Laparoscopic sleeve gastrectomy in adolescents: a retrospective case–controlled study

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Background
Adolescent obesity has been a striking global health issue in recent decades. Although nonsurgical weight loss strategies like lifestyle modifications, physical exercise, and dietary control have been crucial in obesity management in that age group, they have shown disappointing results. Consequently, growing interest has emerged on the surface in bariatric surgery for adolescents. Laparoscopic sleeve gastrectomy (LSG) can be an effective treatment option for adolescent obesity and controlling or even eliminating its obesity-related comorbidities.

Patients and methods
Data were collected from the prospectively maintained database between 2014 and 2019 in the Gastrointestinal Surgical Center of Mansoura University. Obese adolescents aged 12–19 years who underwent LSG with a BMI of more than 40 kg/m^2 or a BMI of greater than 35 kg/m^2 associated with obesity-related comorbidities were included.

Results
A total of 40 patients were included in the study, comprising 18 males and 22 females. The median age was 17 years. The mean preoperative body weight and BMI were 147.15 ± 36.31 kg and 52.55 ± 11.61 kg/m^2, respectively. All patients had at least one comorbidity. Osteoarthritis and depression were the commonest in the study cohort (14 patients each, 35%). After 2 years of follow-up, the Excess Body Weight Loss (EBWL) was 40.84 kg. All patients had achieved %EBWL more than 50% at 12 months. No nutritional deficiency was encountered in the study period. All obesity-related comorbidities (diabetes mellitus, hypertension, Obstructive sleep apnea syndrome (OSAS), and dyslipidemia) had been resolved.

Conclusion
Obese adolescents will grow into obese adults, with increasing burden on health care systems. LSG is feasible, effective, and safe for management of adolescent obesity in the terms of weight loss and resolution of obesity-related comorbidities. Long-term follow-up is needed in future studies.

Keywords:
comorbidities, obese adolescents, sleeve gastrectomy

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Introduction

Obesity is a worldwide epidemic, affecting different groups of population. It has a significant effect on general health and quality of life. Many comorbidities result from morbid obesity, such as type 2 diabetes mellitus (DM), hypertension, and dyslipidemia, which negatively shorten the life expectancy. Adolescent obesity has been a striking global health issue in recent decades [1,2]. Obesity in adolescents, like adult obesity, poses a significant risk on various organ systems, particularly psychosocial problems, and cancers. Obese adolescent will grow into obese adult in the future, with increasing burden on health care systems. Many contributing factors result in obesity, such as individual, dietary, social, behavioral, and environmental factors [3–5].

Multidisciplinary approaches were introduced in the previous studies for the management of adolescent obesity. Although nonsurgical weight loss strategies like lifestyle modifications, physical exercise, and dietary control have been crucial in obesity management, they have shown disappointing results. Pharmacological therapy has a limited effect on weight control, and long-term data are scarce [6,7]. Consequently, growing interest has emerged on the surface in obesity surgery for adolescents. Weight loss surgery remains the

mainstay and effective treatment for obesity and can result in loss of 58–73% of excess body weight. Its efficacy had been proven for long-term weight control and controlling or even eliminating obesity-related comorbidities in adults [8,9].

Adolescent bariatric surgery has gained popularity in the last decade, with an increasing number of cases worldwide. Promising results from previous studies showed major improvements in comorbidities, psychological issues, and obesity-related mortality after surgery. On the contrary, there are many concerns regarding ethical considerations and surgery-related complications. Furthermore, long-term data after surgery, including quality of life, pathological eating behavior, and weight regain, are rare in the literature [8–12].

Different surgical techniques such as sleeve gastrectomy, gastric banding, and Roux-en-Y gastric bypass have been evaluated regarding efficacy, safety, and feasibility, showing controversial results between different centers [8–12]. High-quality evidence such as randomized control studies, systematic reviews, and meta-analysis regarding the safety of adolescent bariatric surgery is still deficient in the literature. Moreover, we conducted this study to assess the feasibility, safety, and short-term and long-term effects of laparoscopic sleeve gastrectomy (LSG) for the treatment of adolescent obesity.

Patients and methods

Study design

Study eligibility

This was a retrospective study to evaluate the efficacy of LSG in obese adolescents. The patients' data were collected from the prospectively maintained database between 2014 and 2019.

This retrospective cross-sectional study was approved by the medical research ethics committee, Institutional Review Board (IRB), Faculty of Medicine, Mansoura University, Code Number: R.21.11.1519. Informed consent was obtained after explaining the importance of postoperative physical exercises, dietary and behavioral changes, and possible risks and potential complications of the study to each included patient.

Inclusion criteria

All adolescents aged from 12 to 19 years with a BMI of more than 40 kg/m^2 or a BMI of greater than 35 kg/m^2 associated with obesity-related comorbidities were included in the study. The comorbidities should be documented by the treating pediatrician or specialized referring physician. All eligible adolescents underwent nonsurgical weight loss management such as lifestyle modifications, physical exercise, and dietary control but with unsatisfactory results within a minimum period of 12 months. Adolescent and family education about potential perioperative complications, as well as strict follow-up programs and dietary regimens should have been provided.

Exclusion criteria

Exclusion criteria were eating disorders, lack of social family support, developmental immaturity, severe and uncontrolled cardiorespiratory disease, syndromes causing obesity (Prader-Willi syndrome), and endocrinal disorders affecting the weight loss such as untreated hypothyroidism and prolactinoma. Patients with history of upper gastrointestinal (GI) surgery were also excluded.

Definitions

The definition of obesity-associated comorbidities includes the following: (a) type 2 DM (fasting blood glucose of <110 mg/dl); (b) hypertension (systolic blood pressure of <140 and or diastolic blood pressure of <90 mmHg); (c) obstructive sleep apnea (breathing disorder during sleep manifested by snoring, apnea, gasping, and chocking sensation); (d) gastroesophageal reflux disease (GERD) (symptoms such as heart burn, regurgitation, and retrosternal chest pain responding to proton pump inhibitor drugs and/or esophageal erosions detected by upper GI endoscopy); (e) depression; and (f) osteoarthritis [8–13].

Preoperative assessment

All patients underwent comprehensive evaluation by a specialized team consisting of pediatrician, dietitian, bariatric surgeon, and psychologist before operation. Laboratory investigations, including complete blood picture, liver function test, serum creatinine, thyroid function tests, fasting and postprandial blood sugar, lipid profile, coagulation profile, and serum cortisol level, were done. Abdominal ultrasonography was done to detect gall bladder stones and other abdominal pathology. Patients complaining of GERD symptoms were given upper GI endoscopy. An informed written consent was given by parents for all patients preoperatively.

Surgical procedure

Standard 5-port LSG was done using French position with the surgeon standing between the patient's legs. Division of the greater omentum from its attachment to the greater curve of the stomach and complete mobilization of the fundus using bipolar sealing device (LigaSure; Medtronics, Minneapolis, MN, USA) was performed. Then, gastrectomy over a 40-Fr calibrating bougie starting 4 cm proximal to pylorus was done using EndoGIA stapler (Johnson & Johnson Company,

Cincinnati, OH, USA), resulting in a gastric pouch size of 100 ml. Titanium clips were used to control bleeding at the staple line when indicated. A drain was inserted in all cases. Detailed surgical steps and intraoperative complications were recorded.

Postoperative care

All patients underwent oral gastrografin for early detection of leaks, and then oral intake was started 12 h postoperatively. On the first day after surgery, after tolerance to adequate oral fluids and pain control, the patients were discharged from the hospital. Patients were encouraged to start with clear fluids for 2 weeks, a soft diet for another 2 weeks, and solid food after 4 weeks. Multivitamins, oral calcium, vitamin D, and proton pump inhibitor were prescribed for patients for 1 year after surgery.

Follow-up

Follow-up visits were scheduled at the outpatient clinic 2 and 4 weeks after surgery and then 3, 6, 12, 18, and 24 months and then yearly. All patients were evaluated for excess weight loss, dysphagia, vomiting, eating behavior, comorbidity improvement, and any other complications. A laboratory investigation was conducted on every visit for detection of any nutritional deficiency, including iron, vitamin D, hemoglobin, albumin, and lipid profile. The patients were advised to do regular daily physical activity. A psychological assessment was done for any psychological problems.

Measurements

On every visit, weight (kg), height (m), BMI (kg/m^2), and waist circumference waist circumference (cm) were measured. Excess weight= preoperative weight−ideal weight) was measured as well as excess weight loss ratio [EWL%=(preoperative weight−current weight/ excess weight)×100].

Statistical analysis

Categorical variables are described using absolute numbers with percentages. Continuous variables are expressed as medians and ranges. The χ^2 or Fisher exact test was used to compare categorical variables, with Student *t* test or the Mann–Whitney *U* test for continuous variables. A *P* value less than or equal to 0.05 was considered to be significant. All statistical analyses were performed using SPSS statistical software, version 23.0 (SPSS Inc., Chicago, Illinois, USA).

Results

A total of 40 patients were included in the study: 18 (45%) males and 22 (55%) females. The median age was 17 years (range, 14–19 years). The mean preoperative body weight and BMI were 147.15 ± 36.31 kg and 52.55 ± 11.61 kg/m^2, respectively. All patients had at least one comorbidity. Osteoarthritis and depression were the most common obesity-related comorbidity in the study cohort (14 patients, 35%). Four patients presented with GERD symptoms, of which two patients underwent upper GI endoscopy before surgery to confirm the diagnosis, as shown in Table 1. No syndromic obesity was identified in the study cohort.

Perioperative data

Operative details are shown in Table 1. The mean operative time was 119.25 min. Intraoperative complications encountered during surgery were two patients with staple line bleeding controlled by clipping of the bleeding vessels and two stapling failure managed by running sutures. No blood transfusion was need intraoperatively. There was no conversion to open approach.

Postoperative complications occurred in two (5%) patients with internal hemorrhage and were treated by laparoscopic exploration and controlled by diathermy coagulation and clipping. The median hospital stay was 3 days without in-hospital mortality. No hospital readmission was reported in the early postoperative period.

Weight loss outcome

There was significant decrease in mean body weight at 18 months after surgery in relation to preoperative values (147.15 vs. 84.47 kg, $P \leq 0.001$), as shown in Table 2. In the first 6 months after surgery, the maximum rate of decrease of mean BMI was achieved (52.5 vs. 44.5 kg/m^2) with loss of nearly one-fourth of mean initial body weight (147.2 vs. 108.5 kg) and EBW of 25.9 kg. The BMI then reaches the plateau of 30.6 kg/m^2 at 18 months. The Excess Body Weight Loss (EBWL) at 3, 6, 12, 18, and 24 months was 15.32, 25.96, 36.21, 39.82, and 40.84 kg, respectively. All patients had achieved %EBWL more than 50% at 12 months.

Nutritional outcome

A total of 17 (42.5%) patients had preoperative dyslipidemia (six patients with high cholesterol and 11 with high triglyceride). The serum cholesterol and triglyceride reached normal values postoperatively at 18 and 24 months, correspondingly, as shown in Table 3. No nutritional deficiency was encountered in the study period during the follow-up period.

Comorbidity outcome

All comorbidities had been resolved. Among the participants in the present study, 10 adolescents

Table 1 Preoperative, intraoperative, and postoperative findings

Total number=40			
	Mean±SD/*n* (%)	Median	Range
Age (years)	16.85 ± 1.76	17	14–19
Sex			
Males		18 (45)	
Females		22 (55)	
Chronic diseases			
DM (type II)		10 (25)	
HTN		4 (10)	
OSAS		12 (30)	
Osteoarthritis		14 (35)	
GERD		4 (10)	
Gall stones		2 (5)	
Depression		14 (35)	
Abdominal US			
Normal		38 (95)	
Gall bladder stones		2 (5)	
Upper endoscopy			
Normal		38 (95)	
Reflux		2 (5)	
Distance from pylorus (cm)	3.5 ± 1.59	3	2–6
Intraoperative difficulties (large left lobe)		2 (5)	
Intraoperative complications			
Staple line bleeding		2 (5)	
Stapling failure		2 (5)	
Operative time (min)	119.25 ± 34.8	120	60–180
Blood loss (ml)	140 ± 112.77	100	50–500
Blood transfusion		0	
Postoperative			
Hospital stay (days)	3.45 ± 1.34	3	2–8
Oral intake (days)	1.3 ± 0.56	1	1–3
Internal hemorrhage		2 (5)	
Leak		0	
Pulmonary embolism		0	
Chest infection		0	
Wound infection		0	
Abdominal collection		0	

DM, diabetes mellitus; GERD, gastroesophageal reflux disease; HTN, hypertension.

had type 2 DM at the baseline. We found complete remission in six (60%) and improvement of glycemic control in two (20%) adolescents at 1 year after surgery, with sustained control until the last follow-up at 2 years. A total of 12 and four participants with Obstructive sleep apnea syndrome (OSAS) and hypertension, respectively, achieved substantial resolution of these comorbidities at the end of follow-up. Participants with dyslipidemia had normalized serum cholesterol and triglycerides after 18 months of surgery (Table 4).

Discussion

Most of the published studies reported the efficacy of bariatric surgery in the management of morbid obesity in adult population. Nonsurgical weight management in adolescents showed unsatisfactory results on the long-term scale, and so bariatric surgery has become a more demanding option for sustained weight loss and improvement of obesity-related comorbidities. Growing evidence in the literature showed that LSG has been an efficient surgical management of adolescent morbid obesity, although there are still concerns regarding the effect of LSG on the normal growth and long-term complications [13].

In the present study, among our 40 morbidly obese adolescents, there were slightly predominant female patients (22 vs. 18 males), with median age of 17 years, and the most common preoperative comorbidities were osteoarthritis and depression (*n*=14). As adolescents live at their peak of phycological and personal development, obese adolescents are more susceptible to psychological diseases than nonobese. These findings were comparable to the study by Khidir *et al.* [14],

Table 2 Analysis of body weight (kg), BMI (kg/m²), and EBWL in the cases of the study along the duration of follow-up

	Preoperative	At 3 months	At 6 months	At 12 months	At 18 months	At 24 months	*P* value
Body weight (kg)	147.15 ± 36.31	124.7 ± 31.55	108.45 ± 26.35	92.7 ± 23.83	85.33 ± 20.57	84.47 ± 20.11	
*P*1		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
*P*2			<0.001	<0.001	<0.001	<0.001	
*P*3				<0.001	<0.001	<0.001	
*P*4					0.003	0.025	
*P*5						0.580	
BMI (kg/m²)	52.55 ± 11.61	44.5 ± 9.88	38.71 ± 8.15	33.11 ± 7.48	30.66 ± 6.9	30.51 ± 6.8	
*P*1		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
*P*2			<0.001	<0.001	<0.001	<0.001	
*P*3				<0.001	<0.001	<0.001	
*P*4					0.001	0.011	
*P*5						0.581	
EBWL		15.32 ± 4.56	25.96 ± 7.11	36.21 ± 11.01	39.82 ± 10.24	40.84 ± 11.26	
*P*1							
*P*2			<0.001	<0.001	<0.001	<0.001	<0.001
*P*3				<0.001	<0.001	<0.001	
*P*4					0.001	0.009	
*P*5						0.717	

*P*1: significance in relation to preoperative value. *P*2: significance in relation to postoperative 3-month value. *P*3: significance in relation to postoperative 6-month value. *P*4: significance in relation to postoperative 12-month value. *P*5: significance in relation to postoperative 18-month value.

Table 3 Analysis of laboratory data in the cases of the study along the duration of follow-up

	Preoperative [*n* (%)]	At 3 months [*n* (%)]	At 6 months [*n* (%)]	At 12 months [*n* (%)]	At 18 months [*n* (%)]	At 24 months [*n* (%)]	*P* value
Cholesterol							
Normal	34 (85)	36 (90)	36(90)	39(97.5)	40(100)	40 (100)	0.005
High	6 (15)	4 (10)	4 (10)	1 (2.5)	0	0	
TGs							
Normal	29 (72.5)	31 (77.5)	35(87.5)	38 (95)	38 (95)	40 (100)	<0.001
High	11 (27.5)	9 (22.5)	5(12.5)	2 (5)	2 (5)	0	
Hemoglobin (g/dl)	12.82 ± 1.69	12.25 ± 2.04	13.39 ± 1.95	12.94 ± 1.37	13.83 ± 1.81	13.47 ± 1.6	0.085
Albumin (g/dl)	4.27 ± 0.33	4.15 ± 0.41	4.09 ± 0.14	4.36 ± 0.19	4.19 ± 0.25	4.50 ± 0.32	0.136
Iron level (µg/dl)	86.19 ± 18.42	89.96 ± 22.55	90.59 ± 18.76	84.05 ± 21.30	88.44 ± 24.11	85.34 ± 23.15	0.076

TGs, triglyceride.

but they reported that the obstructive sleep apnea was the commonest comorbidity (12%) in their 91 obese adolescent study cohort.

In our cohort, mean preoperative weight was 147.15 ± 36.3 kg and BMI was 52.5 ± 11.6 kg/m², and this was higher than that reported in other studies [14,15]. In contrast, Ates and colleagues showed a higher level of mean weight (159.25 ± 19.78 kg) and BMI (61.05 ± 8.5 kg/m²). Superobese adolescents are at risk of developing all disabling health problems and cancers at a younger age than other nonobese adolescents, decreasing their life expectancy; moreover, nonsurgical weight loss therapies usually fail to achieve good results in superobese adolescent. Consequently, obesity surgery is an essential option to treat this serious health problem [16].

In our series, the procedure was done laparoscopically in all cases, with no conversion. The mean operative time was 119.25 ± 34.8 min and the length of hospital stay was 3.5 ± 1.3 days. These results are in correspondence with others [16,17]. The technique of LSG is feasible and safe in adolescents, similar to adult obese population.

The median follow-up was 24 months. There was a significant decrease in mean body weight at 18 months after surgery (147.15 vs. 84.47 kg, *P*>0.001). At first 6 months after surgery, the maximum rate of decrease of mean BMI was achieved (52.5 vs. 44.5 kg/m²), and then it reached the plateau of 30.6 kg/m² at 18 months. All patients had achieved %EBWL more than 50% at 12 months.

Our findings were in line with recent studies in the literature. In Teen-LABS study, the largest prospective multicenter study of weight loss surgery in adolescent including 242 adolescents, of which 67 underwent LSG, there was a significant decrease in mean weight

Table 4 Analysis of symptoms in the cases of the study along the duration of follow-up

	At 3 months [*n* (%)]	At 6 months [*n* (%)]	At 12 months [*n* (%)]	At 18 months [*n* (%)]	At 24 months [*n* (%)]	*P* value
DM (*N*=10)						
Resolved	0	2 (20)	6 (60)	6 (60)	6 (60)	
Improved	6 (60)	6 (60)	2 (20)	2 (20)	2 (20)	<0.001
Unchanged	4 (40)	2 (20)	2 (20)	2 (20)	2 (20)	
HTN (*N*=4)						
Resolved	0	2 (50)	4 (100)	4 (100)	4 (100)	
Improved	4 (100)	2 (50)	0	0	0	0.023
Unchanged	0	0	0	0	0	
OSAS (*N*=12)						
Resolved	0	6 (50)	10 (83)	12 (100)	12 (100)	
Improved	12 (100)	6 (50)	2 (17)	0	0	<0.001
Unchanged	0	0	0	0	0	
Osteoarthritis (*N*=14)						
Resolved	2 (14.3)	14 (100)	14 (35)	16 (40)	16 (40)	
Improved	12 (85.7)	0	4 (10)	0	0	<0.001
Unchanged	0	0	22 (55)	24 (60)	24 (60)	
GERD (*N*=4)						
Resolved	0	4 (10)	6 (15)	6 (15)	6 (15)	
Improved	8 (20)	4 (10)	2 (5)	0	2 (5)	
Unchanged	32 (80)	32 (80)	30 (75)	32 (80)	32 (80)	0.349
Deteriorated	0	0	2 (5)	2 (5)	0	
Depression						
Resolved	0	4 (10)	6 (15)	2 (5)	2 (5)	
Improved	0	0	2 (5)	0	0	
Unchanged	40 (100)	36 (90)	32 (80)	38 (95)	26 (90)	0.001
Deteriorated	0	0	0	0	2 (5)	

DM, diabetes mellitus; GERD, gastroesophageal reflux disease; HTN, hypertension.

and mean BMI at 3-year follow-up (144–105 kg and 50–37 kg/m^2, respectively). Other reports showed satisfactory outcomes after LSG, with %EWL ranged from 45 to 68% [18–24].

Among the participants in the present study, 10 adolescents had type 2 DM at the baseline. We found complete remission in six (60%) and improvement of glycemic control in two (20%) adolescents at 1 year after surgery with sustained control until the last follow-up at 2 years. Overall, 12 and four participants with OSAS and hypertension, respectively, achieved substantial resolution of these comorbidities at the end of follow-up. Our results were consistent with those reported in the literature. We proved that LSG is effective in the management and even reversal of obesity-related comorbidities, which related to weight loss and appetite control [24].

LSG may affect the stores of numerous micronutrients that are essential for normal mental and physical growth of the adolescent. Consequently, it is crucial to maintain nutritional supplementations postoperatively to avoid nutritional deficiencies, as was prescribed in this study cohort [22,24]. In the present study, the iron stores were refilled until 6 months after surgery and then decreased after until the end of follow-up. This highlights that LSG could cause iron-deficiency anemia owing to decrease in intrinsic factor production from stomach after resection, which points to the importance of long-term and maintained follow-up, especially nutritional deficiency, to be corrected earlier. These findings were in line with previous studies [24].

The limitations of the study included that it was conducted at a single center, with a relatively small number of patients (*n*=40), as we reported the initial experience of our center in the management of adolescent with morbid obesity using the LSG technique. Then, the study's design was retrospective. The follow-up of the patients was relatively short and limited to 24 months after surgery, which is considered the 'honeymoon period' of any bariatric surgery. A longer-term follow-up (5 years) is required for a more accurate assessment of LSG's effectiveness in long-term weight loss and the evaluation of long-term complications. The nutritional profile in the follow-up was not completely assessed.

Conclusion

Obese adolescent will grow into obese adult, with increasing burden on health care systems. LSG is feasible, effective, and safe for management of

adolescent obesity in the terms of weight loss and resolution of obesity-related comorbidities. Long-term follow-up is needed in future studies.

Conflicts of interest

There are no conflicts of interest.

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