



# Volumetric Pouch Study After Laparoscopic Sleeve Gastrectomy

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## Abstract

Laparoscopic sleeve gastrectomy (LSG) is considerably utilized as a bariatric method for treating morbid obesity through the reduction of stomach volume. The present study attempted to assess the volumetric changes of the gastric reservoir 1 year after LSG using multi-slice spiral computed tomography (MSCT) as well as to verify their association with weight loss. The current study is a prospective study of 40 consecutive morbid obese patients managed with laparoscopic sleeve gastrectomy. All patients were referred to abdominal MSCT besides volumetric measurement of the gastric pouch 1 month and 12 months postoperatively after the LSG. There were statistically substantial differences throughout the whole period of follow-up ( $p$  value  $\leq 0.05$ ) regarding the ratio of excess weight loss, weight loss, and decreased BMI, in addition to the ratio of excess body mass index loss (% EBMIL) after LSG. Substantial elevation of the overall volume of the gastric reservoir (82.9 SD11 and 171.6 SD23.6 ml at 1 and 12 months, respectively) was observed. However, the current findings did not demonstrate any significant association ( $r=0.131$ ,  $p=0.491$ ) between excess weight loss percentage and the increase in gastric reservoir volume 1 year postoperatively. Sleeve dilatation is a common finding following sleeve gastrectomy (SG) even after conducting a narrow gastric pouch, yet dilatation was not correlated with insufficient weight loss after 1 year postoperatively. Trial registration number: NCT04880902.

**Keywords** Pouch size · Weight loss · Weight regain

## Introduction

Obesity is likely to be the disease of the twenty-first century, and it has been significantly elevated worldwide. It is linked to a slew of additional health problems like diabetes, hypertension, heart disease, infertility, and cancer [1]. Lifestyle interventions like diet modifications and physical activity as well as behavioral therapy are common treatment options for obese patients [2]. However, in the end, the high failure rate (95%) leads to the need for a more successful approach [3]. Bariatric surgery is regarded as the only long-range successful therapy for morbidly obese people, with weight loss ranging from 50 to 75% of extra body weight, which is impressive and shows consistent results over time

[4]. Laparoscopic sleeve gastrectomy is a generally restricted procedure that is frequently utilized by a wide range of surgeons due to its promising results regarding weight loss, high safety profile, and comorbidity resolution. Despite being categorized as a restricted surgery, the results of LSG have been linked to a number of hormonal alterations. Stomach reservoir volume seems to be a crucial element in success [5, 6]. The optimal volume has yet to be determined. Nonetheless, it has been claimed that it should be between 50 and 120 ml [7]. During follow-up, significant pouch dilatation is a typical observation. However, whether dilatation is a natural process or induced by inadequate weight reduction or secondary gain of weight is yet unknown [8]. The study aims to assess the modifications in gastric pouch volume after sleeve gastrectomy utilizing multi-detector computed tomography (MDCT) volumetric study and its relation to excess weight loss.

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## Patients and Methods

### Study Design and Setting

This trial was designed as a prospective single arm. The study was conducted in the General Surgery Department in the period from November 2018 to November 2020.

Ethical approval was obtained from the ethics committee of the university and informed written consent was obtained from all patients. The procedures used in this study adhered to the tenets of the Declaration of Helsinki and were reported in compliance with the CONSORT guidelines. The trial has been registered on [www.clinicaltrials.gov](http://www.clinicaltrials.gov).

### Sample Size Calculation

Sample size calculation was based on the correlation between pouch size and excessive weight loss within the first postoperative year in cases undergone laparoscopic sleeve gastrectomy. Prior data indicated that the correlation coefficient in a similar situation was 0.4 [9]. If we assume that this is the true correlation coefficient, we will need to study at least 34 participants to be able to reject the null hypothesis with 80% power setting type I error probability to 0.05. Calculations were done using the Flahault et al. equation [10].

### Selection Criteria

Adult patients of either gender, aged between 18 and 60 years, with a body mass index (BMI) of  $> 40 \text{ kg/m}^2$  or  $> 35 \text{ kg/m}^2$  with comorbidities such as hypertension and type 2 DM, failure of supervised conservative management for obesity in at least 2 years, were included. We excluded from the study patients with BMI  $> 60$ , previous bariatric surgery, symptomatic reflux esophagitis disease, gastric pathology (tumor, active peptic ulcer), significant psychological disorder, active alcohol or substance abuse, severe eating disorders (bulimia), the severe systemic disease leads to anesthesia or surgery prohibitively risky according to the American Society of Anesthesiologists (ASA) class IV.

### Preoperative Assessment and Preparation

All patients were subjected to preoperative detailed history taking, thorough clinical examination, full blood tests, cardiopulmonary evaluation, abdominal ultrasound, upper gastrointestinal (GIT) endoscopy/series to exclude any

upper GIT lesions in symptomatic cases, 40 mg (4000 IU) Clexane® (enoxaparin sodium: low molecular weight heparin (LMWH)), and subcutaneous injection 12 h prior to surgery.

### Assessments

A standardized five-port technique was followed for all study subjects, as demonstrated in a previous research paper [11]. All procedures were performed under general anesthesia, following capnoperitoneum was established, and dissection was initiated on the greater curvature 4 cm distal from the pylorus. The stomach greater curvature was separated from the omentum, and dissection continued until optimum visualization of the left crus of the diaphragm. Then, a 36-Fr gastric tube was inserted into the stomach. Starting 4–6 cm lateral to the pylorus, a series of linear staples was placed toward the left of the lesser curvature vessels until the gastric tube was reached and then up to the angle of His. The resected stomach specimen was excised, and potential leakage was excluded via methylene blue assay.

### Recommendation During Performing Computed Tomography Technique

The patient was instructed to drink negative oral contrast immediately before scanning until the sensation of a full stomach, and immediately thereafter, the patient was placed on the scanner table in the recumbent position. Examinations were done on MSCT scanners (Toshiba Aquilion One 320 slice) with a dedicated vitrea workstation for volumetric post-processing. Acquisitions were carried out while holding the breath. Moreover, there was no administration of the intravenous contrast agent.

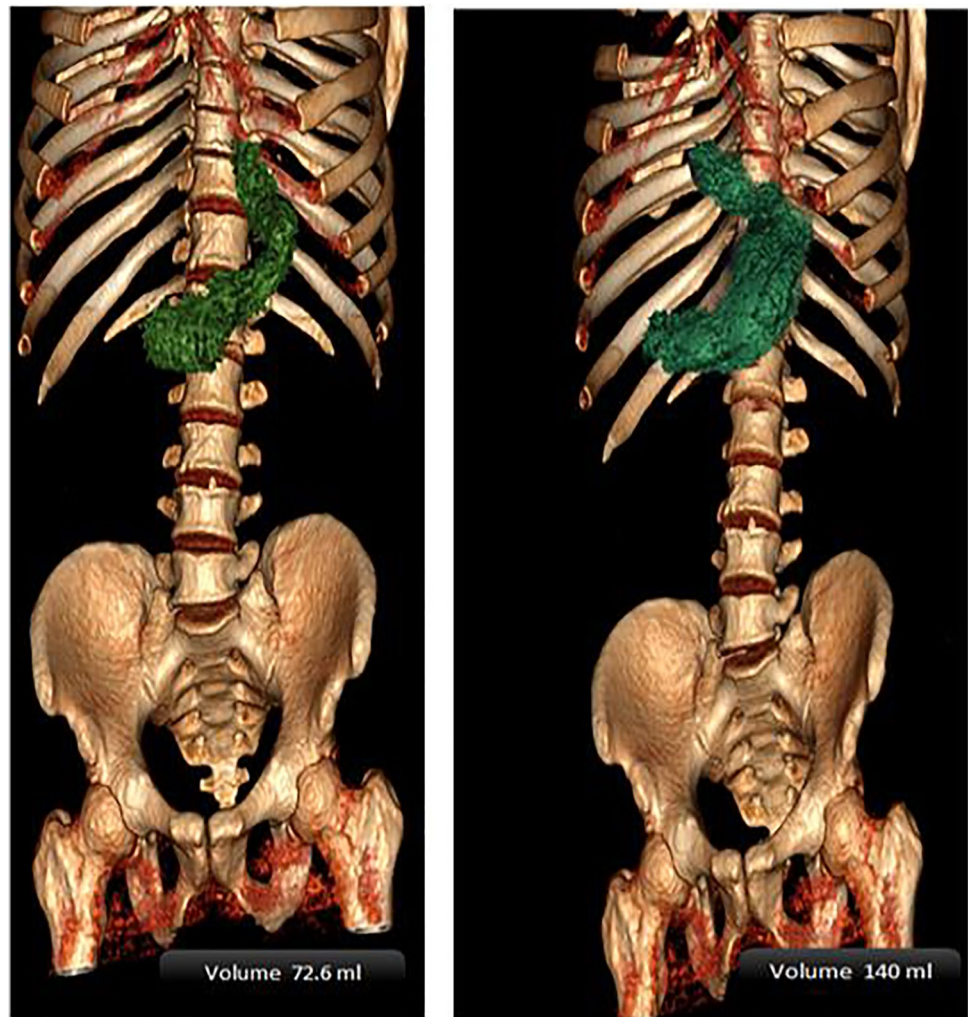
### Volumetric Post-processing and Image Analysis

Images of thin slices with a 1.5-mm slice thickness were reconstructed and transmitted to a dedicated workstation. Volume-rendering images were generated. Whereas total gastric volume was automatically determined according to the software, and finally, the reconstruction with an estimation of the gastric pouch volume was then obtained, as demonstrated in Fig. 1.

### Postoperative Follow-up

Evaluation of follow-up after surgery was done via a multidisciplinary team (includes an endocrinologist, a surgeon, a psychologist, as well as a dietitian) and were scheduled at 1, 3, and 6 months and 1 year postoperatively. It included weight loss data, laboratory investigations, amelioration of comorbidities, long-term complications, quality of life, and

**Fig. 1** MSCT volumetry image of the residual gastric reservoir: (A) 1 month after LSG; (B) 1 year after LSG



gastric volumetry using MDCT at 1 month and 12 months after surgery.

### Outcomes of the Study

The outcome of the study was the evaluation of the volumetric changes of the gastric reservoir 1 year after LSG using multi-slice spiral computed tomography (MSCT) and to analyze their relationship with weight loss.

### Statistical Analysis

All data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013, IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) for non-parametric data and mean and standard deviation for parametric data after testing normality using the

Shapiro–Wilk test. Significance of the obtained results was judged at the 0.05 level.

### Results

The main findings of the current study among 40 obese patients between the age of 18 and 55 years (32.5 SD5), presented with an average weight estimate of 136 (105–180) kg as well as an average BMI of 50 (38–58) kg/m<sup>2</sup>, as displayed in Table 1. They were mostly female (70% (female/male ratio, 2.25)). The median operative time was about 65 min as well as an average hospital stay of about 2 days. One patient had postoperative bleeding managed conservatively via plasma and blood transfusion, and three cases developed an infection in the wound site. Late complications occurred in 5 patients; two patients developed gastroesophageal reflux disease (GERD), two patients developed gall stones, and one patient complained from depression. No other major complications were noted,

**Table 1** Distribution of the studied cases according to different pre-operative, operative, and postoperative parameters

	No. (%)
Sex	
Male	12 (30%)
Female	28 (70%)
Age (years)	
Mean $\pm$ SD	33.9 $\pm$ 10.8
Median (Min.–Max.)	32.5 (17–55)
Onset of obesity	
Childhood	21 (52.5%)
Teenage/childhood	3 (7.5%)
Adulthood	16 (40%)
Family history	24 (60%)
Preoperative height (cm)	
Mean $\pm$ SD	164.4 $\pm$ 7.1
Median (Min.–Max.)	165 (150–183)
Preoperative ideal weight (kg)	
Mean $\pm$ SD	59.5 $\pm$ 5.3
Median (Min.–Max.)	59 (50–74.8)
Preoperative excess weight (kg)	
Mean $\pm$ SD	76.55 $\pm$ 15.1
Median (Min.–Max.)	78 (46–105.3)
Operative time (min)	
Mean $\pm$ SD	64.5 $\pm$ 13.6
Median (Min.–Max.)	60 (45–120)
Hospital stay (day)	
Mean $\pm$ SD	1.8 $\pm$ 1.1
Early postoperative complication	4 (10%)
Late postoperative complications	5 (12.5%)

as shown in Table 1. All data related to weight such as EWL, BMI, and % EBMIL are displayed in Table 1. In comparison to the pre-surgical outcomes, the BMI substantially diminished 1 year following the intervention, as shown in Table 2. In addition, the percentages of % EWL and % EBMIL were statistically substantial during the whole follow-up and after 1 year post surgery, as shown in Table 3. There were substantial increases in all volumes during the study interval. All subjects were referred to abdominal MSCT with a volumetric assessment of gastric pouch within 1 month of surgery and 1 year postoperatively. The gastric volume within 1 month of surgery ranged from 60 to 107 ml with a median of 82.9 SD11 ml, while the gastric volume 1 year postoperatively ranged from 135 to 260 ml with a mean of 171.6 SD23.6 ml. There were statistically substantial increases in the gastric volume after 1 year ( $p = 0.05$ ), as shown in Table 4. The correlation between the percentage of excess weight loss (PEWL) and gastric volume after 1 year shows no

statistical significance ( $r = 0.131$ ,  $p = 0.491$ ), as demonstrated in Table 5 and Fig. 2.

## Discussion

The more bariatric surgeries performed, the higher the number of subjects who will not attain their targeted weight regardless of the treatment used [12]. Weight regain (WR) after bariatric surgery has the ability to impair health outcomes by resurfacing obesity-related comorbidities, reducing the quality of life, and increasing healthcare costs [13].

One of the most significant mechanisms of action for LSG is to reduce stomach volume, which consequently reduces the intake of food. Therefore, residual gastric volume (RGV) is critical to achieving optimum weight loss. The size of the bougie used during surgery, the patient's eating habits, the distance from the pylorus to the LSG suture line, if stapling or other support materials are employed to support the suture, and complete fundus resection are all factors that affect gastric pouch capacity [14].

Numerous methods were utilized in order to estimate the residual pouch volume following bariatric procedures. Based on radiological studies, the most common are biplanar barium or water-soluble iodine-contrasted images, whereas other studies have demonstrated that the resultant sleeve to be a complex geometrical shape with a cylindrical proximal component (gastric body) as well as a truncated cone (antrum). Others utilized gastric scintigraphy for these purposes [15].

Using MDCT with post-processing volumetry study is considered an accurate method to analyze the volume/shape of the gastric pouch following bariatric surgery [16]. Moreover, it has been utilized to detect the correlation between the volume of residual gastric as well as EWL following sleeve gastrectomy [15].

Within 1 month of surgery and 1 year after surgery, all subjects were referred for an abdominal MSCT with a volumetric assessment of the gastric pouch in the current study. After 1 year of surgery, there was a substantial elevation in stomach volume ( $p < 0.05$ ). (The mean volume was 82.93 SD11.45 ml and 175.8 SD23.68 ml 1 month and 1 year, respectively.) We detected a non-significant weak negative relation ( $r = -0.131$ ,  $p = 0.491$ ) between PEWL and elevated stomach reservoir volume 1 year after surgery in the current study.

Two years following surgery, Braghetto et al. discovered a considerable increase in residual stomach capacity. They discovered that the early (3 days) postoperative stomach volume was 116 SD278.24 ml, which grew to 254 SD56.8 ml after 2 years following surgery, as measured by MSCT. Furthermore, they reported that the increase in residual stomach capacity after 2 years of LSG as measured by MSCT did not

**Table 2** Comparison between the various studied periods based on anthropometric measurement

	Preoperation	Postoperation			
		1 <sup>st</sup> month	3 <sup>rd</sup> month	6 <sup>th</sup> month	1 year
<b>Weight (kg)</b>					
Mean ± SD	136.5 ± 17.82	124.3 ± 18	114.7 ± 16.2	100.7 ± 14.1	85.8 ± 12.6
Median (Min.–Max.)	136 (105–180)	122 (98–177)	114 (93–165)	100 (82–145)	85 (67–130)
Decrease from pre		<b>11.8 ± 4.02</b>	<b>21.4 ± 5.7</b>	<b>35.4 ± 7.7</b>	<b>50.2 ± 12.03</b>
<i>p</i> <sub>0</sub>		<0.001*	<0.001*	<0.001*	<0.001*
Sig. bet. periods		<i>p</i> <sub>1</sub> <0.001*, <i>p</i> <sub>2</sub> <0.001*, <i>p</i> <sub>3</sub> <0.001*, <i>p</i> <sub>4</sub> <0.001*, <i>p</i> <sub>5</sub> <0.001*, <i>p</i> <sub>6</sub> <0.001*			
<b>BMI (kg/m<sup>2</sup>)</b>					
Mean ± SD	50 ± 4.9	45.8 ± 4.8	42.4 ± 4.1	37 ± 3.7	31.6 ± 3
Median (Min.–Max.)	50 (38–58)	45.2 (36–54.3)	41.9 (34–49)	36.5 (30.8–44.5)	31.6 (27–38.8)
Decrease from pre		<b>4.2 ± 1.4</b>	<b>7.5 ± 2.7</b>	<b>13 ± 2.6</b>	<b>18.3 ± 4.1</b>
<i>p</i> <sub>0</sub>		<0.001*	<0.001*	<0.001*	<0.001*
Sig. bet. periods		<i>p</i> <sub>1</sub> <0.001*, <i>p</i> <sub>2</sub> <0.001*, <i>p</i> <sub>3</sub> <0.001*, <i>p</i> <sub>4</sub> <0.001*, <i>p</i> <sub>5</sub> <0.001*, <i>p</i> <sub>6</sub> <0.001*			

Sig. bet. periods were performed using post hoc test (adjusted Bonferroni) for ANOVA with frequent measures

*p*<sub>0</sub>, *p* value to compare between preoperation and each period

*p*<sub>1</sub>, *p* value to compare between 1<sup>st</sup> month and 3<sup>rd</sup> month

*p*<sub>2</sub>, *p* value to compare between 1<sup>st</sup> month and 6<sup>th</sup> month

*p*<sub>3</sub>, *p* value to compare between 1<sup>st</sup> month and 1 year

*p*<sub>4</sub>, *p* value to compare between 3<sup>rd</sup> month and 6<sup>th</sup> month

*p*<sub>5</sub>, *p* value to compare between 3<sup>rd</sup> month and 1 year

*p*<sub>6</sub>, *p* value to compare between 6<sup>th</sup> month and 1 year

\*Statistically significant at *p* ≤ 0.05

**Table 3** Descriptive analysis of studied patients according to changes in excess weight loss (%) and percent of excess body mass index loss

	Preoperation	Postoperation			
		1 <sup>st</sup> month	3 <sup>rd</sup> month	6 <sup>th</sup> month	1 year
<b>Excess weight loss (%)</b>					
Mean ± SD	15.70 ± 5.1	28.2 ± 6.3		46.5 ± 7.3	65.5 ± 9.5
Median (Min.–Max.)	16 (2.9–27.2)	27.7 (14.3–47.3)		45.5 (33.3–63.2)	68.1 (43.3–81.4)
<i>p</i> <sub>0</sub>		<0.001*		<0.001*	<0.001*
Sig. bet. periods		<i>p</i> <sub>1</sub> <0.001*, <i>p</i> <sub>2</sub> <0.001*, <i>p</i> <sub>3</sub> <0.001*			
Decrease from 1 <sup>st</sup> month		<b>12.5 ± 3.7</b>		<b>30.8 ± 4.4</b>	<b>49.8 ± 8.8</b>
<b>Excess body mass index loss (%)</b>					
Mean ± SD	17.2 ± 5.7	29.8 ± 13.3		52.6 ± 8.3	73.7 ± 10.1
Median (Min.–Max.)	17.6 (4.1–29.5)	30.8 (–38.5 to 53.3)		51.5 (37.9–69)	75.6 (49.5–92)
<i>p</i> <sub>0</sub>		<0.001*		<0.001*	<0.001*
Sig. bet. periods		<i>p</i> <sub>1</sub> <0.001*, <i>p</i> <sub>2</sub> <0.001*, <i>p</i> <sub>3</sub> <0.001*			
Decrease from 1 <sup>st</sup> month		<b>14.5 ± 4.7</b>		<b>35.4 ± 4.8</b>	<b>56.4 ± 9.3</b>

Sig. bet. periods were performed using post hoc test (adjusted Bonferroni) for ANOVA with frequent measures

*p*<sub>0</sub>: *p* value to compare between 1<sup>st</sup> month and each period

*p*<sub>1</sub>: *p* value to compare between 3<sup>rd</sup> month and 6<sup>th</sup> month

*p*<sub>2</sub>: *p* value to compare between 3<sup>rd</sup> month and 1 year

*p*<sub>3</sub>: *p* value to compare between 6<sup>th</sup> month and 1 year

\*Statistically significant at *p* ≤ 0.05

**Table 4** Volumetric estimations of the whole gastric reservoir at 1 month and 12 months after LSG

Volumetric estimations of the whole gastric reservoir	At 1 month after LSG	At 12 months after LSG	<i>t</i>	<i>p</i>
Mean $\pm$ SD	82.9 $\pm$ 11	171.6 $\pm$ 23.6	25.051*	<0.001*
Median (Min.–Max.)	82 (60–107)	170 (135–260)		

*t*, paired *t*-test

*p*, *p* value to compare between at 1 month and at 12 months

\*Statistically significant at  $p \leq 0.05$

**Table 5** Correlation between percentage of excess weight loss (PEWL) and gastric volume after 1 year

	<i>r</i>	<i>p</i>
PEWL vs. gastric volume	-0.131	0.491

result in weight regain until the completion of their research [8].

According to Clara Panella et al., the ratio of EWL at 1 year was 74.5(63.8–86) versus 55.5(47–74.3) at 5 years ( $p < 0.001$ ). Upper gastrointestinal series was conducted 1 month following surgery, as well as 1 and 5 years subsequently. At 1 month following surgery, the gastric reservoir (VGR) capacity was estimated to be 114.9 (90.5–168.3) ml, whereas at 1 and 5 years, it elevated from 216.7 (155.1–278.6) to 367.5 (273–560.3) ml ( $p < 0.001$ ). At 1 year, there was a substantial inverse association between BMI and VGR, percent EWL, as well as percent EBML, but this dissipated in 5 years [9].

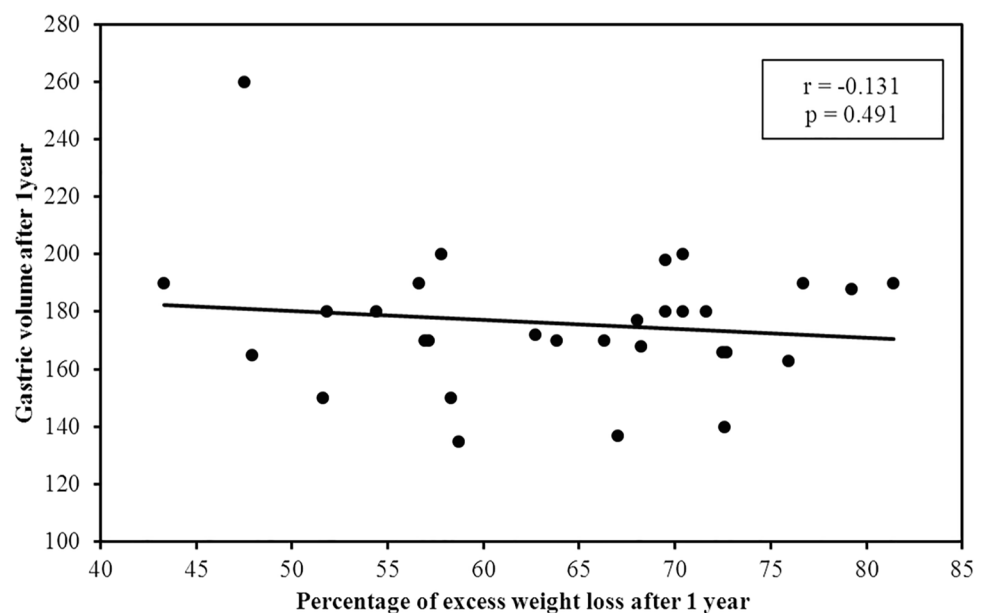
Andres Hanssen et al. used 3D CT reconstruction and stomach volumetry for patients who had LSG and were followed up prospectively and analyzed at 6 months to detect if there was

a link between residual gastric volume and excess weight loss (EWL). The results demonstrated that residual gastric volume and percent EWL have an inverse relationship [17].

Gastric volumetry via 3D gastric computed tomography with gas expansion was used by Emmanuel Disse et al.'s colleagues to measure the gastric pouch after LSG. More than half of the patients had their stomachs dilated. The average of excess body mass index loss (EBMIL) at 1 year was estimated at 63.84% in the patients who had their stomachs dilated versus 64.55% in subjects who had stabilized gastric volumetry. They concluded that dilatation was unrelated to insufficient weight loss [18].

Sabry et al. found that 1 year following surgery, there was a statistically substantial elevation in stomach volume. Although gastric dilatation appears to be a natural reaction to LSG, it is not linked to inadequate weight loss or weight recovery after a year [19].

Ferrer-Marquez and colleagues demonstrated by preoperative measurement that all subjects demonstrated a substantial decline in BMI (33.48 SD5.78 vs. 50.54 SD6.69 kg/m<sup>2</sup>;  $p < 0.001$ ). In comparison of the findings of esophago-gastroduodenal (EGD) transit at 1 (68.39 SD25.89 cm<sup>3</sup>) and 12 (122.58 SD38.76 cm<sup>3</sup>;  $p < 0.001$ ) postoperative months,

**Fig. 2** Correlation between percentage of excess weight loss (PEWL) and gastric volume after 1 year

an elevation in residual gastric volume (RGV) was noted. At a 1-year follow-up, no link was detected between elevated stomach volume as well as weight loss ( $r=0.01$ ;  $p=0.910$ ) [20].

On the contrary, Vidal et al. measured the residual gastric volume by defragmenting the radiological picture (obtained after an upper gastrointestinal series) into two recognized geometrical shapes: a truncated cone (antrum) and a cylinder (gastric body) [7]. The entire stomach reservoir volume can then be determined by summing these two partial volumes. They discovered a 50% elevation in gastric reservoir volume 1 year following LSG, as well as a direct link between increased gastric reservoir volume and reduced weight reduction 1 year after surgery.

Using a stomach CT to quantify the RGV, Deguines et al. found that elevated RGV 34 months following LSG is regarded as a risk factor for weight reduction failure characterized by 50% EWL [21].

Fahmy et al. found a strong association between the ratios of gaining weight gained and the remnant volume, determined by gastric CT with volumetric reconstructions at 2 years after surgery, in a cohort of patients who had gained weight after SG although there are overlapping dimensions after surgery [22].

Daniele Tassinari et al. found that cases with EWL 50% had greater remnant dilatation compared to those with EWL > 50% [23].

Sleeve dilatation is a common finding after surgery. Gastric sleeve diameter is essential for subsequent dilatation; a large diameter sleeve will expand earlier compared to a tighter one. Frequently involved mechanisms are the eating habits of patients, incompletely dissected upper posterior gastric pouch, narrowing of the gastric incisura with consequent gastric upstream dilatation of the remnant stomach, and LSG natural history [9, 22].

Weight loss following LSG is influenced by a variety of factors, including postoperative neurohormonal mechanisms involving ghrelin, PYY, GLP-1, and accelerated stomach emptying. As a result, assessing the residual stomach volume following LSG and its rise can help predict late clinical outcomes and delineate the eventual strategy for further management. The short time of the study (1 year) precludes further identification of gastric dilatation and reflection to weight loss as well as weight regain with longer follow-up. Consequently, more research is required.

## Conclusion

Sleeve dilatation is a common finding following sleeve gastrectomy even after conducting a narrow gastric pouch; nevertheless, dilatation was not related to insufficient weight

loss after 1 year post surgery. Long time studies are needed to confirm this finding.

**Author Contribution** Mohamed Tolba designed the study and shared in data collection and analysis and writing the manuscript. Reda F. Ali and Ahmed Lamey contributed to analysis, writing, and revising the manuscript. Mostafa Balbaa contributed to data interpretation and revision of the manuscript. Taha Ismail contributed to drafting and critical revision of the manuscript. Khalid Ismail shared in interpretation of the results, supervision, writing parts of the manuscript, and critical revision of the final version. All authors read and approved the final manuscript.

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## Declarations

**Ethics Approval** Approval was obtained from the ethics committee of Kafrelsheikh University. The procedures used in this study adhered to the tenets of the Declaration of Helsinki.

**Consent to Participate** Informed consent was obtained from all individual participants included in the study.

**Conflict of Interest** The authors declare no competing interests.

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