super obese (kg/m^2)	SD
Starting	43.10	3.43	57.58	6.89
1 month	39.57	3.45	53.45	7.04
3 months	35.59	4.03	49.80	7.51
6 months	32.56	4.15	45.87	6.81
12 months	29.86	4.41	41.32	6.44
36 months	30.60	3.85	40.28	6.10

Table 4 Percent EBWL during postoperative follow-up visits

	Obese	SD	Super Obese	SD
1 month	20.45	5.67	14.41	5.76
3 months	38.64	12.54	26.26	9.74
6 months	47.60	16.27	34.21	9.66
12 months	61.68	14.63	47.83	14.81
36 months	53.78	15.26	46.50	17.10

weight loss using the hierarchical linear modeling method between class 2/3 and class 4/5 obesity groups. (Fig. 2).

Resolution of Comorbidities

The incidence of sleep apnea, hypertension, diabetes, and pseudotumor cerebri were 19.30%, 5.26%, 7.02%, and 1.75% respectively (Table 1). Seven of the 11 (64%) patients with sleep apnea experienced resolution and were BIPAP independent. Four patients were preoperatively diagnosed with hypertension requiring at least two medications, 2 of these patients were no longer hypertensive and were independent of medications. There were no significant differences between the two BMI groups in terms of incidence of the following comorbidities: nonalcoholic steatohepatitis (NASH), asthma, gastroesophageal reflux disease (GERD), thyroid disorders, and musculoskeletal (MSK) complications.

Discussion

The goal of bariatric surgery is reversal of accompanying comorbidities. Restoration of BMI to near normal has benefits that extend from decreased risk for coronary artery disease, diabetes, and cancer and adding years to life. In this study, stable weight loss was achieved in the entire patient cohort. Patients with BMI 35–50 experienced good outcomes with %EBWL of 61.7 ± 14.6%. In SMO (BMI ≥ 50), patients had an average %EBWL of 47.7 ± 14.9%.

However, the rates of EBWL were no different among the two groups except for the appointment at the first month. SMO patients will have to lose weight at a more rapid rate as compared with MO patients to attain satisfactory weight loss and this goal is not achieved when BMI > 50. One year following the surgery, the majority of MO achieved a satisfactory mean BMI of 29.84. In contrast, SMO patients had a mean BMI of 40.32 1 year after surgery. This difference showed no association with sex. We also observed stabilization of the weight loss achieved by 12 months through our 3-year follow-up period. While comorbidity resolution was satisfactory after bariatric surgery in both the MO and SMO groups, what was consistent in our data is that class 4/5 obesity patients start at a higher weight, and predominately remain obese (with BMI ≥ 40) following the stabilization of the weight loss after a laparoscopic sleeve gastrectomy as their weight loss velocity is no different to those of class 2/3 obesity.

Table 5 Absolute weight loss (lbs.) during the 3-year follow-up

	Obese	Super obese
1 month	27.25	34.74
3 months	48.64	50.93
6 months	68.48	69.97
12 months	84.68	92.52
36 months	84.68	84.14

We concur with current practice in the country that offers laparoscopic sleeve gastrectomy (LSG) as the first choice of bariatric surgery options for the adolescent population. As compared with laparoscopic gastric bypass (GBYPS), it maintains the anatomic configuration of the gastrointestinal tract, causes less nutritional abnormalities in the face of dietary indiscretions (a potential problem in this age group), and causes less late surgical complications. The current results suggest that in the SMO population after a restrictive procedure, comorbidity resolution is satisfactory; however, patients continue to remain morbidly obese. The results are only marginally better after GBYPS [6]. We recommend adjunctive interventions to improve the catabolic slope after LSG in the SO population. This could take the form of more restrictive diets for longer periods during the initial postoperative phase, combination with appetite suppressants or drugs that cause malabsorption. A second strategy would be to consider LSG as the first step of a two-step procedure with GBYPS being offered if necessary, 4–5 years after the first operation if comorbidity resolution is inadequate or if additional weight loss is desired.

Intervention at an earlier BMI, in SMO patients, will allow their weight loss to stabilize at a more acceptable BMI. Why such patients experience a delay in their evaluation by a bariatric surgery center is still unclear. It is important for the pediatric referral community to consider an early bariatric surgery involvement in adolescents with BMI between 35 and 40. The American Academy of Pediatrics has still not placed bariatric surgery on the flowchart of options to treat morbid obesity. It is our practice to currently wait for the completion of linear growth prior to bariatric surgery, and this is usually around 16 years of age. However, there are patients who have completed linear growth as evidenced by skeletal x-rays who could be candidates for earlier bariatric surgery intervention. Recommendation for obesity surgery at the younger ages must be balanced against the risks of metabolic surgery in the growing child.

Roux-En-Y gastric bypass yielded a nadir BMI of 38 kg/m^2 in a cohort of adolescents with starting BMI 55–64 [6]. Considering that weight reduction in the super obese population following a Roux-En-Y was comparable with what we observed following laparoscopic sleeve gastrectomy, it appears that neither operation leads to an optimal weight loss. Additionally, the weight loss benefits of the Roux-En-Y must be balanced against the increased morbidity. With a significant risk of internal hernia and multiple metabolic complications, a Roux-En-Y gastric bypass cannot be offered to all obese adolescents [14–17]. Laparoscopic sleeve gastrectomy is also not benign; notably, there is a considerable risk of GERD following the operation, which could risk this young population to developing Barrett's esophagus [18].

The ideal operation in the adolescent population would be one with long-term sustainable weight loss that stabilizes the individual at his ideal body weight. The operation should increase the rate of weight loss for those who are in class 4/5. This would have to be an operation that not only quickly restores the individual to his/her ideal body weight but also facilitates maintenance at that weight through centrally mediated resetting of the appetite/satiety centers. It is fair to say that this operation is yet to be conceived. While our follow-up rate at around 60% is not impressive, we recognize that adolescents do relocate for education and employment. It is imperative however to reinforce the need for long-term follow-up in this population during the preparatory phase.

In summary, laparoscopic sleeve gastrectomy is an effective intervention with sustainable long-term weight loss and comorbidity reduction. In the super obese, it can be an effective first step procedure to reverse comorbidities. However, at the extreme range of BMI, normalization of weight is less likely. Intervention at an earlier BMI might produce better outcomes, but risk adjustment of near- and long-term complications must be appropriately weighted. The strength of our study is the standardization of the operation, postoperative care, and follow-up. This study uniquely focuses on the differences in the trajectory of weight loss in patients with class 2/3 as compared with class 4/5 obesity. The postoperative strategies in comprehensive adolescent treatment programs should include monitoring %EBWL and velocity of weight loss so that patients falling off the desired weight curves can benefit from focused adjuvant treatment strategies. Additional studies are needed to evaluate the weight loss outcomes comparing different metabolic surgery options to glean an optimal operation for super obese patients.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Disclosures None.

Statement of Informed Consent This was a retrospective study and IRB approval with HIPPA compliance was obtained from the institution for the study.

Statement of Human and Animal Rights/Ethical Approval This was a retrospective study and no human or animal was harmed in the study.

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