Original Article

Impact of gastric pouch volume on postoperative weight loss outcomes: A three years follow-up after laparoscopic sleeve gastrectomy

Mohamed Aabed, Mohamed Tolba, Khalid Ismail, Taha Ismail and Reda F. Ali

Department of General Surgery, Faculty of Medicine, Kafrelsheikh University, Kafr El-Sheikh, Egypt.

ABSTRACT

Background: Weight loss failure following laparoscopic sleeve gastrectomy (LSG) is a main cause of surgical revision, deteriorating patients' quality of life and causing the resurgence of comorbidities. Weight loss after LSG has a multifactorial mechanism. The residual gastric volume (RGV) seems to have a crucial role. Our study aimed to measure the RGV after LSG and its correlation with postoperative weight loss outcomes.

Patients and Methods: The present study was a prospective cohort study conducted on 56 obese patients who underwent LSG. The RGV was measured by multidetector computed tomography at 1-, 12-, and 36-months following surgery and was correlated with weight loss outcomes.

Results: LSG achieves sufficient and durable weight loss as well as comorbidity resolution. There was a statistically significant decrease in mean body mass index (BMI) from 50.66 kg/m^2 preoperatively to 32.94 kg/m^2 3 years after intervention. The percentage of excess weight loss (% EWL) significantly increased from 16.44% at 1 month to 64.1% at 3 years postoperatively. Also, there was a statistically significant increase in mean RGV from 100.23±18.11 at 1 month after surgery to 174.88±18.9 at 1 year which also increased to 292.0±38.26 at 3 years postoperatively. We found a nonsignificant correlation between weight loss outcomes and the increased RGV.

Conclusion: Dilatation of sleeve pouch appears to be a physiological process, and no correlation was found between this dilation and postoperative weight loss outcomes after 3 years of LSG. Long-term studies are required to authorize this result.

Key Words: Gastric pouch, laparoscopic sleeve gastrectomy, weight loss, weight regain.

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Corresponding Author: Mohamed Aabed Mohamed Abdelaziz, BSc, Department of General Surgery, Faculty of Medicine, Kafrelsheikh University, Kafr El-Sheikh, Egypt. **Tel.:** 01032338959, **E-mail:** drmohamedabed19@gmail.com

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INTRODUCTION

Obesity is an expanding pandemic[1]. It has a significant effect on life expectancy and overall health[2]. Metabolic and bariatric surgery is the only long-term effective management for morbid obesity, achieving weight loss up to 75% of the body's excess weight, and these outcomes are steady during a long-term follow-up period[3]. Laparoscopic sleeve gastrectomy (LSG) has become the most performed bariatric technique, it accounted for 58.8% of all bariatric procedures operated on in 2020[4].

LSG is commonly performed by many bariatric surgery centers due to its hopeful results regarding not only weight loss outcomes but also comorbidity resolution with lower rate of complication in comparison with other malabsorptive techniques[5,6].

Although LSG is a mainly restrictive technique, sleeve success or failure has a multifactorial mechanism. Gastrointestinal hormonal alteration and change in the gastric emptying are included factors[7,8]. The residual gastric volume (RGV) seems to be a crucial element. Although, the optimal volume is not determined yet[3].

During follow-up, significant dilation of the sleeve pouch is a common outcome. However, there was no consensus about whether the dilatation is a normal physiological finding after LSG or denotes an explanation of weight loss failure[9]. Our study aimed to assess the RGV after LSG by using multidetector computed tomography (MDCT) to investigate gastric pouch volume and its impact on weight loss outcomes.

PATIENTS AND METHODS:

Study design and selection criteria

Our trial was designed as a prospective cohort single arm study. It was performed at the bariatric surgery unit, Department of General Surgery, Kafrelsheikh University Hospital during the period from November 2018 to October

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2023 and included 56 obese patients who underwent LSG in the period between November 2018 to October 2020. We obtained Ethical approval from the ethics committee of Kafrelsheikh University. The methods used in the study complied with the Declaration of Helsinki guidelines and were reported in compliance with the CONSORT guidelines. Informed written consent was obtained from all patients prior to their participation in the study after defending the risks and benefits.

Calculation of the sample size

Calculation of sample size was based on the correlation between the sleeve volume and percentage of excess weight loss (% EWL) among cases with LSG. Prior data indicated that the correlation coefficient between sleeve volume and % EWL was 0.4[8]. Studying at least 34 participants will be needed if we use 0.4 as the true correlation coefficient to reject the null hypothesis with 80% power setting type I error probability to 0.05. Flahault *et al*., equation was used for calculations[10].

Criteria of enrolment

We included adult patients of either sexes with their ages ranging between 18 and 60 years, and their BMI more than 40 kg/m^2 or more than 35 kg/m^2 with obesity related comorbidities and failed multiple trials of lifestyle management for at least 2 years. Patients with a high BMI of more than 60 kg/m^2, patients with history of previous bariatric surgery, patients who had gastric pathology (peptic ulcer, tumor), symptomatic GERD, and significant psychological or eating disorders (bulimia) were excluded.

Patients' assessment and preoperative preparation

Full history taking and assessment, clinical examination, preoperative laboratory investigations, assessment of the function of cardiopulmonary systems, and abdominal ultrasound were routinely done for all patients. Upper gastrointestinal endoscopy was done for symptomatic cases to exclude gastric lesions. Prophylactic anticoagulant was used 12 h before surgical procedure.

Operative technique

We used the standardized five-port method for all patients in our study[11]. All patients were operated on under general anesthesia, after establishment of capnoperitoneum, abdominal exploration was done, then the operator started greater omentum dissection 4 cm proximal to the pylorus up to the angle of His and until ideal visualization of the left diaphragmatic crus. Then, the insertion of a 36-Fr bougie was done. About 4 cm proximal to the pylorus, stapling of the gastric wall was started and continued till the angle of His sparing 0.5 cm lateral to it. Diluted methylene blue was injected into the sleeve pouch for exclusion of potential leakage and the resected stomach specimen was extracted.

Postoperative follow-up

All patients were followed-up and evaluated after surgery by a multidisciplinary team (surgeon, psychologist, dietitian as well as endocrinologist) and patients' follow-up visits were arranged at 1, 6, 12, 24, and 36 months after LSG. During each follow-up visit, patients were assessed as regard weight loss, comorbidities resolution, late complications, as well as measurement of the volume of the gastric pouch by MDCT at 1 month, 1 and 3 years following the primary intervention.

Technique of computed tomography volumetry and recommendation

Patients were asked to fast for 4–6 h before investigation and intravenous injection of 40 mg butyl scopolamine as antispasmodic then patients were instructed to ingest two packs of effervescent granules (sodium bicarbonate) mixed with about 10 ml water as tolerated on the table, and immediately thereafter, the patient was placed in spine position on the scanner table. Examinations were done on MDCT (Toshiba Aquilion One 320 slice) scanners with a dedicated vitrea workstation for postprocessing gastric pouch volume assessment. Patients were instructed to hold their breath when acquisitions were carried out. For minimizing risks of radiation, limitation of image acquisition to the stomach was followed.

Data was transferred to a dedicated vitrea three-dimensional workstation. Images of 1.5 mm thin slices were reformed; semi-automatic and manual segmentation tools were combined to create a three-dimensional volume-rendering images. The software automatically estimated the volume of the gastric pouch after the reconstruction.

CT scanning also had a crucial role in residual gastric pouch shape evaluation, diagnosis of gastric pouch twist or stenosis, exclusion of retained gastric fundus as well as diagnosis of intrathoracic sleeve migration.

Outcomes of the study

Our study aimed to assess the volume of post-LSG gastric pouch via MDCT and to assess the correlation between these changes with weight loss outcomes within 3 years follow-up.

Statistical analysis

Analysis of our data was done using the software SPSS version 26 (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) Number and percentage were used for description of qualitative data and analysis were done using the χ^2 or Fisher's exact test when appropriate. Regarding quantitative data, median (minimum and maximum) was

used for description of non-parametric data and mean and standard deviation for description of parametric data after testing normality using the Shapiro–Wilk test. Significant results were judged at the 0.05 level. A highly significant difference was present if *P* less than or equal to 0.001.

RESULTS:

From November 2018 to October 2023, 56 obese patients [48 (85.7%) female] underwent LSG were enrolled in the study, 16 patients did not fulfill the study enrollment criteria and were excluded (11 patients did not complete the protocol of follow-up (four patients missed MDCT at 1 year and 7 patients missed MDCT at 3 years), two patients developed postoperative complications necessitating CT abdominal assessment, and three females got pregnant during the study period). 40 patients achieved at least 3 years follow-up, completed the MDCT gastric volumetry protocol at 1, 12, and 36 months, and were finally enrolled in the statistical analysis. The mean age (±SD) at the time of LSG was 36.98±9.56 (range, 22–55), mean preoperative weight was 137.6±19.38 (range, 104–197), mean excess body weight was 79.72±16.56 (range, 56–140) and the mean preoperative BMI was 50.66±5.76 (range, 41.5–72). A sedentary lifestyle was reported in 29 (72.5%) patients and a positive family history of obesity was found in 19 (47.5%) patients and many family members had performed bariatric surgeries. Associated co-morbidities included diabetes mellitus [seven (17.5%) patients], osteoarthritis [nine (22.5%) patients], hypertension [seven (17.5%) patients], and OSA syndrome [five (12.5%) patients.

Table 1 shows the anthropometric measurements of the study cohort at baseline, as well as at 1, 12, 24, and 36 months postoperative. In comparison to the preoperative values, there was a significant decrease in the BMI at 2 years following LSG, then a significant increase was observed during the third year. In addition, there was a statistically significant increase in % EWL, percentage of excess BMI loss (% EBMIL), and percentage of total weight loss (% TWL) during the first 2 years following LSG, followed by a significant decrease after the third year as shown in (Table 1).

In the present study, there was a statistically significant increase in the gastric pouch volume measured by MDCT during the whole follow-up period. The mean gastric pouch volume at 1 month after surgery was 100.23±18.11 ml (range, 70–180) while the gastric volume 1 year postoperatively was 174.88±18.9 ml (range, 140–230) and the gastric pouch volume at 3 years postoperatively was 292.0±38.26 ml (range, 238–410) as shown in (Fig. 1).

In the current study, there was no statistically significant correlation between gastric pouch volume and weight loss data expressed as body weight, BMI, % EWL, and % EBMIL during the whole follow-up period as shown in (Table 2, Fig. 2, and Fig. 3).

In the current study, insufficient weight loss (IWL) was reported in seven (17.5%) patients who failed to achieve % EWL greater than 50% after 18 months following LSG. Significant weight regain was reported in nine (22.5%) patients who regained greater than 15% of their nadir body weight after 3 years following the intervention. However, we reported a nonsignificant correlation between gastric pouch volume with either IWL or weight regain as shown in (Table 3).

Table 1: Weight loss data during the whole study follow-up period

	Body weight	BMI	% EWL	% EBMIL	% TWL
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Preoperative	137.6±19.38	50.66±5.76			
1 month	124.88±18.13	46.02±5.47	16.23±3.63	16.44±3.86	9.29±1.77%
1 year	92.17±16.89	33.98±5.5	58.31±12.14	59.62±12.14	33.24±5.2%
2 years	85.1±16.55	31.37±5.67	67.49±13.37	69.05±13.4	38.38±5.67%
3 years	89.4±18.97	32.94±6.54	62.19±16.31	64.1±16.84	35.28±7.93%
*P*1	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
*P*2	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
*P*3	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
*P*4	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

% EWL, percentage of excess weight loss; %EBMIL, percentage of excess BMI loss; %TWL, percentage of total weight loss
P1 difference between preoperative weigh /BMI and weight/BMI 1 month postoperatively.
P2 difference between weight loss data at 1 month and 1 year postoperatively.
P3 difference between weight loss data at 1 and 2 years postoperatively
P4 difference between weight loss data at 2- and 3-years postoperative
p for paired sample t test **P less than or equal to 0.001 is statistically highly significant.

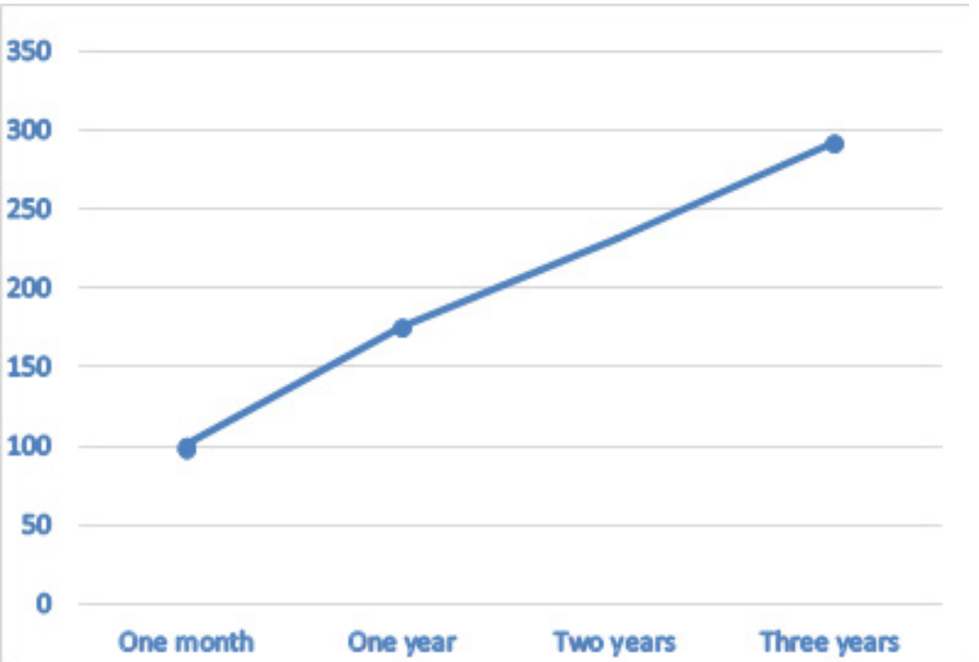

Fig. 1: Line graph showing gastric volume during postoperative follow-up period.

Table 2: Correlation between gastric volume and weight loss data all over the follow-up period

	At first month		At first year		After 3 years	
	rs	*P*	rs	*P*	rs	*P*
Weight (kg)	–0.023	0.89	0.008	0.962	0.306	0.055
% EWL	–0.069	0.67	–0.048	0.77	–0.191	0.238
BMI	0.256	0.112	0.025	0.88	0.247	0.125
% EBMIL	–0.028	0.862	–0.024	0.883	–0.252	0.117

rs: Pearson coefficient. $^{*}P$ less than 0.05 is statistically significant, $^{**}P$ less than or equal to 0.001 is statistically highly significant.

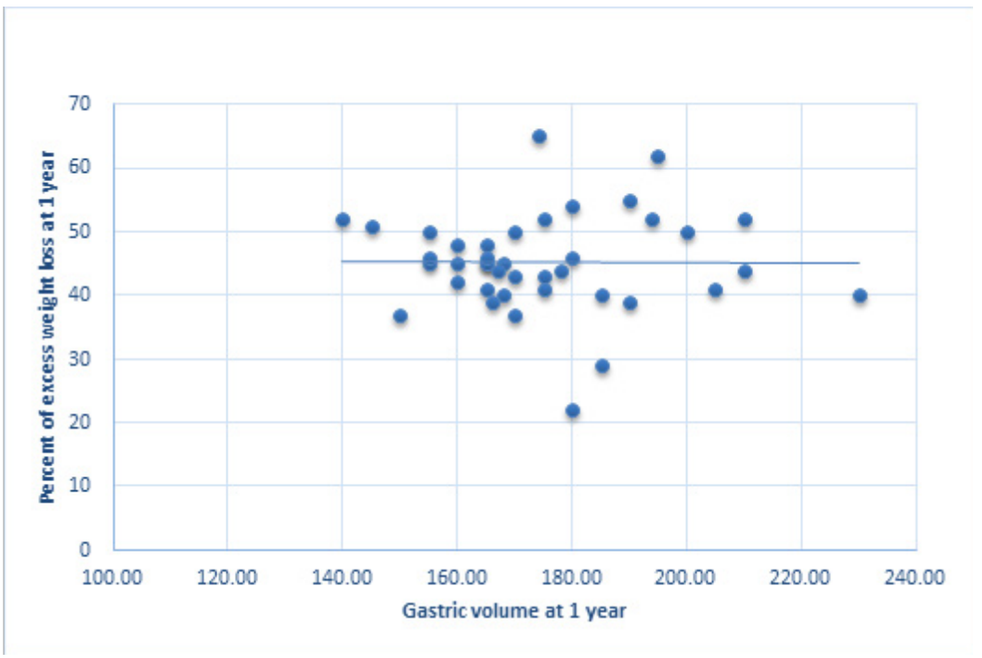

Fig. 2: Scatter dot showing a correlation between percentage of excess weight loss and gastric volume at 1 year (r=–0.048, *P=0.77*).

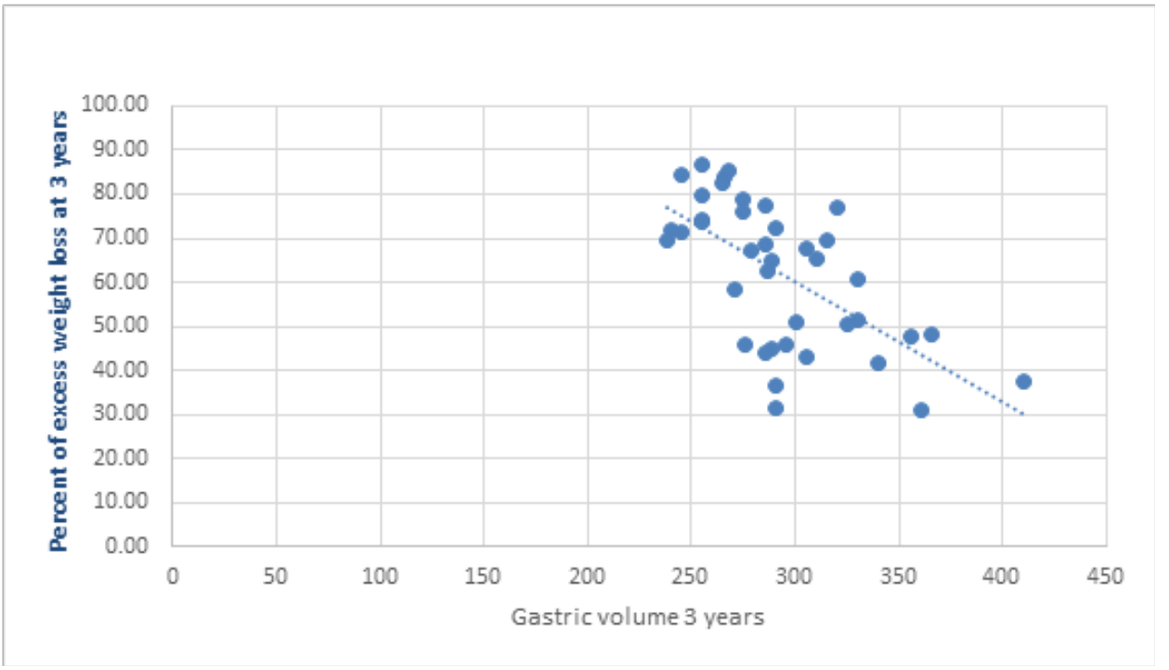

Fig. 3: Scatter dot showing a correlation between percentage of excess weight loss and gastric volume at 3 years (r=–0.191, *P=0.238*).

Table 3: Relationship between gastric volume and weight regain, insufficient weight loss

	Nonregainers (*n*=31)	Regainers (*n*=9)	*P*
Weight regain			
1 month	101.33±18.9	97.92±16.84	0.584
1 year	175.56±18.46	173.46±20.5	0.747
3 years	288.78±36.7	298.69±42.05	0.45
	Failed (*n*=7)	Succeeded (*n*=33)	*P*
Insufficient weight loss			
1 month	104.6±14.16	98.77±19.24	0.385
1 year	176.9±17.22	174.2±19.67	0.701

DISCUSSION

Sleeve gastrectomy was originally introduced as the first step of biliopancreatic diversion with duodenal switch (BPD-DS) or gastric bypass in super obese patients[12]. Currently it is not only an accepted stand-alone efficient technique for management of morbid obesity, but it has become the most frequently practiced bariatric procedure[4,13,14]. during recent years, LSG proved to be an efficient bariatric procedure regarding weight loss outcomes as well as promising results regarding comorbidities resolution[1].

The mechanism of weight loss after LSG is multifactorial, one of the principal mechanisms is the induced gastric volume restriction[7]. However, other factors such as increasing gastric motility and GIT (Gastrointestinal track) hormonal changes have been proposed[15]. Failure of weight loss is considered to be a major trouble requiring surgical revision, deteriorating patient quality of life and causing comorbidities resurgence that ultimately increase medical costs[16].

One of the most important mechanisms involved in LSG success or failure is the RGV which is critical to achieve optimum weight loss[3,17,18]. Incompletely excised fundus, large size bougie, long distance from the pylorus to the beginning of the stable line, improper resection of the remaining posterior wall of gastric folds and distance between stable line bougie are common causes of high RGV[19,20].

Recent studies and meta-analysis reported significant sleeve dilation overtime. The cause of gastric sleeve expansion is still unclear, increased intragastric pressure and eating habits of the patient were expected causes[19,20]. It is, however, still uncertain whether pouch dilatation is a physiological process or

represents a cause of IWL or secondary WR (weight regain) after LSG[3,9,21,22].

Different methods have been used to estimate the RGV after LSG. Recently, MDCT with modern postprocessing algorithms can describe more comprehensively and quantitatively the gastric pouch volume and correlate it with weight loss outcomes and the duration of follow-up after surgery[23].

In our study, participants were referred for an abdominal MDCT with gastric pouch volume assessment of the at 1 month, 1, and 3 years after LSG. There was a significant increase in stomach volume (*P<0.05*). (The mean volume was 100.23±18.11 ml, 174.88±18.9 ml, and 292.0±38.26 ml at 1 month, 1, and 3 years, respectively) We concluded a nonsignificant correlation (r=–0.191, *P=0.238*) between % EWL and elevated RGV up to 3 years after surgery.

Similar to our results; Fischer and colleagues reported a systematic review on LSG included 123 papers describing 12,129 patients and they concluded that the maximum % EWL occurred 24 and 36 months postoperatively with a mean % EWL of 64.3% and 66.0% respectively[24].

Emile *et al*., study which included 5218 patients with average preoperative BMI (43.8±8) which significantly dropped at 12 months to 30.7±3.9 and the average % EWL at 1, 2, and 5 years was 67.3, 70.9, and 69.4, respectively[25].

Similar to our results, Baumann and colleagues reported significant increase in the RGV measured by MDCT from 105.3 ml (1–2 months) to 196.8 ml (6–18 months) after surgery and they also concluded that gastric pouch dilation seems to be a physiological behavior after LSG and was not correlated with IWL or WR[26].

Braghetto and colleagues also observed a substantial rise in RGV after 2 years following surgery, they found that the 3 days postoperative gastric volume was 116.2±78.24 ml assessed with MDCT, and it was increased to 254±56.8 ml after 2 years of surgery and they concluded that the dilatation of gastric pouch did not reflect in regain of weight until the end of their study[9].

Ferrer-Márquez and colleagues reported a significant decrease in postoperative BMI in comparison with the preoperative values (33.48±5.78 vs. 50.54±6.69 kg/m^2; *P<0.001*) and they also found that no correlation was reported between dilated stomach volume and weight loss (r = 0.01; *P = 0.910*) at a 1-year follow-up[27].

A single-center prospective study by Deguines and colleagues included patients with 34 months mean follow-up period after LSG, they evaluated the RGV using Gastric CT Volumetry and found that the mean volume of gastric reservoir was 255 cm3 at 34 months after LSG and they also reported that an elevated RGV was a risk factor for LSG failure and the value of 225 cm3 was reported as the RGV threshold[28].

Also, Disse and colleagues reported that sleeve dilatation occurred in more than 50% of the patients and the mean % EBMIL was 63.8±4% in the group of dilated gastric pouch versus 64.5±5% in the group of stable gastric pouch at 1 year and they concluded that dilatation did not significantly correlate with insufficient weight loss. However, there was nonsignificant higher total weight loss and EBMIL in patients without gastric dilatation in comparison with patients with dilated gastric pouch[21].

On the other hand, Tassinari and colleagues showed that the mean dilation of the gastric reservoir was approximately 50% within long-term follow up with considerable respect to the early postoperative phase and they concluded that patients with insufficient weight loss had significant remnant dilation despite the overlapping postoperative dimensions[29].

Fahmy and colleagues study was conducted on a group of patients who reported post-LSG secondary weight to regain, and they reported a significant correlation betweenthe quantity of weight gained and the RGV which was calculated by using gastric CT with volumetric reconstructions at 2 years of surgery[30].

Multiple studies reported weight regain after LSG with a wide range of regain rates, the true incidence of weight regain, and what constitutes significance, is not well defined due to non-standard weight regain definition and different follow-up periods[19,31–34].

In our study, significant weight regain was considered in patients with weight regain of 15% or more from their nadir weight and this is matched with Voorwinde *et al*. study[35] and Ben-Porat *et al*.[36] we also reported a nonsignificant correlation between the RGV, and weight regain.

Recent studies have reported that only 79.7% and 54.5% of patients who underwent LSG successfully achieved % EWL greater than or equal to 50% at 2 and 5 years, respectively. Our results were supported by a systematic review by Lauti and colleagues included 21 studies with nine of them reported rate of weight regain after LSG. Rates of weight regain ranged from 5.7% at 2 years to 75.6% at 6 years[19].

The weak points of our study include a small sample size with relatively short duration follow-up, this is due to our work being a single center experience. We recommend sharing this study with multiple specialized centers to confirm our results.

CONCLUSION

Gastric pouch dilatation seems to be a physiological behavior after LSG as gastric volume increases even after performing a narrow gastric tube and this dilation was not correlated with postoperative weight loss, insufficient weight loss or secondary weight regain after 3 years of LSG. Long-term studies are needed to confirm this finding.

CONFLICT OF INTEREST

There are no conflicts of interest.

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