The Impact of residual gastric size on the outcome of laparoscopic sleeve gastrectomy

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Background
Laparoscopic sleeve gastrectomy (LSG) has become a primary surgical treatment for obesity and associated diseases; this procedure works by several mechanisms. The new stomach pouch holds a considerably smaller volume than the normal stomach and helps to significantly reduce the amount of food (and thus calories) that can be consumed. The greater impact, however, seems to be the effect of surgery on gut hormones that affect a number of factors including hunger, satiety, and blood sugar control.
Objectives
To compare the outcomes of two different starting distance of stapling 2 and 6 cm from the pylorus in LSG on postoperative vomiting, reflux symptoms and other complications, time of gastric emptying after meals, changes of blood sugar for diabetics, effect on other comorbidities, and degree of weight loss.
Patients and methods
This study (randomized clinical control trial) included a total number of 40 obese patients. All patients were subjected to LSG at Menoufia University Hospital and subdivided into two groups: group 1 included 20 patients subjected to LSG with start of stapling 2 cm distance from the pylorus. Group 2 included 20 patients subjected to LSG with start of stapling 6 cm distance from the pylorus during the period between December 2018 and December 2019 with follow up of outcomes for 6–12 months postoperatively. All cases were calibrated intraoperatively on (36 Fr bougies) and using a gastrointestinal stapler device (Johnson Company).
Results
Both groups were comparable regarding age, sex, BMI, and comorbidities.
There was nonsignificant difference in early and late complication rates between the two groups but vomiting, gastroesophageal reflux disease, and nutritional deficiency were more with group 1. Patients in group 2 (more residual gastric volume) had less gastric emptying time than group 1. There were nonsignificant difference in both groups on improvement/resolution of comorbidities (control of blood sugar and hypertension). Excess weight loss was significant in both groups at 6 and 12 months postoperatively but was (statistically nonsignificant) more with group 1. There was no leakage or mortality.
Conclusions
The two different starting distances in LSG are almost equally effective regarding operative time, improvement/resolution of comorbidities, and percentage of weight loss.
Less residual gastric size comes with more weight loss but may be associated with postoperative complications such as vomiting, gastroesophageal reflux disease symptoms, and nutritional deficiency. So the choice of the starting distance from the pylorus will mostly be decided by the bariatric surgeon regarding patient age, BMI, comorbidities, and life standards.

Keywords:
bariatric surgery, laparoscopic sleeve gastrectomy, morbid obesity, weight loss

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Introduction

Obesity puts individuals at risk of more than 30 chronic health conditions. They include: type 2 diabetes, high cholesterol, hypertension, gallstones, heart disease, fatty liver disease, sleep apnea, gastroesophageal reflux disease (GERD), stress incontinence, heart failure, degenerative joint disease, birth defects, miscarriages, asthma and other respiratory conditions, and numerous cancers [1].

Surgical treatment of obesity is also known as bariatric surgery or weight loss surgery. Surgery is currently the most effective treatment for morbid obesity resulting in

durable and sustainable weight loss and accompanying health improvements [2].

Bariatric surgical procedures cause weight loss by restricting the amount of food the stomach can hold, or causing malabsorption of nutrients, or by a combination of both gastric restriction and malabsorption.

Bariatric procedures also often cause hormonal changes. Most weight loss surgeries today are performed using minimally invasive techniques (laparoscopic surgery); the most common bariatric surgery procedures are gastric bypass and sleeve gastrectomy [3].

Laparoscopic sleeve gastrectomy (LSG) has been a primary surgical treatment for obesity and associated diseases. This procedure works by several mechanisms. The new stomach pouch holds a considerably smaller volume than the normal stomach and helps to significantly reduce the amount of food (and thus calories) that can be consumed. The greater impact, however, seems to be the effect the surgery has on gut hormones that impact a number of factors including hunger, satiety, and blood sugar control [4].

The technique of performing the LSG is not consistent among bariatric surgeons. The common steps are as follows: evaluation for the presence of a hiatal hernia and repair if present; mobilization of the greater curvature of the stomach by division of the short gastric vessels; placement of an intragastric bougie (or some other device to size the sleeve); a stapled vertical gastrectomy, usually starting 2–6 cm proximal to the pylorus; and lastly, removal of the specimen [5].

Various factors can affect the residual gastric size, including the plug size, the distance from the pylorus to the LSG suture line, the distance from the plug to the punch line, and whether stapling or other support materials are used to reinforce the sutures [6].

Patients and method

This comparative study (randomized clinical control trial) included a total of 40 patients with morbid obesity in Menoufia University had been operated with LSG during the period between December 2018 and December 2019 with follow-up for 12 months postoperatively. Patient's safety, informed consent (about the method, possible complications, and the postoperative follow up), written documentation, cost cover, approval for recording the procedure and data, postoperative care, protection, and privacy of all patients were obtained.

Patients have been randomized into two equal groups:

Group 1 included 20 patients who had been subjected to LSG with start of stapling 2 cm distance from the pylorus.
Group 2 included 20 patients who had been subjected to LSG with start of stapling 6 cm distance from the pylorus.

Inclusion criteria

BMI more than 40, BMI more than 35 with comorbidities associated with obesity (diabetes mellitus type 2, hypertension dyslipidemia, arthritis, cardiac diseases), age (18–60 years), and obese patients with failure of adequate diet and exercise program.

Exclusion criteria

Our patients were subjected to full history taking (personal data, special habits, BMI-associated comorbidities) and full clinical examination and investigation. Those excluded were patients with significant psychiatric disorders, active alcohol or drug abuse, active gastric ulcer disease, severe GERD, large hiatus hernia, previous bariatric surgery, obesity due to endocrine cause, pregnancy, and those unfit for surgery.

Investigations done were.

Laboratory

Complete blood count, coagulation, bleeding profile, thyroid profile (TSH-free T3, T4), complete lipid profile, serum cortisol level, liver function test, renal function test, and respiratory function test.

Radiological

Abdominal ultrasound for all patients for detection of gallstones, liver size, any other pathologies, chest radiograph, ECG, echocardiography, and respiratory function tests.

Upper endoscopy

To exclude severe esophagitis, large hiatus hernia, active peptic ulceration, reflux disease, or other pathologies.

Intraoperative devascularization of the greater curvature of the stomach was done using a harmonic scalpel proximally 1.5 cm from the gastroesophageal junction and distally 2 or 6 cm proximal to the pylorus measured using a ruler. Mild bleeding (or oozing) may be more when doing more dissection and mobilization with 2 cm from the pylorus due to approximation to the right gastroepiploic arcade. A 60 mm endo-gastrointestinal (GIA) stapler was

used to divide the stomach along line with the bougie (36 Fr) creating a gastric tube that ensures that the stapler is encompassing equal lengths of the anterior and posterior stomach to avoid 'spiraling' of the sleeve. The staple lines are sequentially fired first away from the incisura, then along the bougie toward the angle of His, and divide the fundus at a distance of .5–1.5 cm lateral to the esophagus.

Around three to four linear staplers (60 mm long) with golden and blue load were used to transect the stomach. Methylene blue was injected through the bougie to detect intraoperative leakage. Nelaton drain or suction drain was applied close to the staple line. The excised part of the stomach was extracted through the 12 mm port.

Postoperative gastrografin meal (for gastric emptying time), esophageal 24 h pH monitoring (for reflux symptoms), and serum glycosylated hemoglobin, iron, vitamin D, vitamin B12.

Results

Totally 40 patients had LSG and were divided into two groups. Group 1 (six males 30%: 14 females 70%) with a mean age of 34.8 ± 8.192 and group 2 (seven males 35%: 13 females 65%) with a mean age of 42.5 ± 7.22.

Each group included more than 16 patients with comorbid diseases (diabetes, hypertension, hyperlipidemia, and sleep apnea syndrome).

Postoperative complications

In our study on different early postoperative complications in both groups, group 1 showed that three (15%) patients complained of vomiting, one (5%) patient had postoperative bleeding, and two (10%) patients developed portal vein thrombosis. On the other hand, group 2 showed that one (5%) patient complained of vomiting.

Our study about the outcome of late postoperative complication in both groups showed that there was nonsignificant difference in developing GERD symptoms two (10%) patients in group 1 and one (5%) patient in group 2. But there was significant difference in two groups in developing postoperative nutritional deficiency as group 1 showed seven (35%) patients and group 2 showed three (15%) patients with vitamin B12, iron and vitamin D deficiency (Tables 1 and 2).

Effect on gastric emptying

There was accelerated gastric emptying in both groups after sleeve gastrectomy. Using gastrografin meal in both groups postoperatively to evaluate the time needed for gastric emptying (when dye appeared in the duodenum).

The group 1 estimated time was about 15–20 min and group 2 estimated time was 12–16 min. Accelerated gastric emptying was nonsignificantly higher among group 2 (LSG 6 cm from the pylorus).

Table 1 Difference between two groups on early postoperative complications

Data	Group 1 (*N*=20) [*n* (%)]	Group 2 (*N*=20) [*n* (%)]	
Vomiting			
Present	3 (15)	1 (5)	0.604
Absent	17 (85)	19 (95)	
DVT			
Absent	20 (100)	20 (100)	
Portal vein thrombosis			
Absent	18 (90)	20 (100)	>0.999
Present	2 (10)	0	
Postoperative leakage	Nil	Nil	

Table 2 Comparison between two groups on late postoperative complications

Data	Group 1 (*N*=20) [*n* (%)]	Group 2 (*N*=20) [*n* (%)]	
GERD			
Present	5 (25)	2 (10)	>0.999
Absent	15 (75)	18 (90)	
Nutritional deficiency (iron, vitamin B12, vitamin D deficiency)			
Present	7 (35)	3 (15)	
Absent	13 (65)	17 (85)	0.028*

GERD, gastroesophageal reflux disease.
*There is non-significant difference between GERD symptoms between 2 groups (5 patients with group 1 and 2 patients with group 2). But there is significant difference between two groups in developing nutritional deficiencies that was more with group 1.

Table 3 Effect on weight loss in the studied groups

BMI	Group		*P*
	Group 1 (*N*=20)	Group 2 (*N*=20)	
Preoperatively:			
Mean±SD	46.016±4.274	44.01±4.458	0.996
Range	35.012#150;50.65	35.03#150;50.04	
6 months postoperative			
Mean±SD	36.702±4.186	38.665±3.735	0.447
Range	30.123#150;40.01	32.45#150;42.67	
12 months postopertive			
Mean±SD	27.281±4.035	28.725±3.246	0.041*
Range	25.67#150;35.7	26.45#150;36.5	
P (*F*)	<0.001**	<0.001**	

*,**There was reduction of BMI in both groups with non-significant difference between two groups but estimated BMI loss was more with group 1 (2 cm from pylorus) after 6 and 1 year.

Table 4 Comparison between the studied groups regarding blood sugar

Blood sugar	Group [*n* (%)]		*P* value
	Group 1	Group 2	
Preoperative	16	15	
Unchanged	0	1 (6.66)	
Improved	14 (87.5)	13 (86.66)	0.512
Remission	2 (12.5)	1 (6.66)	

Table 5 Comparison between the studied groups regarding hypertension postoperatively

Data	Group [*n* (%)]		*P*
	Group 1	Group 2	
Preoperative	16	14	
Unchanged	1 (6.25)	1 (7.14)	0.957
Improved	10 (62.5)	8 (57.12)	
Resolved	5 (31.25)	5 (35)	

Effect on weight loss

In this study, the effect of LSG on the degree of weight loss was measured by BMI 6 and 12 months postoperatively in both groups. During this period there was reduction in BMI in both groups with nonsignificant difference between two groups but is more with group 1 (BMI range after 6 months 30.123–40.01 and after 1 year the BMI range is 25.67–35.7). Group 2 (BMI range after 6 months 32.45–42.67 and after 1-year BMI range 26.45–36.5) (Table 3).

Effect on diabetes and hypertension

Diabetic patients in the study in both groups were evaluated by measuring glycosylated hemoglobin 1 year after LSG. There is nonsignificant difference between the studied groups regarding blood sugar postoperatively. Group 1 included 16 diabetic patients; 14 (87.5%) patients showed improvement in their blood sugar and two (12.5%) patients had remission of diabetes.

Group 2 included 15 diabetic patients; 13 (86.66%) patients showed improvement in their blood sugar and one (6.66%) patient had remission of diabetes and one (6.66 5) patient remained unchanged.

About the effect on hypertension 1 year after LSG in both groups estimated clinically group 1 showed one (6.25%) patient remaining unchanged, 10 (62.5%) patients were improved, and five (31.25%) patients were resolved from hypertension. Group 2 showed one (7.14%) patient remaining unchanged, eight (57.12%) patients were improved, and five (35%) patients were relieved of hypertension (Tables 4 and 5).

Discussion

Several mechanisms that affect emptying after LSG include removal of the fundus with its receptive and propulsive abilities, altered compliance and contractility of the narrow hardly distendable sleeve, removal of the gastric pacemaker area in the body of the stomach, and impeding the action of the antral pump if part of the antrum is resected [7].

In our study; patients had a gasrtografin meal (evaluating gastric emptying to liquids) after the dye appeared in the duodenum. There was accelerated gastric emptying time in both groups after sleeve gastrectomy but accelerated gastric emptying was nonsignificantly higher among the LSG 6 cm from the pylorus. With more residual gastric volume (RGV), other studies show the same results as De Rosa *et al.* [8] show in their study that less RGV reduce gastric emptying. Sioka *et al.* [9] concluded that gastric emptying after LSG is accelerated in the majority of patients as shown by the significantly reduced gastric emptying time. A faster gastric emptying could be one of the mechanisms contributing to weight loss after LSG [10]. Sista *et al.* [11] and García-Toro *et al.* [12] studies show accelerated gastric emptying after preserving more gastric volume or with more antral length.

On the other hand, another study by Catanzano *et al.* [13] shows that gastric emptying after a sleeve gastrectomy seems to be faster, and this is because of the way a resection interferes with the regulatory mechanisms behind food. Furthermore, the previously conservative gastrectomies that kept more of the antrum have slower emptying times than more radical antral resections.

The effect of bariatric surgery upon glucose tolerance is likely to be related to increased production of the

incretin hormone and GLP-1, which has a profound insulinotropic action, coupled to the improved insulin sensitivity resulting from weight loss [14]. Numerous studies have reported 60–80% resolution or improvement of hypertension after bariatric surgery. It has been hypothesized that the normalization of blood pressure is due to the amount of weight loss rather than the final postoperative weight [15].

We found the same effect in this study on improvement of comorbidities (nonsignificant more improvement with less residual gastric size). Regarding control of hypertension postoperatively (only one patient within each group was uncontrolled). Ten (62.5%) patients and eight (57.12%) patients show improvement in groups 1 and 2, respectively. Five patients (about 32%) within each group show complete resolution. And regarding control of diabetes, 14 (87.5%) patients and 13 (86.66%) patients show improvement in their blood sugar in groups 1 and 2, respectively. Two patients and one patient had complete remission of diabetes in groups 1 and 2, respectively. Many studies also show similar results as the study by Weiner *et al.* [16] on 14 diabetic patients [12 (86%) patients improvement and two (14%) patients resolved], and 67 hypertensive patients [two (3%) unchanged, 37 (55%) improved, 28 (42%) resolved]. Boza *et al.* [17] reported a 62.5% resolution of arterial hypertension at 1-year after LSG. Bozkurt *et al.* [18] compared the outcomes of two different starting distances, 4 and 2 cm from the pylorus in LSG. They concluded that LSG from 2 and 4 cm from the pylorus are equally effective in terms of weight loss and excess weight loss (EWL%), but LSG from 2 cm from the pylorus seems to be more effective in remission of comorbidities, especially diabetes mellitus.

On the other hand, ElGeidie *et al.* [19] studied the effect of the size of the residual gastric antrum on the outcome of LSG. They concluded that LSG with or without antral preservation produces significant weight loss after surgery. The two procedures are equally effective regarding EWL%, morbidity, quality of life, and amelioration of comorbidities. The Sista *et al.* [20] study of 256 patients were divided into two groups according to the RGV of less than 1500 ml (group 1: 131 patients) and more than 1500 ml (group 2: 147 patients). FBG levels showed no differences between the two groups. A significant decrease of glycosylated hemoglobin at 6 and 12 months was found in group 2. But on the opposite side Sista and colleagues evaluated the improvement in weight loss and comorbidities after LSG, and their relationship with the resected gastric volume. A high residual gastric size was associated with better weight control and better insulin resistance over the next 2 years. This outcome will in turn have a positive effect on weight loss and the incidence of any comorbid disease. They showed that RGV influences outcomes after LGS on short-term and midterm follow up.

Various criteria are available for evaluating success after bariatric surgery, including the percentage of EWL% and the percentage of excess BMI loss %. According to the International Federation of Obesity and Metabolic Disorders, the procedure is considered successful if the excess BMI loss % and EWL% remain stable and exceed 50% over the long-term follow-up period. However, a significant minority of patients (15–20%) fail to reach this target. The post-LSG EWL% values in most studies vary between 45 and 65% [21].

In our study, 40 patients were subjected to LSG at two different starting distances from the pylorus (2 and 6 cm) and with follow-up after 6 and 12 months postoperatively. There is reduction in BMI in both groups but nonsignificantly higher with group 1 (2 cm distance from pylorus) (BMI range after 6 month 30.123–40.01 and BMI range after 1 year 25.67–35.7). Group 2 (BMI range after 6 months 32.45–42.67 and BMI range after 1 year 26.45–36.5). Less RGV leads to more restriction of food intake and more hormonal effect on satiety and hunger centers. Interpretation of two studies shows almost the same results as ours. Deguines *et al.* used gastric-computed tomography volumetry (GCTV) to investigate the RGV and relate the latter parameter to the outcome of LSG. They found that residual gastric size is associated with successful postoperative weight loss, concluding that a high RGV 34 months after LSG is a risk factor for failure. Knowledge of the RGV can be of value in the management of failure after LSG [22] and in another prospective randomized study by Pereferrer *et al.* [23], the patients were divided into two groups, with initial sections of 3 or 8 cm being removed from the pylorus. The percentage of total weight loss % in the 3-cm group was of a higher percentile than that of the 8-cm group. The residual gastric size was inversely correlated with the total weight loss %. Another two studies show no significant difference between groups with different RGV such as those by Doğan and colleagues, who investigated the relationship between weight loss and the residual gastric size measured during surgery over a 2-year follow-up period. Sixty-two patients, most of whom were women (57 females and 12 males) were thus included in the study. The patients' mean age was 36 (17–56) years. The patients were divided into three groups based on the residual gastric size: group 1 (residual gastric size ≤50 ml) consisted of 14 patients (12 female and 2 male); group 2 (residual gastric size

50–89 ml) included 30 (24 female and 6 male); and group 3 (residual gastric size ≥90 ml) contained 14 (14 female and four male) patients. There was no significant difference in terms of the sex distribution among the groups. And they found that the residual gastric size values differed significantly. Intergroup comparisons at 6, 12, and 24 months postoperatively revealed no statistically significant differences in weight loss or EWL% at any time point.

EWL values of 70% or more were achieved in seven (50%) patients in group 1, 21 (70%) in group 2, and nine (50%) in group 3 after 2 years [24] and the Singh *et al.* [25] study included 100 bariatric patients undergoing LSG. They were divided into three groups according to the volume of the resected stomach and EWL% recorded at each follow-up. They concluded that EWL% was not significantly different among the groups and then not influenced by the RGV.

Sleeve gastrectomy was shown to cause, exacerbate, or improve GERD. The mechanisms by which this happens are multifactorial. Following LSG, a number of other processes occur that may increase GERD risk, including a lack of gastric compliance, increased intraluminal pressure, changes in pressure gradients, gastric fundus removal, changes in LES pressures, and modifications in sleeve shape [26].

The incidence of complications within the first 6 months varies from 4 to 25%, and depends on the procedure used, duration of follow-up, and individual patient characteristics. In our study, group 1 showed that three (15%) patients complained of vomiting, one (5%) patient had postoperative bleeding (managed conservatively by blood and fresh frozen plasma transfusion) and two (10%) patients developed portal vein thrombosis diagnosed by duplex and managed by anticoagulanttherapeutic doses. GERD symptoms were developed in two (10%) patients.

On the other hand, group 2 showed that one (5%) patient complained of vomiting. They were managed by reassurance and antiemetic drugs until improvement and one (5%) patient developed GERD symptoms.

All cases have been improved after 4 months postoperatively.

Genico *et al.* [27] show explanation that with more resected gastric volume there is GERD symptoms due to increased intragastric pressure after stapling, delayed gastric emptying, and dysfunction of the lower esophageal sphincter.

Several studies showed similar results. Elbanna *et al.* [28] studies show complications that include postoperative nausea and vomiting in 23 (13.2%) patients, who were treated conservatively. GERD symptoms developed in 17 (9.8%) patients, who were treated conservatively. Six (3.4%) patients developed asymptomatic gallbladder stones and were managed conservatively. Doğan and colleagues noted bleeding in two patients, and one developed an infection in the wound site. No other major complications were noted. Because of the resection of the fundus, a number of micronutrients such as iron and vitamin B12 are less likely to be absorbed. Iron needs to be transformed to an absorbable form by hydrochloric acid. The quantity of hydrochloric acid produced in the stomach is reduced and the nutrients may pass through the stomach faster after an LSG, thus making it more difficult to absorb iron. Vitamin B12 uptake after LSG can become inadequate due to the lower production of hydrochloric acid, which is needed to release bounded vitamin B12 in food. Anemia was diagnosed in 14 (26%) patients. Iron, folic acid, and vitamin B12 deficiency was found in 23 (43%), eight (15%), and five (9%) patients, respectively. Vitamin D and albumin deficiency was diagnosed in 21 (39%) and eight (15%) patients [29].

Dalmar *et al.* [30] concluded that unlike many gastric bypass surgeries, patients who have a gastric sleeve procedure do not have any change in their ability to absorb nutrients in the intestine. However, the dramatic decrease in food intake can lead to difficulties in taking in adequate nutrition. Issues like diarrhea and nausea might also cause problems with absorbing enough calories and nutrients as well.

In a recent study by Moizé *et al.* [31] the prevalence of vitamin B12, vitamin D, folate, iron, and zinc deficiency were reported to be 3, 23, 3, 3, and 14%, respectively, after LSG and these studies had been concluded to have the same impact on nutritional deficiency as our study, which showed seven (35%) patients and three (15%) patients with vitamin B12, iron, and vitamin D deficiency in groups 1 and 2, respectively, and were treated conservative by enteral or parenteral supplements.

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Conflicts of interest
No conflict of interest.

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