Effect of laparoscopic sleeve gastrectomy on glucose tolerance in morbid obese diabetic patients

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Background
Bariatric surgery offers morbidly obese individuals an accepted weight loss and reduction in obesity-related comorbidities when other conservative treatments have failed. Many types of operative procedures for morbid obesity have been popularized over the past three decades, and they are continuously evolving.
Laparoscopic sleeve gastrectomy (LSG) gained popularity over the past few years with a promising effect on improvement of diabetes mellitus (DM) in diabetic patients.
Aim
The aim of this study was to determine the effect of LSG on glucose tolerance in morbid obese diabetic patients and to correlate these changes with clinical improvement according to glucose tolerance test, glycated hemoglobin, fasting blood glucose, and 2-h postprandial blood glucose at time of 3, 6, and 12 months postoperatively.
Patients and methods
This study included 30 patients with morbid obesity associated with type 2 DM. All patients were evaluated for change in glucose tolerance after LSG and follow-up of these patients at 3, 6, and 12 months postoperatively.
Results
The current study showed improvement of DM in 24 (80%) patients and six (20%) patients had no improvement. Among the patients who improved, 21 (70%) patients showed complete remission of diabetes (patients stopped medication) and three (10%) patients were controlled by oral hypoglycemic drugs (patients decreased medication).
Conclusion
The preliminary results for 1-year follow-up are promising with good control of DM after sleeve gastrectomy. Further long-term follow-up is needed to ensure efficacy of sleeve gastrectomy on type 2 DM control over a longer time.

Keywords:
diabetes mellitus, laparoscopic sleeve gastrectomy, morbid obesity

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Introduction

Obesity is the excessive or abnormal accumulation of fat within the body and impairs health. Obesity has become a plague, which has worsened for the last 50 years. In the USA, the economic burden is estimated to be about $100 billion annually. Obesity may be a complex disease and has multifactorial etiology. It is the second most common cause of preventable death after smoking [1].

Obesity is associated with multiple medical conditions and can cause serious complications of chronic conditions. Obesity needs multipronged treatment strategies and may require lifelong treatment. A 5–10% weight loss can significantly improve health, quality of life, and economic burden of an individual and a country as a whole [2].

Sleeve gastrectomy is a popular surgical technique used in bariatric surgery and considered as a leading successful method in metabolic surgery. Sleeve gastrectomy has proved to be a successful method in reducing weight. There are some disparate effects that patients may experience after sleeve gastrectomy including a reduction in BMI and weight and treatment of associated comorbidities, for example, treatment of high blood pressure, stroke, and cancer. Sleeve gastrectomy has a significant effect on remission of obesity-related diseases including type

2 diabetes mellitus (T2DM), nonalcoholic fatty liver, cardiovascular disease, and obstructive sleep apnea. The complications of sleeve gastrectomy include bleeding either intraoperative bleeding or postoperative bleeding, nutrient deficiencies, stenosis, gastroesophageal reflux (GERD), vomiting, and leakage [3].

Sleeve gastrectomy achieves weight reduction and improvement in glucose metabolism by many mechanisms, including restricted caloric intake, changes in hormonal secretion of gastrointestinal tract, changes in energy expenditure, rearrangement of hypothalamic control, and changes in control of the vagal tone [4].

Patients and methods

This study included 30 patients with morbid obesity associated with T2DM admitted in Menoufia University Hospital. All patients were evaluated for change in glucose tolerance after laparoscopic sleeve gastrectomy (LSG), Follow-up of these patients was done at 3, 6, and 12 months postoperatively.

The follow-up was regarding body weight reduction, percentage of improvement of T2DM, complications, and morbidity.

Inclusion criteria

The following were the inclusion criteria: patients with BMI more than 35 kg/m^{2}with T2DM with or without hypertension, with or without other comorbidities including arthritis, obstructive sleep apnea cardiovascular disease, polycystic ovary, and fertility disorders, aged 18 years or older, failed conservative treatment (diet control, physical exercise, and medical treatment), fit for surgery, and agrees of the follow-up schedule.

Exclusion criteria

The following were the exclusion criteria: hormonal disturbances (e.g. hypothyroidism and Cushing syndrome), psychological instability, alcoholic or drug abuse, unfit for surgery (major organ failure, e.g., cardiac, hepatic, pulmonary, or renal), and pregnancy.

Methodology

Laboratory investigations included complete blood count, liver function tests, kidney function tests, thyroid-stimulating hormone, free T3, free T4, serum cortisol, serum triglyceride, serum high-density lipoprotein, serum low-density lipoprotein, blood sugar level (fasting and 2-hpostprandial), glycated hemoglobin (HbA1c), glucose tolerance test before and after operation, and radiological investigations such chest radiograph, abdominal ultrasound, Duplex arteriovenous study, ECG, echocardiography, respiratory functions, and upper endoscopy for visualization of hiatus hernia or GERD.

After we gained patient consent, we started induction of general anesthesia and sterilization, we used a five-port technique. We introduced the camera through a supra-umbilical port. Two 12-mm ports were placed: one on the left and one on the right at midclavicular line. One 5-mm port in epigastric region was used to retract the liver, and a 5-mm port was used in the left subcostal margin for assistance. Then, the greater curvature of the stomach was devascularized at about 2 cm proximal to the pylorus and then we proceeded upward to esophagus till the angle of His. Then, we used a linear stapler (Endo GIA) (Echlon Flex 60) with two sequential green load firings from the antrum, followed by two or three sequential blue loads for the fundus and remaining gastric body. A 36-Fr calibrating bougie was inserted into the stomach, and the stapler was applied alongside the bougie (Fig. 1). The resected stomach was grasped through one of the 12-mm port sites. Intraoperative leak test with methylene blue dye was done. We controlled bleeding by clipping. We reinforced the suture line by suturing material to control bleeding suture line and for safety. A clear liquid diet is started on the first postoperative day and continued for 2 weeks on fluids. A pureed diet is started in the third week postoperatively as per patient tolerance.

All patients were evaluated preoperative and postoperative regarding body weight reduction in kg and effect on T2DM by fasting blood glucose level, 2-h postprandial blood glucose, and HbA1c level.

The diabetes remission score can help us predict probability of remission after bariatric surgery using the following parameters: age, HbA1c level, insulin treatment, and other antidiabetic medications, as seen in Table 1.

Figure 1

Mechanical stapler positioned for early gastric body tubing with a gastric tube 36 Fr modeling the stomach.

Values are presented as probability (%) with 95% confidence interval, including both partial and complete remission [5].

Results

The study included 30 patients. All findings were tabulated and analyzed statistically. The mean age of the studied group was 32 ± 9 years (range, 20–53 years). A total of 26 (86%) patients were females and four (14%) were males.

Preoperative parameters including duration of diabetes, type of medications, and HbA1c level are included in Table 2.

According to the diabetes remission score, our study showed that nine patients had 0–2 score, 18 patients had 3–7 score, and three patients had 8–12 score, as seen in Table 3.

Our study show resolution of fasting blood glucose, 2-h postprandial blood glucose, and HbA1c in the follow-up of patients after sleeve gastrectomy, as seen in Table 4.

Our study showed controlled glucose level of DM [stopped medications, oral hypoglycemic drugs (OHD)] in 21 (70%) patients, partial remission of DM [decreased dose of medications (OHD)] in three (10%) patients, and no improvement in six (20%) patients, as seen in Table 5.

Our study showed a relation between percent of excess weight loss and fasting blood glucose level in the follow-up of patients, as seen in Table 6.

The effect of sleeve gastrectomy on HbA1c shows improvement, as seen in Fig. 2.

Table 1 Diabetes remission score

Variables	Score
Age (years)	
<40	0
40–49	1
50–59	2
≥60	3
HbA1c (%)	
<6.5	0
6.5–6.9	2
7.0–8.9	4
≥9.0	6
Insulin treatment	
No	0
Yes	10
Other antidiabetic medications	
Only metformin	0
Sulfonylureas and insulin sensitizing agents other than metformin	3
Overall score (sum of four components)	0–22
Probability of remission in each DiaRem score subgroup	
0–2	87 (83–90)
3–7	66 (61–70)
8–12	32 (24–40)
13–17	16 (12–21)
18–22	5 (0–9)

HbA1c, glycated hemoglobin.

Table 2 Preoperative parameters

Parameters	Number of patients
Duration of diabetes (years)	
0–6.9	19
7–13.9	11
≥14	0
Type of medication	
Oral hypoglycemic drugs	30
Insulin	0
HbA1c level	
<6.5	2
6.5–6.9	11
7–8.9	15
≥9	2

HbA1c, glycated hemoglobin.

Table 3 Results of application of diabetes remission score on our patients

Number of patients	DiaRem score	Probability of remission
9	0–2	87 (83–90)
18	3–7	66 (61–70)
3	8–12	32 (24–40)

Table 4 Resolution of fasting blood glucose, 2-h postprandial blood glucose, and glycated hemoglobin, and gradual decrease in hypoglycemic drugs

Parameters	Preoperative	After 3 months	After 6 months	After 1 year	*P* value
Mean fasting blood glucose (mg/dl)	147 ± 3.2	140.5 ± 4.2	133.1 ± 6.4	114.6 ± 6.7	0.003*
Mean 2-h postprandial blood glucose	220 ± 18.5	205 ± 14.2	180 ± 16.1	145 ± 11.8	0.005*
Mean HbA1c %	7.5 ± 0.2	7.2 ± 0.5	6.7 ± 0.3	6.2 ± 0.2	<0.001*

HbA1c, glycated hemoglobin. *Significant.

Table 5 Outcome of type 2 diabetes mellitus after laparoscopic sleeve gastrectomy

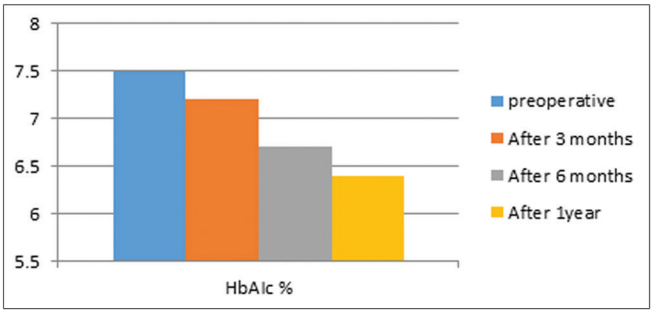
Controlled glucose level (stopped medications) [n (%)]	21 (70)
Controlled by oral hypoglycemic drugs [*n* (%)]	3 (10)
No improvement [*n* (%)]	6 (20)

Table 6 Relation between excess weight loss, glucose level, and diabetic medications

Parameters	After 3 months	After 6 months	After 1 year	*P* value
EWL%	16.5	23.3	37.48	0.001*
Mean fasting blood glucose (mg/dl)	140.5 ± 4.2	133.1 ± 6.4	114.6 ± 6.7	0.003*
Diabetic medication stopped [*n* (%)]	8 (26.6)	14 (46.6)	21 (70)	0.003*

*Significant.

Figure 2



Effect of SG on HbA1c%. HbA1c, glycated hemoglobin.

Discussion

Obesity is a risk factor for several causes of preventable death, including cardiovascular disease, DM, and many types of cancer. Thus, successful treatment and control of obesity should be a major concern. However, multiple studies have shown that detection and counseling rates among physicians remain low [6].

Our study included 30 diabetic patients, comprising four (14%) males and 26 (84%) females, which indicates that females are seeking for bariatric surgery more than males in our community. In agreement with our study, Attia [7] showed a study at the Al-Zahraa University hospital, where 15 (37.5%) cases were males and 25 (62.5%) cases were females. Moreover, a study by Elsherif [8] included 140 patients in the Alexandria University Hospital, where 92 (66%) were females and 48 (34%) were males. In contrast to our study, a study by El-Aziz *et al.* [9] included 50 adult obese patients, where 30 were males and 20 were females.

Previous results show that in urban areas, both obese males and females seek for weight reduction procedures, whereas in rural areas, most patients who seeking for weight reduction procedures are females.

The operative time in our study ranged from 70 to 130 min. In agreement with our study, a study by Attia [7] showed that the mean operative time was 50–120 min. Moreover, a study by Elbanna *et al.* [10] on the effect of preoperative BMI on the final outcome after LSG showed that the mean operative time ranged from 90 to 180 min.

In contrast to our study, a study by Elsherif [8] showed that the operative time ranged from 110 to 240 min. This may be owing to patients with high BMI take more operative time.

Regarding postoperative hospital stay, the mean postoperative hospital stay was 5 days (range, 4–7 days). In agreement with our study, a study by Attia [7] showed that the mean hospital stay was 4.7 ± 0.9 days. A study by Elbanna *et al.* [10] showed that the mean postoperative hospital stay was 3.2 ± 1.5 days (range, 3–11days). This may be owing to more patient compliance.

Regarding age, in our study, the mean±SD age was 32 ± 9 years, with range of 20–53 years. In agreement of our study, a study by Ahmed *et al.* [11] showed that the mean±SD age was 34.7 ± 11.7 years, with range of 13–64 years.

Moreover, in agreement with our study, a study by Shafik *et al.* [12] on 30 obese patients showed the mean age was 33.6 ± 10.51 years, with range of 18–58 years. In contrast with our study, a study by El-Aziz *et al.* [9] on 50 patients showed that mean age was 42.8 ± 8.2 years. This difference could be owing to variations in sample taken.

Regarding associated comorbidities, our study showed 10 (30%) hypertensive patients, two (6.6%) patients with calcular cholecystitis who underwent laparoscopic cholecystectomy, and four (13.3%) patients with hiatus hernia who underwent laparoscopic repair of hiatus hernia.

In contrast to our study, a study by Hady *et al.* [13] showed that preoperatively T2DM was present in 39 (39%) patients, arterial hypertension in 56 (56%) patients, and obstructive sleep apnea in 31 (31%) patients. This could be owing to variations in the samples and the main complaint of patients.

Regarding weight reduction, in the current study, the mean preoperative BMI 46, at 3 months postoperatively was 42%, at 6 months postoperatively was 37, and after 1 year was 30.

In agreement with our study, a study by Elsherif [8] showed that at 6 months, the BMI ranged from 30 to 60 kg/m^2, with a mean of 40 ± 10.2. At 1 year

postoperatively, the BMI ranged from 26 to 37 kg/m^2, with a mean of 33 ± 6.7.

Moreover, in agreement with our study, a study by Hady *et al.* [13] showed reduction of BMI at 1 month after surgery (45.81 ± 7.71 kg/m^2) when compared with BMI before surgery (52.15 ± 8.5 kg/m^2). At 3 and 6 months after surgery, BMI became 42.72 ± 6.86 and 37.98 ± 4.97 kg/m^2, respectively.

Moreover in agreement with our study, a study by Rosenthal *et al.* [14], on 30 obese patients showed that the BMI decreased from 46.12 ± 10.86 preoperatively to 38.27 ± 6.59 at 2 months and 35.78 ± 5.11 at 6 months after surgery.

Moreover, in agreement with our study, a study by El-Aziz *et al.* [9] on 50 patients on the effect of sleeve gastrectomy on metabolic disorders showed that the averages BMI of the patients was 52.4 ± 6.6 kg/m^2. At 3 months postoperatively, the mean BMI became 43.976 ± 5.449, and at 9 months postoperatively, the BMI became 33.428 ± 4.353.

In contrast with our study, a study by Elbanna *et al.* [10], showed that the mean preoperative BMI was 53.8 ± 8 (range, 40–75 kg/m^2), which decreased 1 year after surgery to 47.34 ± 4.4 (range, 37–56.7 kg/m^2). It is owing to the differences in patient follow-up visits and patient response to doctor instructions.

Regarding diabetes remission, the current study showed improvement of DM in 24 (80%) patients and six (20%) patients showed no improvement. Among the patients who improved, 21 (70%) showed complete remission of diabetes [patients stopped medications (OHD)] and three (10%) patients were controlled by OHD [patients decrease dose of medications (OHD)]. The reasons for patients who did not improve [six (20%) patients] could be owing to long duration of diabetes, strong family history, patients on multiple medications, did not follow instructions of doctors (no compliance) at follow-up visits, bad eating habits, and insufficient follow-up time.

In agreement with our study, a study by Attia [7], which included 40 patients who underwent LSG, demonstrated remission of DM up to 60% after 1 year of surgery.

Moreover, in agreement with our study, a study by Jindal *et al.* [15], which included 104 patients, showed that diabetes was resolved completely in 82 (78.9%) patients at 6 months after surgery and in the remaining 22 (21.1%) patients, diabetic status was improved, where 12 patients had the dose of insulin decreased and 10 patients were switched over to oral hypoglycemic agents.

Moreover, in agreement with our study, a study by Elsherif [8] showed that 39 (90.6%) patients of 43 patients who had T2DM stopped oral medications after normalization of the blood sugar level.

In addition, in agreement with our study, a study by McTigue *et al.* [16] estimated that 55.9% of those who had SG experienced remission of diabetes by 1 year.

Additionally, in agreement with our study, a study by Lee *et al.* [17] on 85 patients showed that at 12 months after surgery, the mean HbA1c decreased from 8.1 to 6.1% and 45 (52.9%) patients had complete remission (HbA1c<6.0%), another 18 (21.2%) had partial remission (HbA1c<6.5%), and nine (10.6%) who improved (HbA1c<7%).

In addition, in agreement of our study, a study by Shah *et al.* [18] showed that 53 patients (BMI 45.2 ± 9.3 kg/m^2, and HbA1c 8.4 ± 1.6%) underwent LSG. Before LSG, 48 (79%) patients required antidiabetic medication and five patients managed their diabetes with diet control. At 1 month after LSG, 39 (81.2%) of the 48 patients stopped medications. Antidiabetic medications were reduced in nine (18.8%) of 52 patients. At 1 year, euglycemia was observed in 51 (96.2%) patients without medication and two (3.8%) of the 53 patients had reduced their medication dosage.

Similar to our study, a study by Vrakopoulou *et al.* [19] showed that 35.7% of patients who underwent SG stopped antidiabetic agents 3 years after surgery, reflecting their status of normoglycemia. This may be owing to the fact that patients followed instructions.

Similarly, a study done by Mizera *et al.* [20] showed that of the 240 patients in their study, diabetes remission after 5 years was achieved in 111 (46.3%) patients, including 92 (38.3%) patients who achieved complete remission 1 year after surgery and maintained diabetes remission for 5 years after surgery and 19 (7.9%) patients who achieved diabetes remission 5 years after surgery.

Another study by Gill *et al.* [21] included 673 patients with a mean follow-up of 13.1 months (range, 3–36). DM had resolved in 66.2% of the patients, improved in 26.9%, and remained stable in 13.1%. The mean decrease in blood glucose and HbA1c after sleeve gastrectomy was −88.2 mg/dl and −1.7%, respectively.

Regarding HbA1c, our study showed that the mean preoperative HbA1c was 7.5 ± 0.2; at 3-month follow-up, HbA1c declined to 7.2 ± 0.5; at 6 months, it became 6.7 ± 0.3; and at 1 year postoperatively, it became 6.4 ± 0.2.

In agreement with our study, a study by Shafik *et al.* [12] showed that the mean HbA1c was 7.95 ± 0.88%, with range of 6.55–10.2%. At 3-month follow-up, the mean HbA1c declined to 7.27 ± 0.77%, with range from 5.8 to 9.14%. At 6-month follow-up, the mean HbA1c reached 6.47 ± 0.75%, with range from 5.16 to 8.6%.Moreover, in agreement with our study, a study by Rosenthal *et al.* [14], on 30 patients with 6-month follow-up, 22 (73%) had been taking medications for T2DM preoperatively. They observed resolution of DM in 27% at 2 months and 63% at 6 months of follow-up. HbA1c decreased from 6.36 ± 0.82 preoperatively to 6.02 ± 0.57 at 2 months and 5.92 ± 0.33 at 6 months postoperatively [14].

In addition, a study done by Yang and colleagues showed that preoperative HbA1c was 8.5% in 28 patients who underwent sleeve gastrectomy. Three years after the operation, the complete T2DM remission rates (HbA1c<6.0% without taking antidiabetic medicines) were 78.6% [22].

Regarding postoperative complications, our study showed that of 30 patients who were operated for LSG, stenosis occurred in two (6%) patients, leak in one (3%) patient, and GERD in six (20%) patients.

In agreement with our study, a study done by Latif and colleagues on 49 patients, the follow-up outcome showed that 29 (61%) patients were free of complications, and 20 (39%) patients showed different complications. The early complications were as follows: seven (14%) patients complained of persistent vomiting, one (2%) patient complained of pulmonary embolism, three (6%) patients showed leakage on imaging, and finally, only one (2%) patient died 1 day after operation [23].

In contrast with our study, a study done by Eljadal and colleagues included 15 morbidly obese patients indicated for LSG who were divided into two subgroups: group A (BMI<50) comprised eight (53.3%) patients and group B (BMI>50) comprised seven (46.7%) patients. In the study, one (14.2%) patient from group B had symptoms of GERD preoperatively and had exaggerated symptoms after 6 months. Moreover, three patients [one (12.5%) from group A and two (28.6%) patients] showed new-onset symptoms of GERD after 6 months, and three (42.9%) patients from group B showed surgical site infection. There was only one (6.6%) mortality from group B owing to pulmonary embolism, which occurred on the 14th day postoperative [24]. This may be due to defect in patient care at hospital and follow up [18].

Conclusion

LSG may have profound effect on resolution of type 2 diabetes and its clinical manifestations. So, LSG may support treatment of diabetes in morbid obese diabetic patients. Further long-term follow-up is needed to ensure the efficacy of sleeve gastrectomy on T2DM control over a longer time.

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Nil.

Conflicts of interest

Nothing to declare.

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